UiA University of Agder

Master

Supporting active learning through immersive mixed and virtual reality technologies

NORA MARIA BECKER & STIAN HANSSEN LANDE

SUPERVISORS
Ghislain Maurice Norbert Isabwe
Morgan Konnestad

University of Agder, 2023
Faculty of Engineering and Science
Department of Information and Communication Technology

Abstract

As the world economies continue to grow, natural resources are being used at such high rates that may negatively affect future generations. One of the issues is that the general population may know some solutions for reducing energy consumption, for example in transportation, but few may know about sustainable food production and sustainability concepts in a wider context. It can be challenging to create learning tools and learning content to suit the learning needs of the general population.

This master thesis explores mixed (MR) and virtual (VR) reality technologies as a support tool for learning sustainability concepts through active learning strategies. The research investigates design choices and their effectiveness in creating immersive learning experiences as well as the user's perceived experiences of presence and motivation to learn. A human-centered design approach is adopted to create a 'sustainable future city' use case focusing on learning concepts of sustainable horticulture such as vertical farming, hydroponic-, aeroponic- and aquaponic systems.

The research investigates the state-of-the-art of MR and VR technologies, and looks into perceived levels of presence and motivation in an immersive experience that combines MR and VR as one application. Human-centered design activities taken include interviews with five randomly sampled participants to validate requirements, interests in topics, and technology choices. Further on, design and development tasks were carried out to develop a functional prototype running on Meta Quest Pro head mount device. A mixed method approach was taken for the user testing and evaluation of two design iterations. That involved user observation in UiA's usability laboratory, questionnaire and in-depth interviews with 10 participants. This study's findings indicate that key design decisions for the immersive experience included guided exploration, realistic visualization, and hand gesture interactions. Further, there were positive outcomes on both observation and feedback from users as high levels of presence, fun, and interest in the topic were distinguished. Some main specific findings were that while most participants were observed to experience presence as expected, one participant indicated that they had a low sense of presence and were distracted by the environment and unfamiliarity with the technology. This suggests that users can feel low levels of presence even when they are fully involved in the virtual environment, because of the cognitive process required to experience presence. Further regarding motivation, all participants stated they preferred the immersive experience over traditional means such as textbooks, as it made learning more fun and interesting in an active way.

The study was limited in scope and sample size, nevertheless it was concluded that overall the design decisions made for the use case were at a large extent effective in supporting active learning, and the designed tool can be easily used by the general population.

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Nora Maria Becker
Stian Hanssen Lande
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Chapter 1

Introduction

Mixed and virtual reality immersive experiences are used more and more in education. The affordance of visualization, exploration of, and interactions with virtual environments can make abstract topics more understandable for learners, as well as create a fun and interesting educational immersive experience. Virtual reality has been around for some time and is becoming more accessible for people, and mixed reality has also started to see more use. As designers, it is of interest to understand how these immersive technologies can be used to facilitate active learning, while taking advantage of their ability to make it fun, interesting, and create an immersive experience learners can feel present in.

The following sections introduces the background where the reason and motivation of the idea of the project came to be, the target group will be presented, the scope of the research will be described, the problem statement will be put into context and explained, as well as aim, objectives, research questions, limitations and constraints of the project, and the report structure comes thereafter.

1.1 Background

The reason and motivation behind why this research area for the project had been chosen, was because educational and immersive technologies is a personal passion and there is interest to learn more about it. Additionally, the research has significance and value as it is relevant not just to the field of study 'Multimedia and Educational Technology master's programme at UiA', but also to fill gaps in those fields, such as new ways to use mixed reality in combination with virtual reality elements and active learning experiences. It is important with more research into this niche field as it contributes to the discussion of future and different ways that support learning. It could help other researchers in their efforts, advance the field, and be helpful to the industry and community at large.

Furthermore, the idea for the topic evolved from a suggestion by one of the supervisors with the use case of virtual tourism in a city. From that initial suggestion, the idea was developed into 'sustainability' and 'sustainable future cities', which was then further specified towards the subtopics of horticulture and crop production. The subtopic of future sustainable horticulture was chosen because most people today are not that knowledgeable about it and its concepts. This makes it relevant and of worth to learn about, as food production is of high importance to human livelihood. The general population may know about some sustainable solutions when it comes to energy, lifestyle, or transportation, but few know about sustainable food production. Therefore, it was decided to focus on and explore this area of sustainability in the mixed and virtual reality immersive experience.

1.2 Target group

The target group for data collection was chosen to be the general population in Grimstad, ages 19 and up, and also students at the University of Agder in Grimstad. None of them need to have pre-existing knowledge about either the technology used nor the topic of sustainability.

1.3 Scope - main area of research

The scope of the master project consists of several parts. The first main part is to research educational mixed and virtual reality by designing, developing, and implementing a use case immersive experience that supports active learning through a human-centred design approach. The chosen topic for the use case was 'sustainability' as it is an important topic to learn about. To gather data, the summarized and interpreted findings of a street interview with five participants were used to validate the requirements, interest in the topics, and technologies chosen as part of the human-centred design approach. Further, the design decisions made shall be discussed in terms of their effectiveness to answer research question one, by discussing implemented design principles and state-of-the-art studies where design decisions are compared between those made in the design of the use case and those made in other works.

The second main part of research was to measure the level of presence and motivation users perceive in the use case. It is important for MR and VR designers and developers to consider the users' level of presence as it immensely affects whether they really want to use or continue to use the application [1]. Presence is about attention [2], and designers want users to experience high levels of presence so that they focus their attention on the digital environment to trick the brain into thinking the digital elements are real and users feel physical presence in the virtual environment [1], [2]. In contrast, low levels of presence means that there is low attention on the digital environment, and instead users focus on the real world, and end up not being immersed in the experience [2]. Low attention could in this way lead to that users lose interest in the application, as well as an overall negative experience and feelings, such as boredom and frustration, and thus do not feel the urge to use or continue with the application. Therefore, it was also important to look at motivation [3] and see if the immersive experience is fun and makes the topics that will be learned interesting.

To be able to gather data on measured level of presence and motivation, a user test was conducted by qualitative dominant mixed methods approach with observation of user tasks, questionnaire, and in-depth interviews with 10 participants over two iterations with five participants on each iteration. Changes made between iterations were based on feedback found in iteration one. This was done to try to see differences, and up the level of experienced presence and motivation when the data later was compared to iteration two. The tests were summarized and interpreted to answer research question two. Findings and discussion of both research questions was then used to come to a conclusion.

1.4 Problem statement, aim, objectives, & research questions

1.4.1 Problem statement

People learn better when they learn through active learning strategies [4]. There is also a challenge today in regard to being aware of sustainability issues and to preserve life for the future. Therefore there is a need to live sustainably, but another challenge thus presents itself. How do we learn about sustainability? How should people learn about sustainability today? The new generation of learners prefer to use the internet and multimedia content for learning on their phones, tablets and computers. They want their content to be fast paced, visual and straight to the point, quickly being able to learn about topics instead of reading them in text books with long chapters, no pictures, and in difficult formal language. However, sustainability should be a concern for everyone. Some people are not necessarily academic, and prefer to learn in a way that is best and easiest for them. In order to address sustainability, it is needed to include everyone as a target group, and to achieve better learning, active learning should be applied. Further, with the involvement of technology it is possible to show a reality which is not there as of yet.

Because sustainability and concepts around it are highly abstract, it can be harder for people to learn about them as easily as they could if they could look at the real things. Mixed and virtual reality technologies are here, but the problem is how can the available technology be combined with the available knowledge about sustainability to make people learn in an active way? As far as can be told, this has not been done very well yet. This could be because there are challenges tied to the design and development as the technology is relatively new and there are still investigations on how to design good quality user experiences for such new technology, and at the same time implement pedagogical principles and theories so people can really learn through it. In other words, this presents two challenges where one is the technology to design and develop according to good principles, while the other is to implement active learning strategies from a pedagogical perspective where the technology is used as the mediator. The bottom line is to allow people to learn, as well as to allow this learning to be facilitated by technology.

1.4.2 Aim

To design a mixed and virtual reality immersive experience that supports active learning and assess users' perceived level of presence and motivation.

1.4.3 Objectives

- To investigate gaps in the area of education, active learning, supported by immersive mixed and virtual reality technologies.
- To design a prototype of an effective mixed and virtual reality immersive experience that supports active learning, with the topic of 'Sustainable Future Cities' specifically focused on learning concepts in horticulture through exploration.
- Collect data by user testing through observation, interviews, survey, and iterations of the user's experience of the mixed and virtual reality immersive experience.
- To interpret and assess the relationship between users and their perceived level of presence and motivation when they use the mixed and virtual reality immersive experience prototype.

1.4.4 Research questions

RQ1 - How to design an effective mixed and virtual reality experience supporting active learning?
RQ2 - To what extent do user's perceive the level of presence and motivation in the mixed and virtual reality experience?

1.5 Limitations and constraints

- There are limitations on finding research materials and guides. The immersive technology is both niche and always developing at a fast pace. Especially when there are new features, such as improved passthrough in mixed reality, along with how to develop for the Meta Quest Pro and how it works with Unity packages. This also goes for the combination of education, active learning and immersive technologies.
- It was a limitation and risk that the University only had one Meta Quest Pro headset available, due to the fact that if it stopped functioning, it would prevent development as well as testing.
- Another limitation with the Quest Pro was that though it was an improvement over the Quest 2, it was still limited with its hardware, in that it could not run super realistic graphics without being plugged into a PC. This means the graphical fidelity will have to be less realistic, so the visual part for the prototype could not reach real-life realism even if the concepts were visualized as realistically close as possible.
- The target group was limited in that people from Grimstad in Norway were the most likely available participants to conduct interview and user testing with.

1.6 Report structure

After chapter 1 Introduction, comes chapter 2, which presents the state-of-the-art and definitions and characteristics of immersive technologies, presence, active learning, and active learning strategies. It also provides an overview of what others have done in the field of immersive technologies in education in terms of mixed reality and virtual reality, active learning and immersive experiences, and the combination of these two. After that, chapter 3 describes the methods used to gather data as well as for analysis of data. In chapter 4, 10 design principles for educational virtual reality design are presented, along with how they were followed and applied in the immersive experience use case. Further, the development process itself and design decisions made are described. Following that, chapter 5 presents the digitalized, summarized, and translated findings of the study and discusses them in regard to the research questions. Lastly, chapter 6 concludes the thesis based on what was found in the previous chapter, and notes possible future work.

Chapter 2

State-of-the-art

This chapter presents the definitions and categorisations intended for immersive technologies, presence and immersion in virtual environments, active learning characteristics and its forms in inquiry and experiential learning, learning styles, as well as strategies and activities. Furthermore, the chapter discusses research that has been done in the field to establish the state-of-the-art and identify gaps that can be found in terms of mixed and virtual reality used in education and the combination of the two, active learning and immersive experiences, and design solutions with regards to the visual, interactive, aural, and text.

2.1 Immersive technologies

Immersive technologies and extended reality (XR) are the terms used for technologies that enhance 'extends' our senses, and therefore our reality [5]. There are many categories and subcategories of immersive technologies. To make categorisation easier there is a reality-virtuality continuum shown in Figure 2.1, where on one end there is our real reality and no immersive technologies used to enhance it, and on the other end there is fully immersion where one would become present in a fully digital reality [6].

There are three main categories; augmented reality (AR), mixed reality (MR) and virtual reality (VR). Augmented reality is the real time projection of interactive digital elements onto a real world environment [5]. Mixed reality is when the digital and real world are displayed simultaneously and can have interactions with both the digital and physical objects at the same time [5]. Virtual reality is an immersive digital environment that replaces the physical world as well as provides the user with a feeling of presence in the digital world [5].

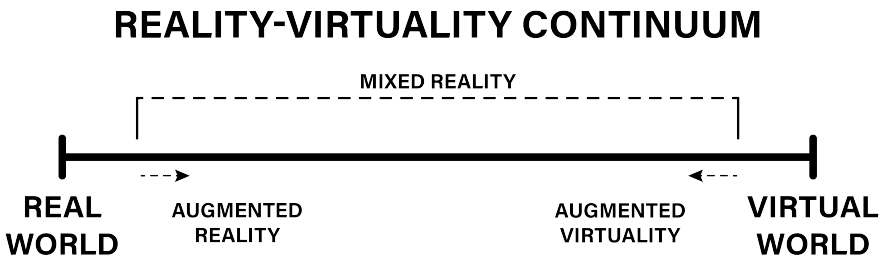


Figure 2.1: Reality-virtuality continuum, adapted from [6]

2.2 Presence & immersion in virtual environments

Presence in the context of virtual environments has been defined as the feeling of 'being there' in the digital world while physically being in the real world [2]. One may be aware that they still are in the real world, but their senses such as hand motions and visual perceptions tricks the cognitive processes to think the experiences are realistic, even if they know the digital environment is not physically real [2]. High or low levels of presence are determined by where the attention of the subject is placed between the virtual and the real world [2]. In other words, whether the person puts their attention fully on the virtual world, or whether they actively think about the fact that they are physically in the real world. Presence can be influenced by immersion, which is the sense of feeling included or enclosed in an activity or environment [2].

2.3 Active learning characteristics

There are different opinions on what people think active learning should be defined as. Although, when hearing the term most will likely think of someone learning something by 'doing' some type of activity or action [7]. Furthermore, they may also likely think of what it is not, such as students listening passively to a teacher talking about a subject in a traditional classroom setting, therefore it is not teacher centered, but rather student and learner centered [8]. Moreover, another important characteristic of active learning is that it shares the core value of constructivism, which is that learners construct their knowledge by merging new experiences with experiences from previous ones [9], [10].

2.3.1 Experiential learning

There are several different active learning forms, two of them are experiential learning and inquiry-based learning. They share similarities, and some key differences. One of the most important points for experiential learning is about the cognitive process of reflection when learning something hands-on [11]. It is important that the learner reflects upon the experience, both during and after the activity or action. Kolb's Experiential learning cycle shows this process and its elements in four stages [11]. Further, the combination of reflection, observation and active learning can help with problem solving and strengthen recall abilities [12].

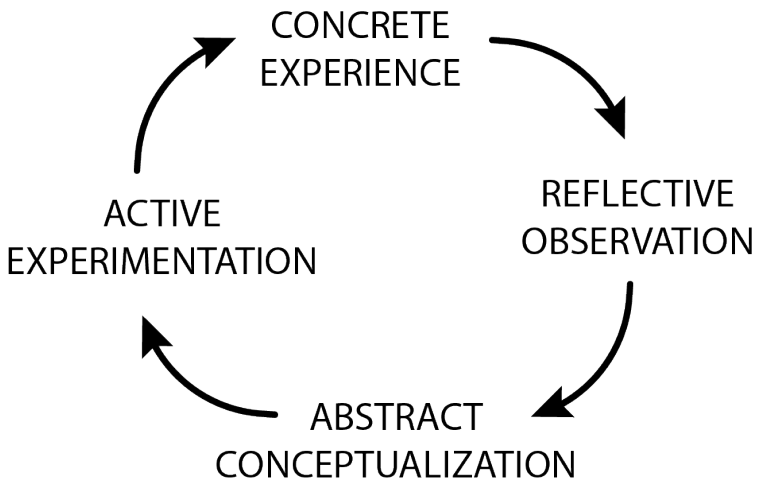


Figure 2.2: Kolb's learning cycle, adapted from [11]

2.3.2 Inquiry-based learning

Inquiry-based learning shares similar traits with experiential learning. There are different approaches to inquiry based learning, although one of the most important points is exploration by doing something hands-on and asking questions at the start of and during the active learning process. Banchi and Bell [13] proposed four different levels of inquiry; confirmation inquiry, structured inquiry, guided inquiry, and open inquiry. The difference between the lower and higher levels is that learners are more guided in the lower levels and more independent and self-directed in their learning process at the higher levels [13]. Therefore, motivation [3] plays a larger role for learners in the higher levels as they need to be more self-driven. For the lower levels, a teacher or guide can design and make the activities more structured [13] by for example the use of outlining learning outcomes with help of Bloom's taxonomy of educational objectives [14] and ask questions to test and reflect upon the knowledge learned.

Figure 2.3: Levels of inquiry, adapted from [13]

2.4 Learning styles - the VARK model

Each individual learns differently, therefore researchers have tried to identify and categorize learners' preferred learning styles. An example would be Kolb's four learning style categories [15] that have connections to the experiential learning cycle. Other examples are the VARK model, which consist of four modes of preferred learning styles; visual, aural, read/write, and kinesthetic [16]. A study tested on 91 students found 86.8% (79 students) of their respondents to be multimodal and 13.8% (12 students) to be unimodal [17], which shows that a blend of different modalities is effective for most. Therefore it is a key factor to consider in the development of an active learning environment and implementation of its strategies.

2.5 Active learning strategies & activities

Active learning strategies are activities that let learners get a deeper understanding, as more senses such as sight, hearing, touch and others are used and it can become easier to remember and recall after [12]. The learner is usually fully present in the moment and immersed in the activity or action. It can be more interesting and fun than passive learning [4]. Some examples of active learning activities are; real-world experience such as learning about insects in nature rather than from a textbook, role-play scenarios based on real events that could happen, learn through storytelling, play games, learn through case studies, simulations and many more [18].

2.6 MR & VR in education

Creating immersive experiences in educational contexts is a continuously developing field. They are utilized in higher education as well as K-12 to teach computing, science, medicine, math, and more [19]. This section will go over some applications of mixed and virtual reality in educational immersive experiences, first each separately, and then cases where both are combined.

2.6.1 Mixed reality in education

Technologies exclusively made for the realm of mixed reality are not widely available as of yet. Therefore it stands to reason that there is not much research of the use of it as an educational tool either. Even so, there are some. One study by Wu *et al.* [20] used mixed reality to teach radio frequency identification in higher education on a sample size of 35 students who were taking a related course [20]. It was found that the use of mixed reality provided an overall improved experience, as it was suggested that the visualization aided student comprehension both in theoretical and practical aspects [20]. To display mixed reality, they used a head-mounted display (HMD) in the form of HoloLens [20]. However, it should be kept in mind that mixed reality was used as an addition to various other learning methods, some of which were lectures, labs, and smaller exercises [20].

The HoloLens might come to mind as the technology that most in the field think of when they hear 'mixed reality'. Although it should be said, there are also other ways to be part of the mixed reality realm. In another study, by Salman *et al.* [21], mixed reality was utilized to teach nonsymbolic mathematics to four preschool children by use of a projector and small rocks. This way, they had interactions with real world objects that affected the projected image on top [21]. An infrared camera and depth images were used to track the objects and hands [21]. It was found that the unrestricted nature of the experience encouraged exploration, and that children were engaged by the game [21]. That is to say, it was unrestricted within the designated projected area, as interactions could not occur outside of this area due to the camera and projector being in a fixed location [21].

2.6.2 Virtual reality in education

Immersive technologies is a niche field, even the most known branches such as virtual reality headsets are not bought or used by the everyday individual, nor is it used as a normal tool in an educational setting. It is understandable that there are few who buy for personal use, although in education it shows a lot of potential as a support tool for learning, which means there are gaps to fill here.

As mentioned previously there are few examples of mixed reality in education. On the other hand, virtual reality is a little more commonly seen utilized for immersive learning experiences [19]. A study by Nersesian *et al.* [22] utilized virtual reality to teach middle schoolers to count in binary. They created an immersive learning experience on the Oculus Quest [22] and tested an experiment group of 19 participants and a control group of 15 who were taught by a certified instructor [22]. The virtual environment consisted of a small area with a color station to interact with [22]. To learn, participants interacted with levers on the station to produce certain colors by configuring the right order of levers to produce binary values [22]. It was found that the experimental virtual reality group performed equally well to the control group in the learning assessments, which led to the suggestion that virtual reality could be a supplement to traditional learning methods [22].

Furthermore, another study by Georgiou *et al.* [23] used a virtual reality experience developed by Chu *et al.* [24] and tested an immersive learning experience that teaches high school students the special theory of relativity. The immersive experience was designed for the Oculus Rift, and involved exploration of the milky way galaxy with a spaceship to solve inquiry-based tasks [23]. It was tested on 109 high school students [23], and results showed that students reported positively in regard to engagement, active participation, critical thinking and attitude towards the subject [23]. One of the most prominent benefits was said to be the visualization, and that observing the concepts helped understand them, as well as recall them later [23].

2.6.3 Mixed & virtual reality experience in education

While some studies have looked at mixed and virtual reality separately and assessed them for their educational value such as the study by Allcoat *et al.* [25], and others such as Remolar *et al.* [26] have looked at combinations of augmented and virtual reality, few have curated a combination of mixed and virtual reality in an immersive learning experience.

The study by Allcoat *et al.* [25] that looked at mixed and virtual reality in learning experiences tested 75 students with the HTC Vive for virtual reality and the HoloLens for mixed reality [25]. In this study, learning experiences were developed for both mixed and virtual reality, with the goal to teach students about solar panels [25]. Both versions were made equally in terms of information, content and learning material, to ensure fair evaluation [25]. Their findings suggested that mixed and virtual reality did not seem to surpass traditional methods in terms of learning, however it was deemed a suitable alternative to those methods [25]. However, they also noted that it may have emotional advantages, such as with satisfaction and engagement [25].

As mentioned, there were few examples to look at where mixed and virtual reality were combined into one experience. Therefore, a study by Remolar *et al.* [26] that combines augmented and virtual reality will be looked at instead as an example of a combination of the two in education, since augmented reality shares similarities with mixed reality. It taught Roman history by use of augmented and virtual reality [26]. The virtual reality part of the experience was to design a Roman city and then explore it in a first person perspective [26]. Meanwhile, the augmented reality aspect consisted of pointing a phone camera at a marker which made digital models from the city appear of buildings or characters with additional information about them [26]. The virtual reality part was self-directed and creative, while the augmented reality part was informative. The study involved 30 students and 15 teachers who tested on an Oculus Rift virtual reality headset [26] for the virtual reality part, and an Android phone for augmented reality [26]. Findings from the study revealed that students were positive towards the application, and also that it showed clearly that the experimental group outperformed the control group in terms of acquired knowledge from the experience, as compared to traditional methods [26]. However, though this is a study where both augmented and virtual reality were utilized as part of the same experience, they were still run on separate devices rather than being a singular experience on one device.

2.7 Active learning in immersive experiences

Immersive learning experiences naturally lend themselves to follow an active learning pedagogic approach, but how should active learning be supported in these immersive experiences? The following section will look at how others have adopted active learning approaches in their immersive learning experiences as examples.

One study by Wolfartsberger [27] implemented active learning in the form of engineer design evaluation in virtual reality. Highly detailed engineer design models were compressed to be displayed and interacted with in the HTC vive HMD [27]. Engineer design models could be disassembled and put back together, and the user could move around both physically in the real world and use teleportation to position themselves in the virtual environment [27]. Active learning is achieved as users are actively engaged with the virtual environment and do tangible interactions to inspect models and their structure. This way, users could comprehend and review the design in a way that gave them more control of the inspection and real world comparability. The study tested 72 students and university visitors and found that the virtual reality experience was a great addition to existing design review methods, and not necessarily a replacement [27].

Another study, by van Ginkel *et al.* [28], utilized immersive experience to improve students oral presentation skills. 36 students were part of the study [28] where they held presentations in front of 100 virtual avatars in an auditorium [28]. The experience was held in the HTC vive HMD [28]. They could hear coughing and applause, and controlled their own imported powerpoint while they held a presentation [28]. After the presentation, they were given feedback by an expert who was present when they took off the headset [28]. Active learning was supported quite directly as the user learned oral presentation skills by doing oral presentations. They did the presentation in what felt like real conditions, with an animated audience that whispered the moments before, became quiet when the presentation started, and applauded afterwards [28]. In this way, along with the visuals, it simulated a real environment and allowed the user to role-play a real presentation setting. The experience could be reflected on, along with the provided feedback, to improve their presentation skills [28]. The results showed that the students improved equally well to the control group, which the researchers admit could be due to an expert being present in both cases who provided feedback on the students' presentations [28]. Nevertheless, the experience consisted of users doing things and thinking about what they were doing in a realistic environment and highly practical sense.

In common, these studies involve visualization and simulations of real world situations and entities, and the ability to interact and be present in these environments. The environments are educational in purpose, and allow the users to experience situations and the freedom to explore and inspect unshackled by real world limitations, which contributes positively to the overall experience.

2.8 Design for active learning in immersive experiences

2.8.1 Interactions

Interactions are essential parts of an immersive experience. Without them, the user has nothing to do, which defeats the point of active learning. The following section looks at some examples of how others have implemented interactions in their immersive learning experiences, who they recruited as participants, and their findings.

One study by Bazargani *et al.* [29] made an immersive learning experience to teach topology relations. The experience included an escape room where the learner had to do certain interactions that were designed to be educational about topology relations in order to escape, such as explore the environment to find different objects around a house, answer questions, and draw shapes related to topology relations [29]. To make inputs for these interactions, the user could grab objects, paint with a brush, and move with two types of locomotion system; continuous movement and teleportation [29]. The study made use of the HTC Vive HMD and included 37 students [29]. It was found that the students found immersive learning experiences useful [29].

Another study by Markowitz *et al.* [30] created multiple immersive learning experiences in a study that consisted of four smaller studies to educate about the consequences of climate change. All studies made use of an Oculus Rift HMD to display the immersive experience [30].

In study one, participants first went scuba diving in real life before and after the virtual experience [30]. In the immersive experience, users embodied a stationary coral and used their coral arms to collect nearby items [30]. Meanwhile, a narrator told them about life in the ocean and ocean acidification, and as the immersive experience went by, the environment gradually changed into what experts expect it to look like in 40 years due to ocean acidification [30]. Study one involved 19 high school student participants [30] and found vast improvement in students' knowledge about the topic after the immersive experience [30]. Additionally, they state that immersive virtual reality can be used effectively in a high school classroom [30].

In study two, the immersive experience was similar to the first with the difference being that some participants had a normal scuba diver body instead of a coral [30]. Further, the researcher also simulated haptic feedback by poking the participant with a stick as a fish in the virtual environment bumped into their virtual bodies [30]. There was also no real life scuba diving before or after the immersive experience [30]. The second study included 49 university students [30] and found that, again, the experience was effective to gain knowledge about the topic, but there was no significant difference between the scuba diver body and the coral body [30]. There also was no notable difference in the sense of presence between the two bodies, which led to the suggestion that virtual avatars do not make much of an impact on the experience's intended learning outcomes [30].

Study three's immersive experience consisted of scuba diving off a boat into a reef, after an introduction by narrative and text [30]. Once in the water, participants used their hands to swim to find a reef and various ocean life within [30]. The animals were picked up and placed in a bucket [30]. After, they were moved to another reef impacted by acidification, where there were far less animals to collect to highlight the consequence of climate change [30]. At the end, participants compared the amount of animals they found in each zone while the narrator explained the effects [30]. The third study was held with 167 participants who were visitors to a film festival [30] and showed that the physical movement along with the environmental narrative led to positive changes in attitude and curiousness towards the topic [30].

The fourth and final study had similar conditions to that of the previous study, only that it evaluated other movement mechanics and their effects on attitude and knowledge gain [30]. These alternate mechanics were by use of their arms or with a joystick [30]. 44 university students used these movement mechanics to explore the reef and find animals, similarly to study three, and then were moved to another reef where ocean acidification had impacted the environment [30]. In this fourth study, it was found that the different locomotion systems had little to no difference in results, and it was suggested that it may have been due to the approaches being too similar [30].

In regard to interactions, the notable takeaways are study three and four, where the participants searched for sea snails in a reef environment, while climate change gradually revealed itself more and more [30], [30]. They made use of grab interactions [30] and locomotion methods that include swimming with their arms or joystick [30].

As for mixed reality, one study by Ogunseiju *et al.* [31] tested an immersive mixed reality experience to teach sensing technology in the field of construction. They used the HoloLens 2 as the selected HMD device for mixed reality [31]. The learning environment was meant to teach engineering students how to implement typical sensing technologies in a construction project [31]. To do this, it was split into three parts; exploration of the environment, tutorial on sensors, and implementation of sensors [31]. In the exploration part they were presented with construction activities and related information, and can select tasks such as be asked to identify safety risks [31]. Further, the sensor tutorial part gives instructions and a guided activity that involved a laser scanner on how to implement each sensor while addressing risks and other factors [31]. Lastly, the sensor implementation part lets students select construction activities in the environment and implement sensor technologies [31]. For all scenes, interactions with the environment were handled with hand tracking to do actions such as grab objects to move them and select menu items from a distance [31]. The study involved 18 engineering students [31], and found that the environment provided useful scaffolding support for learners to acquire knowledge about the topic [31]. It was also stated that the interactions were easy to do and easy to handle [31].

It can be seen as a common theme that immersive learning experiences include basic grab interactions and locomotion techniques such as continuous movement or teleportation.

2.8.2 Visualization

The visuals of immersive experiences can be realistic, cartoonish, stylized, and everything in between. To create a higher sense of presence however, it may be useful to take the realistic route, as one study by Slater *et al.* [32] revealed. In said study, researchers compared a ray traced environment to a ray casted environment, the difference being that the ray traced environment included the users shadow and reflection, and overall had more realistic lighting [32]. The study included 33 participants recruited from the University College London campus [32], and utilized a Virtual Research V8 head mounted display [32]. Even though the study is quite old, published in 2009, it is still noteworthy that they found that the ray traced environment suggested a higher level of presence, as well as stress levels, due to the slightly more realistic graphics [32].

Another study by Asgary *et al.* [33] visualized volcano activity in mixed reality, to use for training and emergency exercise. It created an application that made use of the HoloLens [33] to visualize volcano unrest conditions and eruptions [33]. A real volcano was modeled and used for the visualization based on elevation data, and particle systems were used to create different states of volcano activity which could be displayed [33]. As a result, the visualization showed a realistic display of the volcano [33]. The study admits it had not been fully tested for effectiveness, though with some internal testing conducted [33].

2.8.3 Text

Immersive learning experiences are great for visualizations and interactions, but they may also require text to comprehensively convey the learning material. However, the amount of text should be balanced, as one study by Hunvik and Lindseth [34] found. They created an immersive learning experience for the Oculus Quest [34] to teach artificial intelligence education, and tested it on 15 students [34]. Most respondents mentioned there being too much text [34]. The large amount of text was deemed excessive for a virtual reality environment, and participants suggested instead to incorporate more audio or visual elements [34]. These findings reveal that immersive learning experience designers need to be mindful of how they convey their learning material, and that they find a balance. It should be said that there can also be too little text, which could leave participants confused due to a lack of information [21].

2.8.4 Audio

Audio and voice narration can be important factors in immersive experiences. One study by Kelling *et al.* [35] included an immersive experience that told the story of an artist through their art, and included narration and ambient music. They used a Samsung Gear VR HMD [35] and tested on 32 conveniently sampled participants [35]. It was found that narration led to positive user experience and that most participants agreed that the inclusion of voice narration was interesting [35].

Chapter 3

Methodology

This chapter contains the experimental setup which describes the user test process and setup of the controlled environment where it was conducted, data gathering methods which include a human-centered design process to develop a prototype to use for testing and a mixed methods research approach that include in-depth pre- and post-test interviews, observation, and questionnaire. Additionally, the chapter goes over qualitative analysis as a methodology and thematic analysis which was used to analyze the gathered data.

3.1 Experimental setup

Experimental setup for the user testing included a controlled environment, namely the usability laboratory at the University of Agder, campus Grimstad. Over the course of two weeks in march 2023, user testing was conducted for two iterations of the prototype. Each test included five different participants. Tests were held with one participant at a time, and lasted for 60 minutes. The tests started with a three minute pre-interview, followed by two minutes of instructions on how to control and equip the Quest Pro headset. After, 30 minutes were reserved for the user tasks and observation. In this phase, the participants were observed as they used the prototype and completed tasks. Additionally, the experimenters took notes on paper. After the observations, there was a 10 minute digital questionnaire where the experimenters left the room while the participant answered. Lastly there was a 15 minute post-interview that went in-depth on their experience.

The physical conditions for the tests in the usability laboratory included three chairs, a desk, and a computer that let the observers view what the participant saw in the immersive experience, which was needed to take notes of the participants behavior, and also to see which paths they took to complete the experience. The controlled environment was quiet and had enough space for the participants to move around freely in the immersive experience without risk of collision with the real world. Further, the room was well lit which was important to ensure that the Quest Pro produced accurate tracking data of the head and hand movements of the participant.

Figure 3.1: Scenario of the experimental setup and usability test (pictured: an actor, not a real participant)

3.2 Data gathering

Data gathering is an important step in a research process to answer the research questions. The researchers can find and learn a lot by getting to know their users, respondents and stakeholders. After collecting data, they should be analyzed. This can be done with different methods. It can be helpful to develop a structured process one may follow when gathering data. The next sections detail the different methods used in the data gathering and analysis process of the project.

3.2.1 Human-centered design process

The prototype was designed in a human-centered design approach. A human-centered design approach puts humans in the center of all steps of the development process by application of known usability principles and consideration of human factors in the creation of interaction systems [36]. It is an iterative process whose purpose is to enhance the overall usability and increase the chance that the design meets the requirements [36]. Human-centered design activities are divided into steps, which can be returned to at any point due to the iterative nature of the approach. The first step is to plan the HCD process, then to understand and specify the context of use [36]. Next is to specify the user requirements, produce design solutions, and finally, evaluate the design against requirements [36]. These steps can be iterated upon and returned to as many times as it takes until the designed solutions meet the requirements [36].

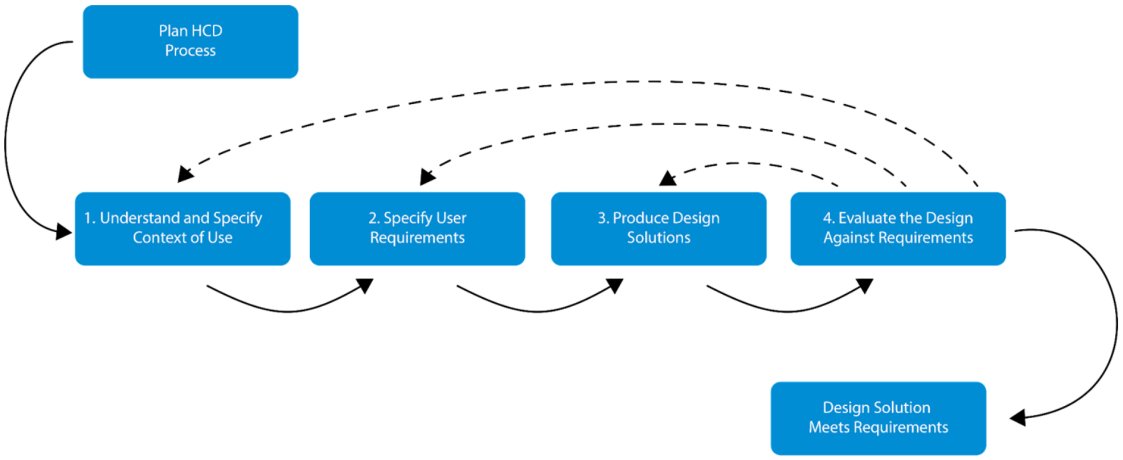


Figure 3.2: Human-centred design activities, adapted from [36]

3.2.2 Qualitative dominant mixed method

Mixed method research, also called mixed method design, is when researchers combine both qualitative and quantitative techniques together in various stages of research, for instance in their data collection, analyzation or interpretation of data phase [37]. There is a debate whether a mixed method approach can be considered a true method, as well as what constitutes a mixed methods approach [37]. Some say a true mixed method approach is when the researcher uses qualitative and quantitative methods equally when conducting their research project [37]. On the other hand, others think of it as a continuum where one side is qualitative dominant, the middle is equal status, and the other side is quantitative dominant mixed method [37]. So in this sense, as long as there are elements of both qualitative and quantitative methods present in one or more stages of the process, the research can be considered a mixed method approach [38]. The main reason for that a researcher would choose a mixed method approach is that one or more elements from a paradigm benefits the research [38]. As an example, there could be a research project where there has been a mostly qualitative approach, and additionally the researcher could ask the participants to answer a questionnaire to gather quantitative data.

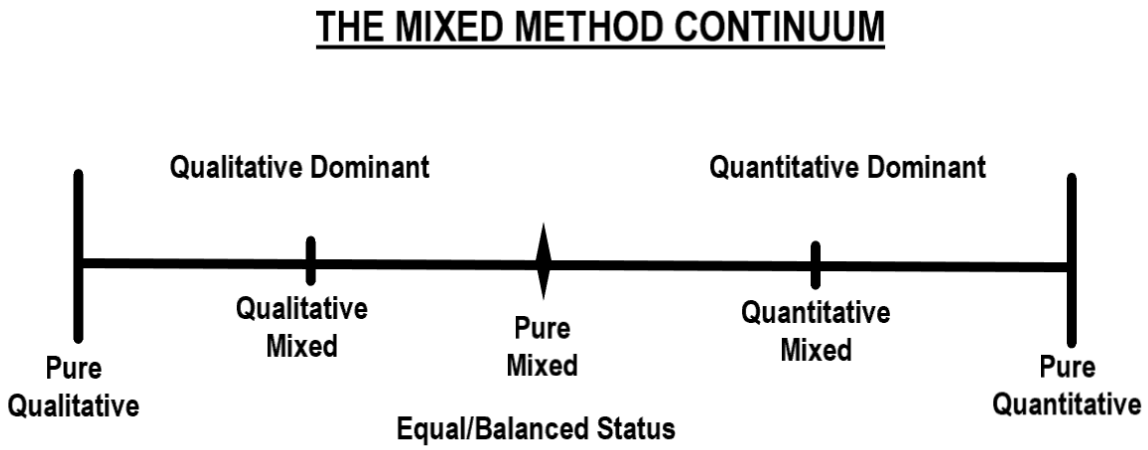


Figure 3.3: The mixed method continuum, adapted from [37]

3.2.3 Biases in research

Data gathered from participants in usability tests may be affected by bias, which is important that researchers keep in mind. Bias can lead to changes in behavior or responses in the test participant, and in that sense directly impact the findings and result of a study. In the context of user testing, researchers should be aware and mindful of potential biases that could occur [39]. For instance, the Hawthorne effect is a bias that can occur in participants where because they know that they are involved in an experiment, their behavior subconsciously changes from what it would have been like in a natural setting [40]. Additionally, participants could also display signs of Social Desirability Bias, where they behave differently because they want to please or impress the researchers [41]. Participants are not the only ones who can fall victim to bias, as it is also possible for the researchers to show bias, as with the Experimenter effect. This is when the researcher influences the participant's responses to, or interpret the data, to show what they expected to find out [42]. Further, the researcher should be mindful of the Priming effect, as how questions are prepared and formulated can impact the participant's response [43]. Words and phrases in the questions could prime the participant to answer a certain way. As an example, if a participant was asked "Was this a good experience?", instead of "How was this experience for you?", they may be more likely to give a positive response which would distort the data.

3.2.4 Qualitative interviews

Interviews can be held to gather qualitative data about a participant's thoughts and opinions. They can be structured, unstructured, or semi-structured [44]. Further, interviews can be held in a controlled environment setting, for example in a usability laboratory, but also out in the field, such as on the street or another natural setting where potential users and target groups can be found and sampled [44]. Semi-structured interviews, as the name suggests, are a combination where the interviewer has both planned questions and topics, but there is also room for asking the respondent to elaborate on their answers and probe for more information [45]. Field interviews are flexible and can easily be conducted in an informal setting, which makes it possible to recruit respondents on the street and interview them there and then.

Interviews can be short and direct, but also in-depth where the interviewer explores an individual's thoughts around an experience more deeply. In-depth interviews are useful to deeply understand a user's experience and opinions, for example after usability testing of an interactive system or prototype [44]. The questions included in the interviews and survey questionnaire were adapted from the presence and immersive tendencies questionnaire by Witmer and Singer [2]], and a review by Nortje [46] to inform the questionnaire on motivation. Additionally, motivation related questions were informed by Ryan and Deci [3].

3.2.5 Usability testing

The main goal of usability testing is to find out if a system, service or product (for example a prototype) can be used by the intended target group to carry out its intended tasks. [45] There are different ways to do usability testing. A typical usability test may be conducted in a controlled environment such as a usability laboratory, and but use of data gathering techniques such as interviews, observation and questionnaires [45]

To test and evaluate the design, user testing with ten participants was conducted over two user testing sessions as part of an iterative process. First a user test with five participants was held, then changes were made for the next iteration of the prototype and tested by five new participants. The user tests were held in the usability lab at the University of Agder, campus Grimstad. Participants were recruited through a combination of personal networking for people who were strangers, to avoid bias interference. Further, an announcement was published for multimedia bachelor students at UiA, and random people were approached on campus in Grimstad and asked to participate. These selection methods were chosen because these candidates had a higher probability to accept and spend an hour to participate in the test, not to forget the travel time to and from campus. In the end, it resulted in a diverse group of participants of various ages, genders, and technological familiarity, which was ideal. To conduct the test, an interview guide was made which can be seen in Appendix A.

Pre-test interview

The user test began with a short pre-test interview to establish the participants familiarity with immersive technologies and preferred approach to learning. Pre-test interviews are shorter interviews that are held before the test of the prototype. The purpose of this interview is to have simple questions so as to put the participant at ease, and sometimes also get some sense of some of their background. The pre-test interview included three questions.

Observation

After, they were given the Quest Pro and asked to complete user tasks in the prototype and observed as they did it. Observations are a data gathering method where users are observed as they perform tasks, typically as they use a prototype, to find out if the designed prototype satisfies set goals [45]. They are often used in combination with interviews for user tests to see if what the participant says matches up to what they do. The observers took notes of what the participant said and did, and also helped if they got stuck or could not progress. User tasks were prepared and observed as the participant completed them. The observer also took notes of the path each participant took, and if they encountered any errors, as well as things the participants said. Participants were reminded periodically to think aloud, to help understand how they experienced it through the think aloud technique. The think aloud technique is to request that they tell you what they think about when they complete their tasks [47]. If they forget to do this, they can be reminded by prompts that ask what they think of the moment [47].

Questionnaire

Once the participant reached the end of the prototype, a digital survey questionnaire was given and they went through and selected the options that felt right. The survey questionnaire consisted of questions that relate to their overall experience, to what degree they experienced active learning, their level of presence, and motivation.

Questionnaires are a set of questions, often presented as a document, for the participant to answer. They usually consist of a mix of closed-ended and open-ended questions and provide quantitative data in the form of statistics. Questionnaires are faster to complete than interviews and can be easily distributed. Questionnaires are similar to structured interviews in that they are a collection of closed and open-ended questions used to gather participants' thoughts [45]. However, questionnaires are easy to distribute and can be answered by participants on their own without an interviewer present [45]. It is therefore important that the questions inside a questionnaire are well formulated and not open to misinterpretations. The response format of a questionnaire is often a likert scale, which can be used to measure opinions [45]. Participants can choose on a scale of typically one to five, where one could mean that they highly disagree and five could mean they highly agree with a statement [45].

Post-test interview

Lastly, an in-depth semi-structured interview was held to understand their experience in more detail and open up for elaborations and a chance to ask why they showed certain behaviors. It provided more details to accompany what was said in the survey questionnaire, and could help rationalize why some choices were made over others.

3.3 Qualitative analysis of data

A qualitative analysis can be conducted once the raw data of the study has been prepared [48]. The analysis process should then start with becoming familiar with the data by revisions, for instance looking over an interview [48]. After, a structured approach should be applied to organize, categorize, and segment the data into usable parts that reveal the nature of the findings [48]. One such approach is to do a thematic analysis.

3.3.1 Thematic analysis

To analyze the collected data, a thematic analysis was conducted. Thematic analysis is a framework often used for analyzing qualitative data. Mostly used if there is a lot of data, although it can be useful for smaller sample sizes of data as well [49]. It is a useful, easy to use, and flexible approach [49]. Useful, because it helps researchers organize and sort their data into codes and patterns, which has validity as it makes it easier to analyze, interpret, discuss and construct knowledge [49]. It can also make it easier to find, sort, and get an overview of data that is confirmed, and/or not confirmed by previous research [49]. Further, it is flexible, because the framework is a guide with phases where one can move back and forth between them [49]. There are different ways of doing it, and can be customized to the researcher's needs, and what they think is important for their research [49]. Notes from the user testing were written by hand and then digitialized, coded, translated to english and full sentences, and then sorted into themes and subthemes. Noteworthy data from themes were used to interpret the data in the Findings and Discussion chapter to answer parts of the research questions. The thematic analysis of user testing with iteration one and two can be found in Appendix B and in Appendix C.

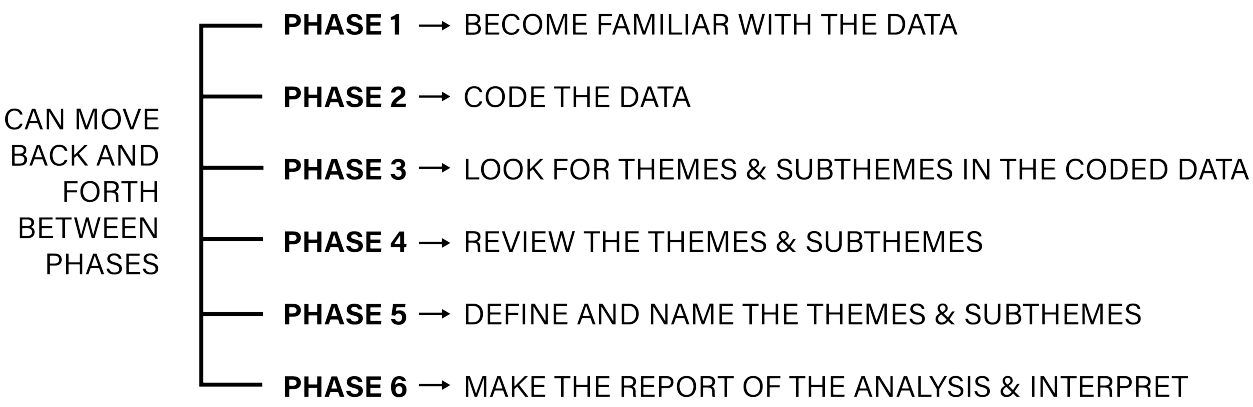


Figure 3.4: Phases of thematic analysis, adapted from [49]

Chapter 4

Design & development

This chapter details the design and development process of the sustainable future city prototype. It describes the prototype itself and what it includes, present list of applied educational-VR design principles, the inspiration behind it, the hardware and software used to develop it, how the development utilized a human-centered design approach, the interactions that can be found in the prototype, the scripts that made it work, the various models and assets and how they were procured, how the information windows were made to highlight text along with a voice-over, and lastly the numerous challenges encountered during development and the solutions that were found. To watch a short video demo of the prototype, follow the link in Appendix D.

4.1 Educational-VR design principles used for the mixed and virtual reality immersive experience

In this section, educational-vr design principles were chosen and applied based on guidelines proposed by Johnson-Glenberg [50]. They present 18 guidelines for educational VR and point to nine of which are deemed most important. To design the sustainable future city prototype, all 18 guidelines were looked at and the most appropriate for the project were used.

The educational-vr design principles used are presented, explained in a general manner, then concretely explained on how it was applied in the mixed and virtual reality immersive experience and reasons why. Further, they are again brought up in the context of how it supports design decisions effectively in the immersive experience as well as to answer research question one in chapter 5.1.2.

List of chosen and applied educational-VR design principles;

- ***Principle 1: Make it easy to use and presume that the user is a beginner, even if they may not be.*** Reason: Inclusion. So that everyone can use the application, even if they do not have the knowledge to use controllers. Anyone should be able to use it to learn and have fun with the learning material [50]. ***How principle 1 was followed, applied, and reasons why;***
  - There is hand tracking instead of controllers because it makes it easier for beginners to navigate through and interact with the immersive environment and learning material.
  - There are simple, easy to learn, and only a few hand gestures such as pinch, grab and poke to have interactions that are easy to do for everyone.
  - There is familiar UI such as the text concept spheres for the concepts in the immersive experience. They have similar design and layout as the window for web browsers on computers. For example design elements such as an X at the top right corner to close the window and the text scrolling options. There are other familiar design elements as well such as a button that can be selected to replay the voice over again.

- ***Principle 2: Do not use many UI elements or put them in places that can disturb the experience.*** Reason: Because it can take the user out of the experience and make them lose the immersion and their feel of presence. For example, do not put UI elements on the screen that follow the head movements and stay at the center of the user's vision [50]. ***How principle 2 was followed, applied, and reasons why;***

  - There are no static UI elements on the screen that follow the user's head movements.
  - The UI for the text concept spheres are all in one window to avoid having multiple windows open at once. Instead, voice-over and full-text can be switched between with the use of buttons.

- ***Principle 3: Introduce the learning content step by step through exploration where at the end all the learning content from previously are revisited.*** Reason: It is better to learn one piece of content at a time and not all at once, because this makes it easier and is a great strategy to learn and remember it [50]. ***How principle 3 was followed, applied, and reasons why;***

  - The user has to find the areas with the visualization of the concepts and its spheres with the learning material by exploring the immersive environment. They are pathed so the learners can choose to follow them. Further, the text content is written in a manner that introduces the material step by step, as well as still being flexible to choose and read in those areas in the immersive environment where the concepts are intertwined with each other, for example in the hangar. Furthermore, at the end all the learning materials previously learned are revisited by doing the end quiz to finish.

- ***Principle 4: Exploration that is guided.*** Reason: To make sure that the users learn what they should, but also give some freedom to explore to satisfy curiosity and make it more fun and interesting [50]. ***How principle 4 was followed, applied, and reasons why;***

  - Users should learn what they should therefore realism plays a big role. The concepts and topics presented should be based as close as possible to the real world, both visually and text based as well. An example from the mixed and virtual reality immersive experience is the vertical farm system where salads are stacked on top of each other like in an real vertical farm and the the pink lighting and other lighting options are the real LED color-light choices made for such set ups. Although, some of the surroundings such as the bridge to the city, and the future sustainable city centre are design choices with fantasy elements as they are not something that exist in the real world. Those choices are still relevant and have a point as it makes exploration more fun and interesting for the user.
  - Other design elements and measures taken that help with explorational guidance are; signs to indicate where the topic areas are, and parts in the city that are invisibly locked off with colliders such as to prevent walking on the grass, walkways that are irrelevant, or through buildings, so that the user will automatically walk on the walkways that lead to relevant areas.

- ***Principle 5: Have text, but not too much.*** Reason: Because too much reading in VR can be a burden on the eyes [50]. ***How principle 5 was followed, applied, and reasons why;***

  - The main thing in that all concepts are visualized. The text is an addition to explain the visualization of the concepts.
  - The texts for each concept are concise and use simple language.
  - There is a voice over which guides users through the text so they do not have to read it with their eyes. Users can choose to listen if they want.

- ***Principle 6: Implement elements that require the user to learn the material through error.*** Reason: So that users can learn from the errors they make [50]. ***How principle 6 was followed, applied, and reasons why;***

  - The main example of that principle 6 was applied is the endquiz. User may fail on the quiz, which means users have to try again, and thus learn from their mistakes.

- ***Principle 7: Implement immediate or non-disturbing feedback on action for both interactions in the environment and learning material.*** Reasons: In terms of interaction with the environment it is important so that they will not lose the immersion and feeling of presence. As for the learning material, it is important so that users can learn through feedback such as with errors, and also it will help with reflection and recall later [50]. ***How principle 7 was followed, applied, and reasons why;***

  - Interactions such as teleportation, ray, grab, and poke interactions have audio that plays whenever something is hovered over or selected.
  - Concept spheres become lighter in color when hovered by users.
  - The end quiz provides non disturbing feedback as it changes color on the virtual computer screen to red if the quiz is failed, or green when it is passed.

- ***Principle 8: Implement design elements that make learners reflect on the learning material.*** Reason: So that the learners build knowledge and get a deeper cognitive understanding of the learning material [50]. ***How principle 8 was followed, applied, and reasons why;***

  - The realistic visualization of the concepts are there for the users to inspect freely and reflect on.
  - There is time between traveling to each concept sphere which can be used to reflect on what user's just learned.
  - The quiz forces users to reflect and recall what they learned.

- ***Principle 9: Use hand gestures to promote 'active' learning.*** Reason: Physical action can help make it more fun and interesting. And the use of kinetic senses with the combination of virtual senses can make learning easier to remember [50]. ***How principle 9 was followed, applied, and reasons why;***

  - Hand tracking and the ray, grab, and poke interactions force the user to actively perform gestures to progress or actively interact with the environment. For instance, the button to change colors of the LED lights is an activity that contextually shows how different LED light colors can be utilized, and is controlled by the user as they push the button.

- ***Principle 10: Hand gestures that give the user the feeling of control.*** Reason: Gives the learner more freedom to explore and make choices of their own, which can further improve enjoyability and help with memorisation [50]. ***How principle 10 was followed, applied, and reasons why;***

  - Gestures such as to open doors and push buttons or keyboard keys give users control and agency in the environment.
  - The ability to teleport and explore around the environment also gives users control in the environment.

4.2 The immersive experience use case

The prototype is an immersive experience where the user explores an example of a sustainable future city to learn about sustainability concepts that can be found therein. They do this by exploration of the environment which lets them see and experience the topic. The sustainable concepts are included in the prototype as concept spheres, which are selectable blue spheres that can be found near areas where the topic is visualized in the virtual environment, and explains the topics further when selected.

4.2.1 List of included sustainable concepts

- **Sustainability**
- **Controlled environment agriculture (CEA)**
- **Vertical farming**
- **LED lights**
- **Hydroponics**
- **Aeroponics**
- **Aquaponics**

4.2.2 Intended learning outcomes

The following intended learning outcomes were developed based on Bloom's taxonomy of educational objectives [14]. After the immersive experience;

- The learner should be able to describe sustainability
- The learner should be able to list areas on the topic of 'sustainable future city'
- The learner should be able to recall, recognize and relate concepts learned in the immersive experience to the real world
- The learners should be able to outline and differentiate between traditional farming and Controlled Environment Agriculture
- The learners should be able to describe or outline, recognize and differentiate between different systems used in Controlled Environment Agriculture settings

4.2.3 Description of the immersive experience

Along the way through the prototype, concept spheres can be found and selected. Selecting a sphere will open a window of text and a narrator will read it out loud. Users can listen to or read the descriptive texts themselves, which explain the related sustainability concepts to substantiate what they see in the virtual environment. To move around, they can walk freely in the real world space they have available, as well as use teleportation to jump forward inside the virtual environment. Additionally, there are also interactions where users can push buttons and open doors. It is a vertical prototype, which is to say that it elaborates on the specific topic of agriculture and plant production in underground farms. There are three scenes in the prototype; the mixed reality, the city, and the underground farm.

The mixed reality scene, which can be seen in Figure 4.1, consists of a small miniature model of the city along with some selectable spheres, and a door that can come up from underneath the ground which has a bridge on the inside that users can cross. The reason for this scene is to include a mixed reality environment which can transition into full virtual reality when users go through the door. Additionally, in a final version of the prototype, there could be multiple future cities that all have different sustainability concepts and ideas within them, and it could be possible to select which city the user wants to visit from here. A storyboard/sketch to illustrate the base concept of this idea can be seen in Appendix E.

The city scene, which can be seen in Figure 4.2, is large and detailed so the user can explore a sustainable future city. There are no concept spheres, but there is an enterable hangar to reach the underground farm scene.

The underground farm scene, which can be seen in Figure 4.3, is the most developed part of the prototype. This scene is thought of as the agriculture and plant cultivation concept area, and is fully functional and explorable with its environment, elevators, concept spheres, interactions, and quiz to test users' knowledge. The various farm systems found reflect real world applications and facilities where such sustainable methods are used. A storyboard/sketch was made to illustrate what the environment should look like and some interactions that were considered, which can be seen in Appendix F.

Figure 4.1: The mixed reality scene

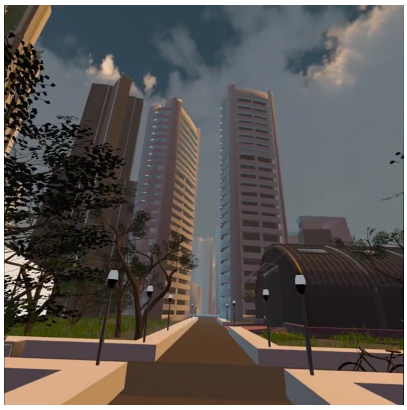


Figure 4.2: The city scene, seen from ground level

Figure 4.3: The underground farm scene

4.3 Inspiration for design and text-script

The look and design of the environment were inspired by real world future sustainable solutions. It was important that what was shown was based on real life application of the technologies, as the goal was to be educational about the topic.

4.3.1 Inspiration for 'sustainable future city'

A National Geographic article was used as inspiration for the city, which showcases concepts of future sustainable cities where experts were consulted [51]. It inspired some of the visual design elements of the city, how the buildings should look in regard to style and that they should have rounded corners, the added greenery in the city and terrain, and the color palette used. Further, it helped provide an overview of the broad variety of concepts that exist in a sustainable future city, such as concepts within the areas of transportation, lifestyle, and energy. Part of the scope was to create a vertical prototype, which meant that only one such concept area would be implemented, which was horticulture and crop production. The article also helped inspire how text in the prototype should be brief, concise, and use simple language. How the text is presented as well, in rectangular frames, also inspired how the information windows in the prototype should look. It was beneficial to make them clear to understand, that they provide an overview of the topic, and that they only provide the most relevant information. Lastly, the article inspired the idea where users start with a bird's eye view of the city, as they can look down on it when it is small scale, and then they are able to go into the city as it becomes full scale and can explore it on a ground level.

4.3.2 Inspiration for the transition between the MR and VR environments

The part where the user can look inside and go through the archway from the mixed reality scene and transition into the inside of a fully immersive VR space was inspired by an AR application that has a similar effect, where users can enter Vincent Van Gogh's home [52].

4.3.3 Inspiration for horticulture systems and visual elements

The look and design of the hydroponics and vertical farm [53], [54], aeroponics [55], and aquaponics, [56] systems, how the salad is stacked vertically, its lights and colors, and the disinfection room, were inspired by pictures and video of real world facilities where these techniques are used. The aquaponics station's visuals were inspired by images of real world systems. However, the implementation in the prototype was changed slightly to make the system more presentable, by inclusion of a larger fish tank that has glass to see through so the fish are clearly visible.

4.3.4 Text script

The text script was written to describe and explain the concepts in the immersive experience. They are factual and are visually represented by blue spheres, or concept spheres seen in Figure 4.4 where the user can click on and get the descriptions both as a written text and read out loud by a narrator. They can be found besides the visual representations of the concepts. A full version of the text script can be found in appendix G.

Figure 4.4: Example of a selectable concept sphere

4.4 Hardware - Meta Quest Pro

Meta Quest Pro was released in October 2022 [57], only a short while before the work on the master thesis began. It is advertised as a mixed reality headset, due to its notable improvements over the Quest 2 in regard to its full color improved passthrough feature [58]. Additionally, it had better sensors to read tracking data, better optics, resolutions, field of view and audio [58]. The Quest Pro is also backwards compatible with Quest 2 applications, which also meant that it was possible to develop for the Quest Pro with the same tools that are used for Quest 2 development [58].

4.5 Software & usage

The immersive experience was developed using Unity [59], Microsoft Visual Studio [60], and Blender [61]. Early stages of development was spent problem solving and figuring out what is possible with VR in Unity, in regard to interactions, graphical fidelity, performance, maneuverability, render engines, and passthrough functionality.

4.5.1 Unity

Unity is a game engine developed by Unity Technologies that can be used to develop games and applications [59], [62]. It is free to use, supports 2D, 3D, AR and VR projects, and focuses on being a feature rich tool that can be used by professionals and beginners alike. Unity is based on components [63] and frameworks that simplify the development process, and there is also an asset store built into the editor which allows quick and easy utilization of downloadable assets [64]. Further, unity supports installation of custom packages of pre-programmed components that further simplifies development [65].

4.5.2 Oculus Integration SDK

Oculus Integration SDK [66], developed by Meta, is a collection of helpful scripts and components for developers to set up development for Oculus VR headsets. This includes the Meta Quest Pro [58], the latest release in the Quest series at the time of writing, and the targeted device for the immersive experience.

The Oculus Integration SDK consists of other, smaller bundles of SDKs, such as the interaction SDK and OVRPlugin [66]. In these bundles there are libraries of scripts, prefabs [67] and assets that can be used to help develop on the Quest VR headsets [68]. For example, the OVRPlugin contains prefabs of usable rigs that are already configured to receive tracking data from the Quest headset, as well as cameras for each eye [69]. Additionally, it enabled use of Quest features such as hand tracking and passthrough [69].

4.5.3 Blender

Blender is a free program that can be used to create 3D models and animation, in addition to many other features [61], [70]. For the prototype, Blender was used to source and download creative commons models through BlenderKit [71], and also to reduce the face count of high resolution models downloaded from other sites. BlenderKit is an add-on to Blender, and is a large database of assets and models that are free to use, and can be imported directly into the Blender project [72]. It was also used to reduce the amount of faces on downloaded assets which was helpful for high resolution models that would have been too large for the Unity project otherwise.

4.5.4 Microsoft Visual Studio

Microsoft Visual Studio is an Integrated Development Environment (IDE) that can be used to create and analyze code efficiently [60]. It was used as a companion tool to Unity to write all the scripts in C#. It helped organize the code, pointed out errors, and came with suggestions for code which sped up the process.

4.6 Human-centred design approach

A human-centered design approach was chosen to develop the prototype. It considers human needs, affordances, ergonomics, and purpose in the design [36]. Additionally, human-centered design increases the usability, accessibility and provides an overall improved user experience as a result of the design [36]. A prototype needed to be developed as a proof of concept in order to answer the research questions and fill the identified gaps in this research field. A human-centered design approach ensured the result was usable, effective, and provided a positive user experience as well as accurate data from the test participants.

To follow a human-centered design approach, related activities were conducted alongside development of the prototype. Traditionally, human-centered design activities are held before development. However, due to a lack of experience with Unity, the Meta Quest Pro, and its functionalities, development began alongside planning of the HCD process. In this case, development is referred to in the sense of figuring out the 'what' and the 'how' of what was possible and achievable with the technology within the timeframe. Much of the time early in the project was spent figuring out how this prototype could be created, as this had to be learned alongside the research. It was done this way because it was prioritized to find out if it was even possible to create the prototype. Also, it was helpful to know what was technically achievable or not when planning the HCD process.

4.6.1 Specify context of use

To understand and specify the context of use for the prototype, multiple activities were involved. Firstly, other related studies were looked at to see what they had done and whether it could be improved upon and implemented. Then, a PACT (People, Activities, Contexts, Technologies) analysis was carried out to describe the target group, what they are expected to do, where they do it and what technology they use. The full PACT analysis can be seen in appendix H. Further, personas were created to get an idea of the users' needs, goals, and expected behavior [73]. Sample personas can be seen in Figures 4.5 and 4.6. They consist of imaginary potential users and describe their backgrounds, needs, preferences and goals. The full list of personas can be seen in appendix I. In addition to personas, user stories were created to describe the expectations and experience of the users, from their perspective [74].

Persona 1 - Leah Moen

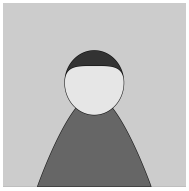
General information & Background

Name: Leah Moen
Age: 19
Role: New student
Residence: Grimstad
Occupation: student at University of Agder, studies multimedia
Income: 0 kr/year, but gets help from Lånekassen and her parents
Skills and knowledge: Grew up with technology, but as most people, has not tried mixed or virtual reality before, but is very open to it if an opportunity would arrise. She also loves going fishing with her grandpa since she was little. Can speak norwegian and english.

User stories/user goals:
"As a new student I'm open to trying out new ways of learning. I think I'm a visual and practical learner so I can see the potential in being able to 'visit' or experience a 'sustainable future city'. Especially as such concepts are difficult to imagine when you are just reading a text about it, because no-one can 'visit' the future, so it would be cool to 'visit' it in that way, digitally."

Figure 4.5: Example of persona

Persona 3 - Nils Petter Gundersen



General information & Background

Name: Nils Petter Gundersen
Age: 34
Role: Electrician
Residence: Grimstad
Occupation:
Income: 427 000 kr./year
Skills and knowledge:.

Is somewhat familiar with VR technology, however he is not particularly interested in it. He only knows what he has seen in the media, and has not tried it himself.

User stories/user goals:
"As an electrician, I enjoy problem solving and being active when I learn. However, I feel I have learned what I need to know, and do not feel the need to spend a lot of time learning outside of work. If I do, I prefer it to be simple and not take up too much time of my day. I would not bother to read a whole book on a topic, instead I would Google it and find a concise description. "

Figure 4.6: Example of persona

As mentioned, these activities were carried out simultaneously as the prototype was developed, which meant they had multiple iterations as discoveries were made in Unity of what was possible there. To validate the context of use, and requirements, street interviews were conducted with people in Grimstad, with the purpose to validate design decisions made and to identify potential improvements or oversights [75]. These interviews were held with five people who were asked out in public in Grimstad. These people were of different ages and genders, educational preferences and technological familiarity. This selection method was chosen because the target group is the general population, ages 19 and up, with no need for preliminary knowledge of either the technology or topic, and this method resulted in data from such people.

4.6.2 Specify user requirements

User requirements were specified by use of a version of the Volere snow cards [76]. With Volere, functional requirements, as its name suggests, describe the functionality of the design, how parts of the system work together and actions within [76]. Non-functional requirements however, describe requirements such as the look and feel, as well as requirements related to the efficiency and usability of the system [76]. Functional and non-functional requirements were developed based on descriptions procured from the context of use specification, and organized as Volere snow cards, as can be seen as examples in Figure 4.7 and 4.8. A full overview of described requirements can be found in appendix J.

Requirement #: 5 **Requirement Type**: 9 **Event/use case #**: X

Description: The user should be able to interact with the environment by grab, ray and poke interactions
Rationale: Interaction with the environment gives the user agency and makes the experience more immersive
Source: The project group

Fit Criterion: The user can interact with objects through grab, ray and poke interactions
Customer Satisfaction: 5 **Customer Dissatisfaction**: 3

Priority: 1

Supporting Materials: Oculus Integration SDK documentation

History: Created 26.02.2023

Figure 4.7: Functional requirement

Requirement #: 13 **Requirement Type**: 10 **Event/use case #**:

Description: The visualization should be as realistic as possible for the concepts users are to learn about.
Rationale: It is important because these are real world concepts that need to be visualized accurately to convey the learning material.
Source: The project group

Fit Criterion: The visualizations of concepts are accurately portrayed as they are in real life.
Customer Satisfaction: 3 **Customer Dissatisfaction**: 6

Priority: 3

Supporting Materials:

History: Created 19.03.2023

Figure 4.8: Non-functional requirement

4.6.3 Produce design solution

As mentioned, the prototype was developed based on the context of use and requirements specification. First, the prototype was developed as basic scenes to test the interactions and functionalities of the Oculus Integration SDK. Functionalities include setup of VR and Quest Pro to work in Unity, interactions such as the grab, ray and poke interactions with objects and UI elements, Unity settings, render pipelines, scene management, and script related behavior. They were essentially standalone assets and behaviors, which could then be modified to fit the user requirements as they evolved. Environment refers to the virtual environment and assets that make up the mixed reality, the city, and the underground farm scenes. These were first implemented as basic layout and visuals, and then gradually improved as the requirements specifications were iterated upon.

A conceptual model was developed to visualize the internal system and how it responded to user actions in the prototype, which can be seen in Figure 4.9.

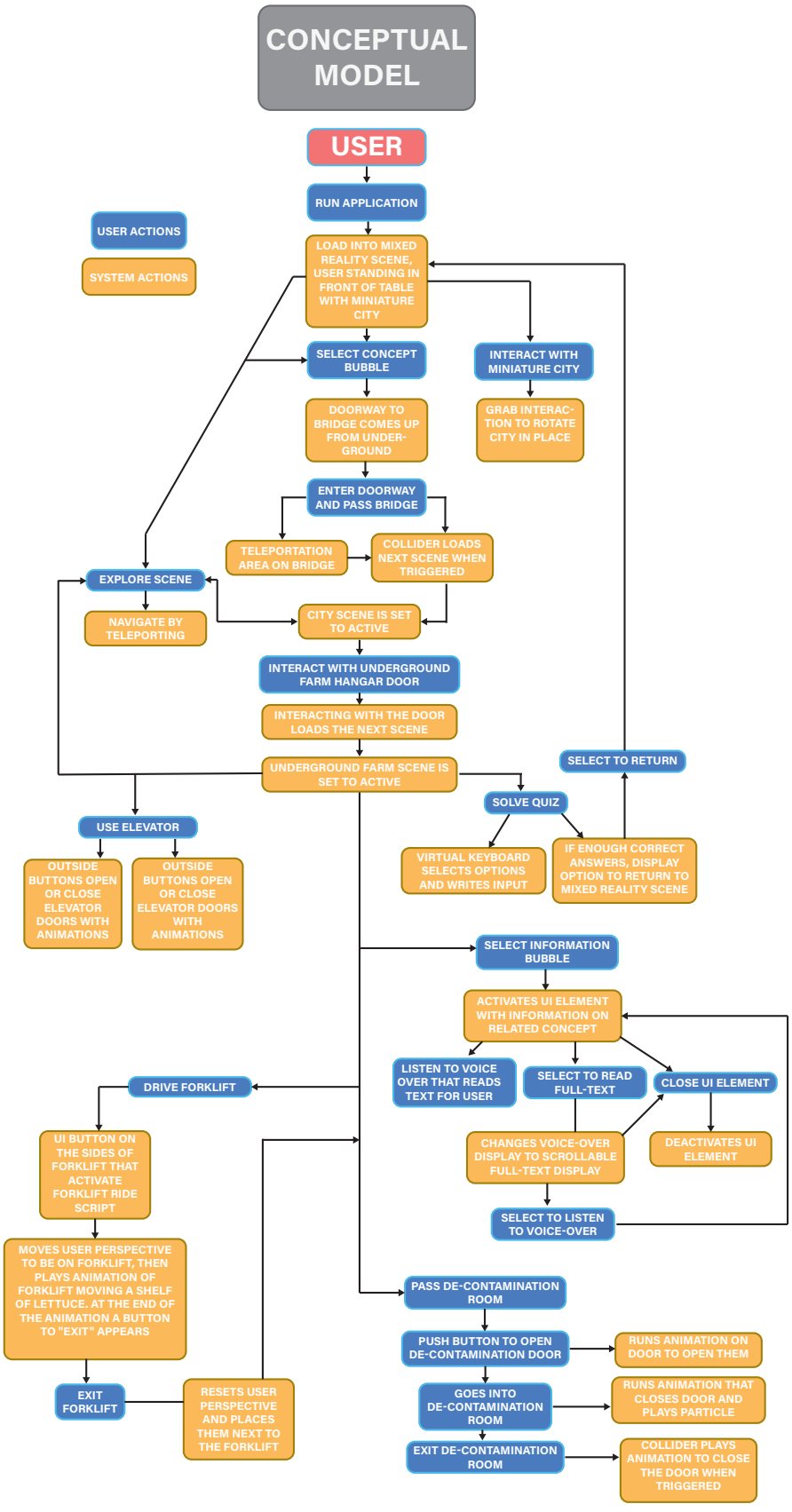


Figure 4.9: The conceptual model

Before the conceptual model, the prototype consisted of disconnected scenes that had been used to test and problem solve functionalities. By this point, the base functionalities worked as intended, such as the Quest Pro worked with the rig, hand tracking, grab, ray, and poke interactions, teleportation, and the selection of spheres to open UI elements. The environment had also been developed further to include a basic version of all the areas that were intended to be implemented. The conceptual model could then be used to guide how all the different parts should be assembled. All the prepared functionalities and environments could then be put together to create the first version of a high-fidelity prototype where it was possible to go from the miniature model of the city in mixed reality, into the city itself in virtual reality, and then to the hangar and underground farm. Information in the form of text and voice over were also added to some of the concept spheres, as well as details in the environment, in particular around the sustainable concepts to make them seem more like their real world counterparts. Further, a hierarchical task analysis was conducted to identify the user's tasks in the immersive experience, which can be seen in Figure 4.10.

Figure 4.10: The hierarchical task analysis

4.7 Interactions

The Interaction SDK is a collection of components that can be dropped into projects to handle controller and hand interactions [77]. It is part of the Oculus Integration SDK, and was used to add ray, grab, and poke interactions to the immersive experience. Each of them have an interactor and an interactable component that let Unity understand when a gameobject is interacted with, which enables an Interactable Unity Event Wrapper component to turn these interactions into events when interactions such as selection occur on the gameobject. To do such selections, it is possible to use hand tracking.

4.7.1 Hand tracking

Hand tracking allows users to use their hands to interact with the virtual environment, without the need for separate controller units. It can help increase the feel of presence [78], and also make interactions feel more natural for users who are less experienced with VR [79], [78]. Sensors on the outside of the headset track the hands and fingers, with surprising accuracy. That said, tracking can be lost if hands are at certain angles where fingers cannot be seen.

In Unity, hand tracking can be added through the Oculus Integration SDK [79]. It is included as an optionable input method in the oculus integration sample rig, and can be interchanged with controllers which makes it easy to swap between input methods if needed [79].

4.7.2 Ray interactions

Ray interactions allow the user to select something from a distance. There are two components that enable this behavior, the Ray Interactor, and the Ray Interactable [80]. The Ray Interactor shoots a line, or a ray, out of the gameobject it is attached to at a set distance that tries to detect if it collides with the surface of a Ray Interactable [80]. In this case, the Ray Interactor is attached to the user's hands. The Ray Interactable component is added to gameobjects that are supposed to be targeted by the ray. This allows actions on the gameobject to be tied to event triggers, such as when it is hovered or selected by the ray.

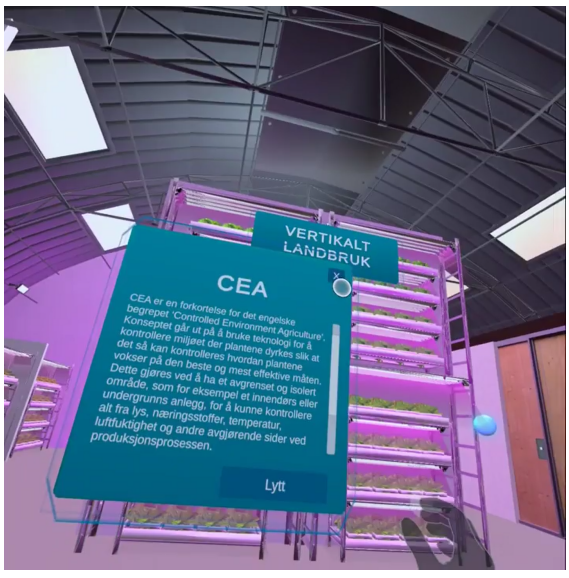


Figure 4.11: Ray interaction where menu is hovered

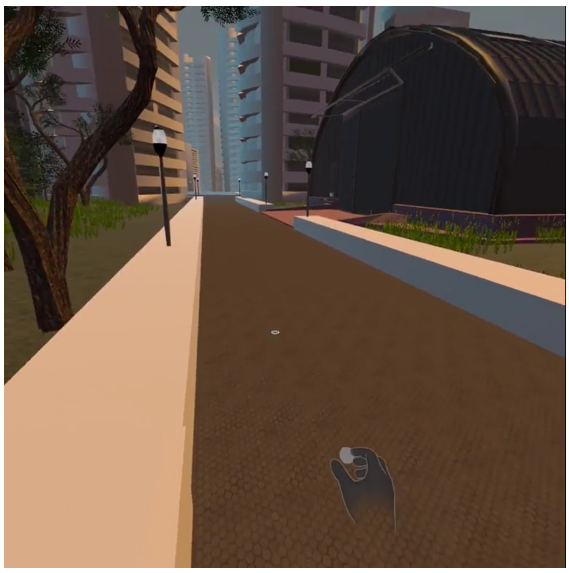


Figure 4.12: Ray interaction where user teleports

In the immersive experience, ray interactions were used extensively to handle interactions with the concept spheres, User Interface (UI) elements, and teleportation. Spheres can be selected from a distance, which opens a window of text that can be listened to (voice over), or read independently. The window is a UI element that has buttons for the mentioned options, as well as a button to close it. It functions identically to the spheres, where it can be targeted and selected by the ray, only that UI interactions require an additional PointableCanvasModule gameobject to be in the scene. There also needs to be a Pointable Canvas and Pointable Canvas Mesh component attached to the UI gameobject, for the ray to detect its surface.

4.7.3 Hand grab interactions

Hand grab interactions allow the user to grab objects with their hands. Similar to ray interactions, hand grab interactions require their own interactor and interactable components [81]. The hand grab interactor looks at the hand's fingers to know when a selection is made, and if so it attaches the selected gameobject to the hand so it follows it, as long as the object has Hand Grab Interactable and Grabbable components attached [81].

Figure 4.13: Hand grab interaction to grab the hangar door

In the immersive experience, hand grab interactions were used for the openable hangar doors and office door within. The hangar and office doors can be opened if the user grabs the handle and either pushes or pulls. In the system, users do not actually grab the door, instead they grab an invisible "Grabbable Handler" gameobject. It was also an idea to use hand grab interactions for tasks where the user had to pick up objects to move them, but time ran out before such a task could be implemented.

4.7.4 Poke interactions

Poke interactions allow the user to poke objects with their fingers and enable pushable buttons. It also requires its own interactor and interactable components so Unity knows which object is the finger and which is the button [82]. To determine the thresholds for when the button is hovered or selected, it has two child gameobjects where one has a Plane Surface component, and the other has a Box Proximity Field component. Together with the button gameobject itself, they determine where the button push begins, and how far it has to be pushed before it selects. Poke interactions are included in the underground farm area for the various buttons that can be pushed there, as well as the keys of the virtual keyboard in the office that is used to answer the quiz.

Figure 4.14: Poke interaction on elevator button

4.8 Scripts

There are multiple scripts that control behavior in the prototype. Some were inspired and adapted from tutorial material found online, but most were worked out through trial and error with use of basic C# code. All script files include comments that detail what each line of the code does, and a full overview over the scripts, what they do, and any references or inspirations attached can be found in appendix G.

While some scripts such as those for the keyboard and grabbable doors are inspired and adapted from online tutorial material, it should be said that there was one use of code for a shader, which was used as is. This is the shader that can be found in the mixed reality scene, which is placed on the walls around the door to the bridge and on the ground, which can be seen in Figure 4.15 and 4.16. This shader, courtesy of user DMGregory on stackexchange.com [83], hides anything behind and prevents it from being drawn in the frame. This created the illusion of being able to see the inside but only when seen through the door.

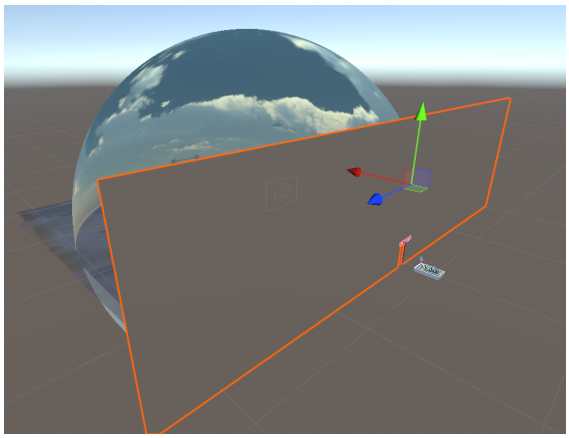


Figure 4.15: The invisible shader applied to the wall seen from above

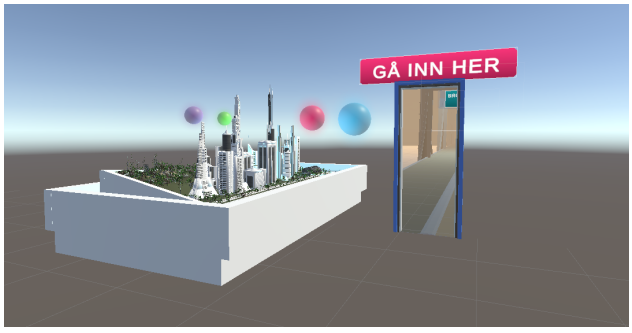


Figure 4.16: The invisible shader applied to the wall seen from the user's perspective

4.9 Models & assets

In the prototype, most 3D models are either made of basic shapes or downloaded assets. All downloaded assets were ensured to be creative commons and free to use. This was done because the prototype had an ambitious virtual environment, considering the large scale explorable city and underground farm area. These environments required detailed terrain, exterior, and interiors to become a believable experience, which was important because the research looked at users' perceived level of presence, and details made the environment worthwhile to explore. Additionally, due to the amount of time allocated to learn and figure out VR in Unity, this meant less time could be spent on modeling the high number of assets that were required. Therefore, downloaded assets were modified and adapted to be used in the prototype. It should be said that this applies to objects that are complex and highly detailed. Simpler objects that could be made with basic shapes, such as the table under the miniature model seen in Figure 4.18, walls, ceilings, and floors, were self made. Other examples of self made models are the pushable buttons and the virtual keyboard, which can be seen in Figure 4.17 and 4.19.

Figure 4.17: Pushable button

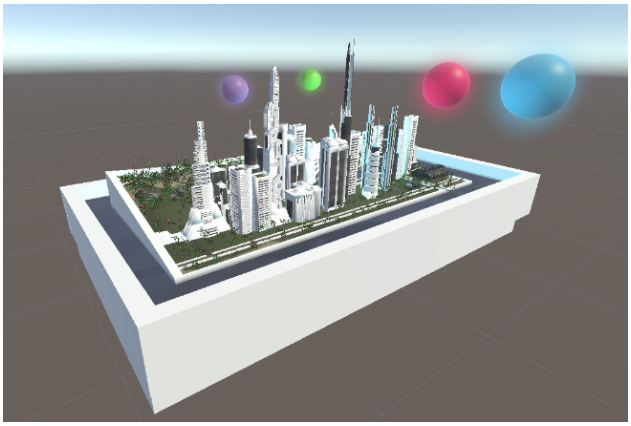


Figure 4.18: Miniature city model

Figure 4.19: Virtual keyboard

4.9.1 Downloaded assets workflow

Downloaded assets were either imported directly into Unity, if they had few faces, or into Blender if they had many faces. As mentioned in the optimization chapter, high resolution assets were put through Blender where a decimate modifier [84] was applied to reduce the total number of faces. This was essential so that Unity could handle the high amount of models in a scene. Figure 4.20 and 4.21 shows the before and after of the decimate modifier. It does its best to not change the shape of the model, but if the number of faces are reduced too much it will be noticeable.

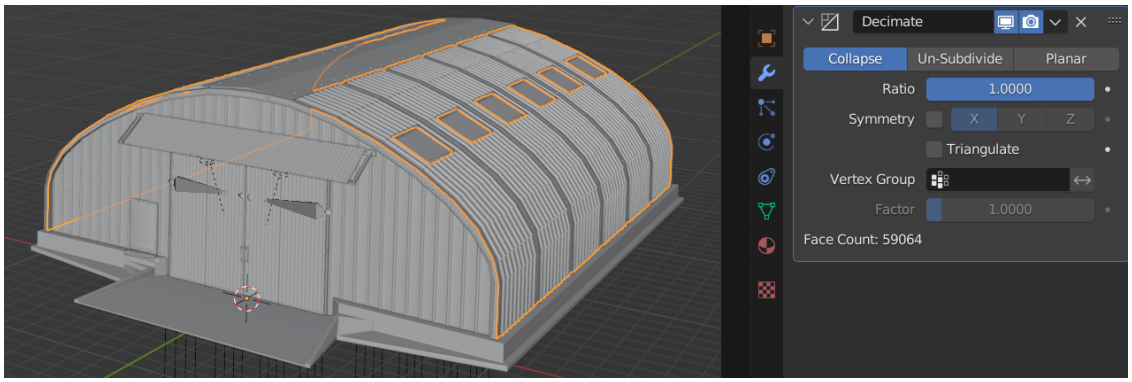


Figure 4.20: The hangar model before decimate modifier is applied

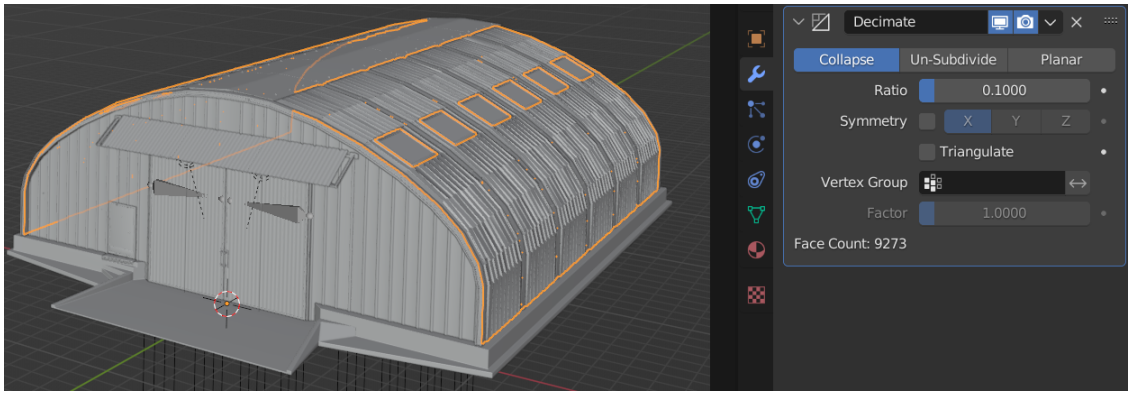


Figure 4.21: The hangar model after decimate modifier is applied

Downloaded assets were sourced from various sites. A full overview of downloaded assets, how and where they were used, and credits can be found in appendix G.

4.9.2 How the city was made

The city is a good example of how downloaded assets were modified and adapted to fit the project. Multiple assets were combined to make a sustainable city that felt futuristic. The buildings in the city were found as part of a larger city model, courtesy of the user scifijunk on Turbosquid.com [85]. The model was larger than needed, so it was first imported into Blender to cut off a small piece which was used.

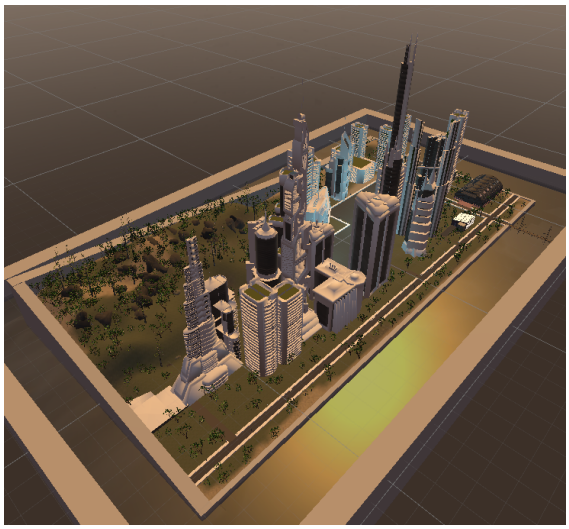


Figure 4.22: The complete designed city

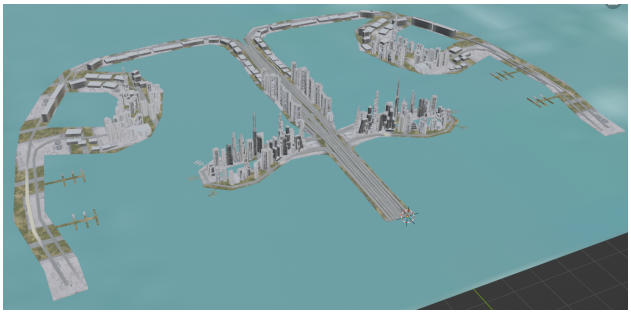


Figure 4.23: The downloaded building model [85]

To create terrain, a terrain generator tool was added from the Unity asset store [86]. Gaia 2021 is a terrain and scene generator tool that can quickly generate unique and detailed terrains [86], which was used to generate terrain that fit the city shape. Tree and rock model assets were then placed manually to complete the terrain, and the terrain was painted with appropriate textures and grass areas.

Further, the hangar and aquaponics building were placed on the outskirts of the city. Paths were laid out, and had street lights, benches and bins placed on it. Buildings were decorated with grass and leaves, and a fountain area with a statue was placed in the center, which can be seen in Figure 4.24.

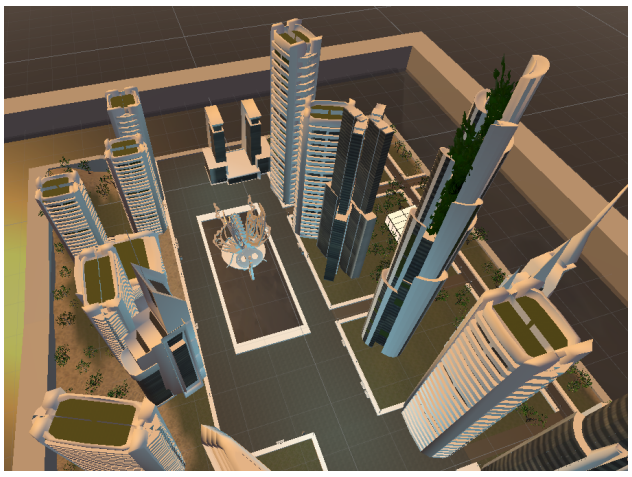


Figure 4.24: The city center, with fountain statue and grassy buildings

4.10 Voice over & animation of text script

concept spheres opened up windows of text that could either be listened to, or read on its own. A voice-over narrates while the text follows along as it changes color from dark to light synchronized with the voice, as seen in Figure 4.25.

Figure 4.25: Text window that appears after selection of the CEA sphere

Such a feature is not built into Unity, which meant another solution had to be found. To achieve this effect, videos were created for each information sphere that included both the voice over and animated text. The voice over came from an artificial intelligence text to speech tool, which was part of ClipChamp. The voice over was then imported into Adobe Premiere, along with the text which was animated in Adobe After Effects to match the speech patterns of the AI voice. Once the video was exported, it could be imported into Unity and played inside the information window. Unity has a video player component that allows controllable video playback [87], which made it so that when user's opened the information window, the video would start playing, as well as stop when they closed it.

4.10.1 Voice over

Clipchamp is a free, online video editing tool owned by Microsoft [88]. Though video editing was done in Adobe Premiere Pro and After Effects, Clipchamp was used in the project for its AI voice, text to speech functionality [89]. It was selected because it provided voice-over narration that sounded professional, and also because it was free to use [89]. It was able to do a professional voice-over in Norwegian, with a voice named Finn, which could then be exported as an audio file and imported into Adobe Premiere Pro.

4.10.2 Animation of text script

Adobe Premiere Pro and Adobe After Effects were used to create the video. Adobe Premiere Pro is a video editing tool [90], while Adobe After Effects is meant for motion graphics [91]. As they are both Adobe products, they work well together and projects can be linked between both softwares. Because of this, the text could be animated in After Effects and imported directly into Premiere Pro, where the AI voice-over could be put underneath it.

In Adobe After Effects, the text was animated with a range selector animation and keyframes, which gradually filled the text with color. This was keyframed to match the timing of the voice over, to highlight the text as the voice read it, then exported in Adobe Premiere Pro to video format.

4.11 Problems & solutions

4.11.1 Passthrough

Passthrough is a feature on Meta Quest headsets that allows mixed reality experiences where real and virtual worlds are blended [92]. Meta Quest Pro improved on its predecessor, the Quest 2, by addition of color, higher resolution and better framerate in passthrough mode [93]. The immersive experience uses passthrough in the main bridge scene, where the user can see both the digital miniature city model as well as the real environment.

Passthrough is enabled on the OVRCameraRig in the OVR Manager component [94]. There also has to be a OVR Passthrough Layer component to create a passthrough layer that decides whether passthrough is drawn on top of or behind the digital content, which in this case is set to be an underlay, or background [94]. In order for passthrough to be shown as the background, the main camera needs to have its background set to be a solid color with an alpha value of 0 to make it transparent [94]. In other words, the camera's background refers to what the camera sees when there is nothing to draw in that part of the frame. When the camera's background is set to be transparent solid color, combined with the passthrough layer being set as the underlay, this means that passthrough will be seen as the background behind objects in the scene.

Initially, passthrough functioned as expected in the mixed reality scene, as it was one of the first features that were worked out early in the development. However, at one point it was attempted to change the render pipeline [95] to the Universal Render Pipeline (URP) [96], which introduced some issues to passthrough. The purpose to change render pipelines was to access light and shader options that were only available with the URP [96]. Unfortunately, passthrough was not supported in URP, as it showed the color of the background instead of being transparent. Even if passthrough worked as intended in the editor, it did not do so in the build version. This meant that the URP could not be used, which led to use of the Built-in Render Pipeline [97]. A possible reason as to why this issue occurred is that the alpha value was not respected by URP color settings in some way and thus set to be opaque instead of transparent, which made the passthrough layer not visible through the background of the main camera.

4.11.2 Teleportation

Teleportation is a way of locomotion where the user can target a desired area and select to move themselves there in an instant [98]. It is a method commonly used in VR experiences because it could reduce the risk of sickness, headache, and in particular nausea [99], which are prevalent challenges present in virtual environments. Another benefit of teleportation as a locomotion system is that it has been found to let the user move faster than other techniques such as joystick or leaning [99], which allows for a more efficient user experience. Further, it does not necessarily impact the feeling of presence [99].

Teleportation sure sounds great. However, there was one slight issue that presented itself during development, as the Oculus Integration SDK did not include a framework for teleportation with hand tracking at the time of development. It supported teleportation with controllers, but was not available for hand tracking. It did seem like this was planned to be added in the next release of Meta's Interaction SDK [100], [101], however it was not available at the time of development, and therefore an alternative solution was implemented instead.

The solution was quite simple, as it made use of the ray interaction ability combined with hundreds of small square planes. The planes were aligned in rows and columns to create a larger area, and placed as a child to the OculusInteractionSampleRig gameobject, which contained the main camera gameobject. Each plane had a ray interactable component attached and a Teleport.cs script. This made it so that they could be targeted and selected by ray interaction. In other words, the user can point at the ground and select to be teleported to where they targeted.

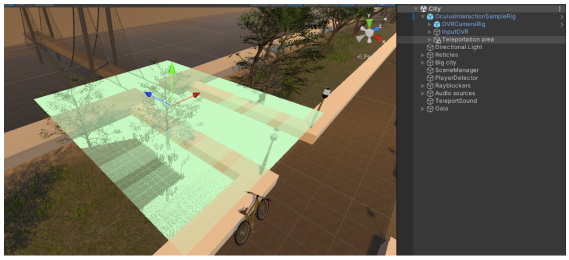


Figure 4.26: Area of teleportation planes

```
public class Teleport : MonoBehaviour
{
    public GameObject player;

    public AudioSource teleportSound;

    Unity Message | 0 references
    public void Start()
    {
        teleportSound = GameObject.Find("TeleportSound").GetComponent<AudioSource>();
    }

    0 references
    public void TeleportHere()
    {
        player.transform.position = transform.position - new Vector3(0, 0.04f, 0);
        teleportSound.Play();
    }
}
```

Figure 4.27: The teleportation script

The Teleport.cs script changes the user's position to be that of the selected plane, as well as play a sound that provides feedback. Because there are so many of these small planes, the result is that it feels like the user can teleport anywhere within this area, when in actuality they are merely moved to the plane closest to the ray pointer.

Because the planes were placed as a child to the user gameobject, and the teleportation script moved the user gameobject, this meant that the planes move along with the user and are always underneath them. This method was efficient to keep the number of plane gameobjects in the scene low, but on the other hand it allowed the user too much freedom to travel wherever they wanted, even through walls or into unintended areas. To prevent this, colliders with ray interactable components were strategically placed to block the ray and stop the user from going out of bounds. This solution mostly solved the issue, however there were some occurrences where users still got through.

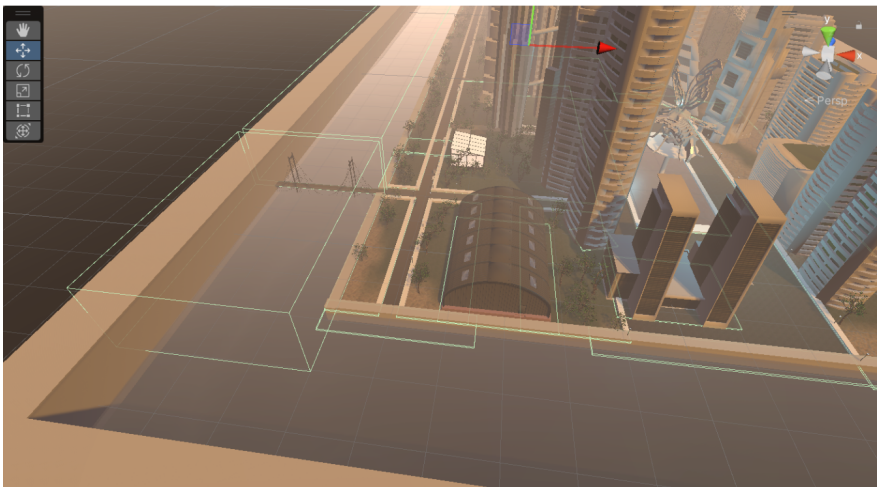


Figure 4.28: Colliders that prevent teleportation into certain areas

4.11.3 Optimization

Optimization is an important aspect of MR and VR development. If the experience is plagued by a poor framerate, it can ruin the whole impression and flow. Meta Quest Pro has better hardware than that of the Quest 2 [93], but it is still limited in performance when it is not plugged into a PC. Because the research looks at the user's perceived level of presence, it was vital to ensure the immersive experience did not require the Quest Pro to be plugged into a PC, as cables could potentially distract from and lessen the feel of presence. However, this meant that it did not take much before the size of the project started affecting the framerate negatively. To improve performance, a combination of solutions that involved draw calls, occlusion culling and triangle counts were implemented.

Draw calls

A draw call is a command sent by Unity to the graphics API that tells it what to draw in the frame [102]. While the draw call itself may not require many resources, the preparation of a draw call can be resource heavy, in particular if it has to change materials between calls [102]. Meta has provided performance targets for the Quest series, where they recommend between 400 and 600 draw calls for the Quest 2 [103]. The city and underground farm areas of the prototype struggled to reach this target, as they included many duplicated objects that could be seen in the same frame. In particular, all the trees in the city and the vertical salad shelves in the underground farm demanded a lot of resources. They were all separate objects, so Unity went through each one and repeated the operation of assigning materials, rather than do it once and apply it multiple times. They made it so the draw calls would rise to between 3000 to 8000, which impacted the amount of frames per second significantly.

To solve this issue, a simple yet highly effective method was applied. All that was needed was the FBX Exporter package, which made it possible to group all the gameobjects and export them as a single model in FBX format [104]. This model could then be imported into Blender, where a simple join command [105] merged all the objects to become one. This joined model was then exported back to Unity and replaced the original objects. Now, all the necessary materials could be applied to this one object rather than separately doing the same operation for all individual trees or shelves. This process resulted in that the original 3000 to 8000 draw calls were turned into 100 to 500, which is below the recommended performance target set by Meta of 400 to 600 [102].

Occlusion culling

Occlusion culling is an optimization technique in Unity where it only spends resources to draw objects that are visible to the camera [106]. This includes objects that are hidden behind something else, which dramatically reduces the amount of objects the engine has to render. It works best when it is clear which objects are behind others, which is why there are walls behind the shelves inside the hangar. Further, occlusion culling data is baked into memory [106]. Unity then uses that data to know what can and cannot be seen by the camera [106].

Objects can be set as either an occluder, the object that hides other objects, or an occluder , the object that is hidden. Generally in the prototype, shelves and other small objects are set to be occludees so they are hidden by the larger walls, while the walls and larger objects are set as occluders. There are also some objects that are set to be both. As a result of occlusion culling, the amount of unnecessary draw calls and total triangle count is reduced greatly to improve performance.

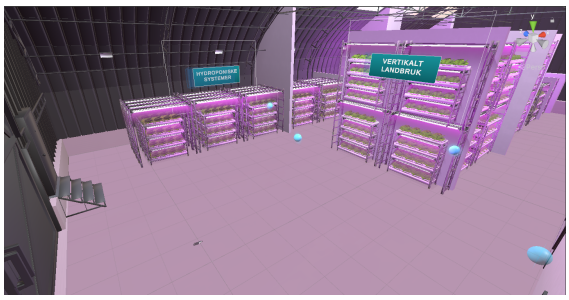


Figure 4.29: Occlusion culling disabled

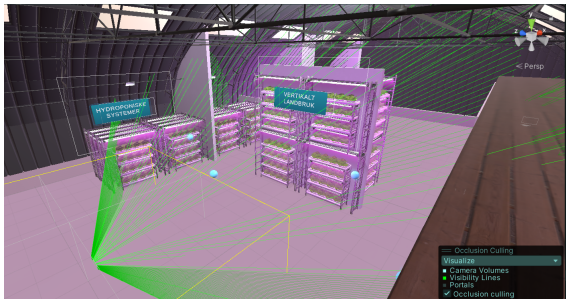


Figure 4.30: Occlusion culling enabled

Triangle count

In Unity, models consist of triangles that build up the mesh. The amount of triangles in the scene can impact how well the application performs. If a model consists of a high triangle count, it will demand more resources than a model with a low triangle count. For the Quest 2 headset, Meta recommends between 750 000 and one million total triangles [103]. Before optimization efforts in the prototype, the triangle count could go as high as 7.5 million which was well over the recommended amount. To improve performance further, objects were imported into Blender to apply a decimate modifier that simplifies the mesh and reduces the polygon count. The models were then exported back to Unity and replaced the old ones, which pushed the triangle count down to between 400 000 and 1.2 million, well below the recommended range suggested by Meta [103].

Chapter 5

Findings & discussion

5.1 RQ1 - How to design an effective mixed and virtual reality experience supporting active learning?

5.1.1 Virtual sustainable future city: user requirements validation

User interviews were conducted with five participants of the target group to validate requirements, design decisions, user needs, and find out if there is an interest in the topics and use of technology and knowledge gaps. Respondents were randomly selected on the street in Grimstad. The following sections are the summaries and interpretations of the findings. The topics of the questions are sustainability, learning, and technology. The street interview was done simultaneously during the later stages of iteration one. The digitalized, summarized, and translated findings from the street interview to validate requirements can be found in Appendix K.

1. **Topic: Sustainability - Are you thinking about the future and the possibility of saving natural resources?**
   Summary of Findings - Four out of five participants said they think about the future and the possibilities of saving natural resources. One of the participants said that as a farmer they think about natural resources such as to watch out for mixed synthetic fertilizers. Participant 3 said they think about it, and that 'it is an exciting topic'. Participant 4 said that they think we are lucky to live in Norway, because they think in other countries it is much more difficult to live sustainably. ***Interpretation*** - It seems that there was both an interest to learn more about sustainability and agriculture, as well as it being an 'exciting topic' may indicate that there would be motivation to learn about it. Furthermore, it seems like there is a need for Norwegians to learn more about sustainability because many people do not know, or feel like they do not fully understand what it is.

2. **Topic: Sustainability - Do you care about the environment? How?**
   Summary of Findings - All of the 5 participants said that they care about the environment. When asked on how many mentioned recycling. One of the participants said yes, but they don't quite know how to put it into words. They are conscious about it but without any plan. Another said that they do what they can. ***Interpretation*** - Similarly to question 1 there seemed to be a need for Norwegians to learn more about sustainability because of feeling there is little knowledge of what it means.

3. **Topic: Sustainability - What do you think of when you hear the word "sustainability"?**
   Summary of Findings - Participant 1 expressed that the word "sustainability" was positively charged. Participant 2 conveyed that it is important. However, they expressed that it is used a little too much as an excuse. They gave an example that they had friends that work in construction, and that it sometimes might get overused there. Participant 3 went for a more general meaning of the word by explaining that it is important to not overexploit resources, because there should be enough for next generations. Both participants 4 and 5 gave more specific examples on what they thought about when they heard the word. Participant 4 thought about education, and that children should be taught more about healthy food. Participant 5 thought about the clothing industry, and that creating new things all the time was unnecessary. ***Interpretation*** - In a similar manner as question 1 there seemed to be an interest to learn more about sustainability, as well as there being an interest to see and learn about the characteristics of sustainability. Being able to reflect on the topic seemed also of interest. An interest in agriculture, food production and to educate about food production seemed also like there was relevance to learn about.

4. **Topic: Sustainability - Can you give some examples of sustainable solutions?**
   Summary of Findings - Most participants mentioned renewable energy, electrical cars, avoid long flight trips, do not waste food, and also rather reuse and try to fix things instead of buying new. Participant 2 also brought up that farmers today are more aware of sustainable solutions than before such as for example when selecting artificial fertilizers. ***Interpretation*** - Here it comes across that there is an interest in learning about different topics in sustainability, which validates the relevance of the idea 'sustainable future city' with different main areas, as well as the topic of food production.

5. **Topic: Sustainability - How can one teach or inform others about "sustainability"?**
   Summary of Findings - Participant 1 said that they personally did not have much to contribute on this question, but feel that the information should be research based. Participant 2 answered with something similar, by saying it should be fact-based as well as that fancy words should not be used, rather there should be explanations and specific information should be provided. "Show instead of tell" was something participant 3 stated, and explained it by saying that people live in their pattern and fall quickly into their habits, therefore they think it is important that people can see the consequences of what they do. Both participants 4 and 5 mention talking with the young people. Participant 4 said it would be good to have face-to-face discussions, and participant 5 said to educate them by showing them how to learn practical skills. ***Interpretation*** - It appears to be that information should be required to be research and fact based. Therefore, concepts should also be based on real life and explained in a simple manner. 'Show instead of tell' teaching seemed to be thought of as a good approach, as well as to be educated by doing something practical. These points validate requirements as MR and VR experiences can be perfect to fulfill these needs, especially when it is used as a support tool for active learning.

6. **Topic Learning - Have you learned anything recently? What?**
   Summary of Findings - All the participants answered, and many gave specific answers such as participant 3 said that they were at an internship at the hospital. Participant 2 said that they recently had learned about the moon and moon phases, because of that people could see Jupiter and Venus in the sky this year. Though most of the participants said that they learn something new every day, but can not directly say what. ***Interpretation*** - It seemed like it depends on the context. Obligational learning such as interest in one's own education for getting a job played a role for the drive of learning more on a field. Then again in a more day- to-day context it seems external factors such as for example the media and technology can awaken an interest for new topics.

7. **Topic Learning - How do you usually go about learning about something new?**
Summary of Findings - Most of the participants mentioned they talk to others, either friends or someone with experience. Three of them said they read up, either through books or through google. Participant 3 goes in to understand, and does not move on before they have understood, referring to self-discipline. ***Interpretation*** - The most common preference for learning something new seemed to be social in nature. Friends, guidance or someone with expertise in the area are important and relevant factors. Furthermore, reading and getting information fast via technology such as the internet are also mostly preferred.

8. **Topic Learning - When you are going to learn something, do you go more in-depth on what you are going to learn about or do you keep it simple? What usually makes you want to learn deeply or superficially about something? Can you give some examples?**
Summary of Findings - All participants said that it depends on how interested they are in the topic. Three of them said they usually kept it simple, but indicated that a higher interest level would lead to go more in-depth. Participant 1 mentioned how it can drive a snowball effect where they want to gain more knowledge. Participant 3 went a little in-depth if it was interesting, but usually kept it simple. However, they noted that they go in-depth in their studies. Participant 5 noted that if it was necessary, they automatically went in-depth. ***Interpretation*** - It seemed that in-depth learning depends strongly on the topic of interest or when it was necessary in an educational and work related context. Furthermore, if the interest level was low and not work related, or just a curiosity on a new topic, it was kept simple as that would be enough to gain satisfaction from the learned topic and acquired knowledge. Although, for some it could spike more in-depth learning.

9. **Topic Technology - What digital technologies do you use in a typical week?**
Summary of Findings - All participants mentioned their smartphone. Other technologies people said were PC, television, radio, smart watch, and some special ones such as door locks. ***Interpretation*** - While all of the participants used their smartphones, none of them mentioned any VR device. It is an uncommon item to have for the general public and personal use in the context of used digital technologies in a typical week. This suggests that MR and VR headsets are not technologies used for this context.

10. **Topic Technology - Do you use digital technologies to help you learn? Which**
Summary of Findings - All participants used digital technologies to help them learn. Most of them mentioned the internet, smartphone or PC, and that they usually start by looking up things on google. Participant 2 brought up that their work had many digital and interactive courses after corona. ***Interpretation*** - It seems that there is an interest and openness in using digital technologies to learn.

11. **Topic Technology - Do you follow or keep up to date with new developments in digital technology?**
Summary of Findings - Most participants did not intently keep up to date, mostly they kept either halfway up to date or just a bit. Participant 1 did not pay attention, and mostly only cared if what they had worked. Participants 2, 3 and 4 followed only a bit. Participant 5 thought some new solutions were unnecessary and came too quickly. ***Interpretation*** - It seemed like there is not a huge interest in the general population to keep up to date with new developments in digital technologies.

12. **Topic Technology - What do you think of when you hear the terms: 'Extended Reality', 'Virtual Reality', 'Augmented Reality' and 'Mixed Reality'?**
Summary of Findings - Four out of five had heard of at least VR before, one of which had heard of AR as well. No one seemed to have heard about MR, although participant 2 had not heard the term MR, but figured out it was a mixture of both. Participant 1 had heard of VR, but was not interested in it. Participant 5 thought of movies and science fiction when they heard the terms, and wondered if it actually existed. ***Interpretation*** - There is a knowledge gap for Norwegians to learn more about VR, and especially MR.

13. **Topic Technology - Have you tried VR before? What was it like?**
Summary of Findings - More than half, three out of five, had tried VR before and thought it was fun or cool. Two of them felt sick or disoriented by it. Participant 1, even though they said it was fun, also mentioned they did not get any benefit from it personally, but they see the potential in work contexts. Participant 5 had not tried VR, but mentioned their grandchildren had and had become bored with it. ***Interpretation*** - It seemed that there is openness and an interest in fun VR experiences, as well as a need to make it fun. Further, it seems that there is a need for taking steps to prevent motion sickness in VR.

14. **Topic Technology - Would you be willing to learn about something new using VR?**
Summary of Findings - Most of the participants said yes. For participants 1 and 4, it seemed to depend on what they were supposed to learn and if it was purposeful. Participant 3 saw the potential of learning about procedures as a nurse, and that it is harder to read about theoretical topics, than it is to see it. Participant 2 mentioned that they like to be hands-on, and experience things and be able to touch them. ***Interpretation*** - It seemed like there is an interest in learning with VR if it is purposeful. As well as that it is sometimes difficult to learn just via a textbook, so VR experiences could fill a gap by making it possible to learn practical skills or get an overview of difficult topics in an active way. Additionally, there is an interest to learn in a hands-on approach.

15. **Topic Technology - How real do you think a VR world can feel? What makes you think so?**
Summary of Findings - All participants thought it could feel very real. Two of them thought it could feel especially real if the VR experience introduced other senses as well. Participant 3 mentioned that how real it feels depends on how the VR world is made. ***Interpretation*** - There is a need for a certain level of quality in how the VR world is made to make it feel real.

16. **Topic Technology - Optional question → What would you have liked to get out of VR?**
Summary of Findings - Four out of five participants wanted VR to be used in learning or an instructional manner, while one had no use for VR. Participants 1 and 4 brought up the possibility of using VR in health, and both gave the example of viewing or participating in an operation in VR. Participants 2 and 3 thought it could be used for learning in a general sense, as they mentioned using VR in schools or using it like they use Youtube to learn practical tasks like car model instructions and moving things. Participant 5 preferred that people stayed in the real world. ***Interpretation*** - It seemed like there was an interest in using VR for learning. Most thought it would be useful for practical and active topics and areas.

5.1.2 Mixed and virtual reality user experience design decisions

This section discusses design decisions considered in this research work to produce effective immersive learning environment.

Combining mixed and virtual reality for educational application scenarios

As mentioned in chapter 2, there are some examples of mixed and virtual reality used in education. However, these examples are taken from studies and experiments, and the technology is yet to be universally implemented into education. The majority of studies published investigate virtual or augmented reality, while it seems far less research has been done on mixed reality. Admittedly, this may be because mixed reality is a more recent concept than that of virtual and augmented reality. Further, there were few to no studies that attempt a combination of both mixed and virtual reality in one continuous experience. Instead, when searching for such a combination, the results tend to include augmented reality rather than mixed reality, in a combination of augmented and virtual reality technologies. The prototype proposes a design that intends to fill these gaps, serve as an effective immersive experience that supports active learning while also being a combination of mixed and virtual reality, and showcase the potential of the technology for use in education.

The design decision to focus on ***exploration and visualization of concepts*** was supported by studies mentioned in chapter 2, which showed that exploration and visualization of concepts repeatedly came up as particularly positive aspects of an immersive experience. It was also supported by design principle 4, which informed that this exploration should be guided, as described in the chapter 4. Additionally, design decisions were also informed by these studies in the sense that their ideas could be transformed and taken further, such as with the mixed reality applications by Wu *et al.* [20] and Salman *et al.* [21]. The application used by Wu *et al.* [20] had a similar use of mixed reality to the sustainable future city prototype in the sense that it consisted of digital objects projected onto the real environment, as the mixed reality in the designed prototype also contains digital objects projected onto the real environment. It was used as an addition to traditional methods such as lectures and labs, and while the sustainable future city prototype could also be intended for use as an addition to other methods, it was desired that it would also work as a standalone application to introduce users to the topic and spark an interest in the subject matter.

The Salman *et al.* [21] study supported the decision to focus on ***freedom in the exploration***, as they had positive responses to the exploratory nature of their system, as users could experiment freely. Additionally, the studies by Nersesian *et al.* [22] and Georgiou *et al.* [23] also supported the design as they had positive findings with their interactions and explorable galaxy. These ideas of freedom and experimentation were taken further in the sustainable future city prototype as users can go where they want in any order they want, and explore as much as desired in the virtual environment. This way, users are encouraged to be active participants within the environment and have to take actions for progressing.

As brought up in chapter 2, there was a lack of cases where mixed reality had been combined with virtual reality as one experience. Studies seem to mostly include comparisons of the two virtualities in separate experiences, such as the study by Allcoat *et al.* [25]. Alternatively, studies that combine virtual and augmented reality are more present. The study by Remolar *et al.* [26] used augmented reality as an additional source of information that related to the virtual reality experience. However, it was a separate part of the overall experience, as the virtual reality part ran on an Oculus Rift HMD, while the augmented reality part ran on an Android phone [26]. In a sense, this supported the design decision in the sustainable future city prototype to ***make the mixed reality scene as a source of introductory information***. To take it further, the mixed reality scene also provides an overview of the city before users arrive in it, and importantly it serves as a transition between mixed and virtual reality when users go through the door to cross the bridge.

Active learning in immersive experiences

The designed MR & VR prototype supports users to learn by doing a number of activities, through which they construct their own knowledge based on previous experiences. This is reflected in the prototype as users are active when they explore and interact with the virtual environment. The exploration is purposeful as it communicates the intended learning outcome through the environment, as well as through the various concept spheres that can be interacted with to reveal text and narration that explains what the users see. Users have to navigate from the mixed reality scene, through the city, and throughout the underground farm to gather all possible information to solve the end quiz, which was supported by design principles 3, 4, and 6 [50] as it includes users learning content step by step, being guided on a path, and end with answering a quiz based on the learning material.

Studies found in chapter 2 on active learning and immersive experiences reinforced this design decision, as Wolfartsberger [27] has positive findings as users are active and closely inspecting virtual models. Likewise, the virtual environment in the sustainable future city prototype can be inspected as closely as the user fancies. Additionally, being able to walk around physically as well as teleport to cover more distance in the virtual environment is another feature that is present in the sustainable future city prototype, which can also be seen in the study by Wolfartsberger [27]. These modes of navigation give the users freedom to explore the environments. This freedom allowed users to comprehend and make connections to the learning material in their own way and create unique experiences as a result of the individual's curiosity. Users had to actively move through the environment and inspect the models therein, and because the experience was self-directed in the sense that they could decide for themselves which areas they wanted to explore in any order, it gave them a sense of agency. This design decision is further supported by design principles 9 and 10, as it includes the use of hand gestures to be active, and to provide users with control and agency.

In the sustainable future city prototype, the city and underground farm areas visualize the learning material and simulates an explorable environment where these ***visualizations are realistic and represent the real world concepts as they are***. This design decision was supported by studies such as van Ginkel *et al.* [28], who found that the realistic simulation of holding an oral presentation gave users a valuable experience to reflect on which helped improve their skills. The sustainable future city prototype aims to provide a realistic simulation of exploration in an environment such as the future city itself and the underground farm area, and in a similar sense to participants of the study by van Ginkel *et al.* [28], users can have this experience where they visit an underground farm and see realistic visualizations of the concepts to construct their own knowledge and reflect on it afterwards. The study by Wolfartsberger [27] and van Ginkel *et al.* [28], reinforced this design decision to make the users active participants of the experience, and actors in the narrative who do things, and then can reflect on what they did to learn the intended learning outcomes. This design decision was further supported by design principle 8 to make the users reflect on the learning material and their experience.

Design elements for active learning in immersive experiences

Interaction

Interactions are important design elements to make active learning effective in an immersive experience. The most important interaction design decision that was implemented in the sustainable future city prototype is the ***ray interaction for teleportation***. Why is this important in terms of effective active learning in an immersive experience? Well, because that can be used for exploration of the immersive environment. Furthermore, ray interactions can be used to interact with parts of the environment from a distance. There are also poke and hand grab interactions where the user can interact with elements and objects in the environment directly, by pushing buttons with their fingertips or grabbing objects to move them. In iteration two of the prototype, interactions all have designated sound effects for hovers and selections, to provide auditory feedback for user's actions, as design principle 7 recommends. For active learning it is important to do practical activities that lead to actions, as it is more interesting and thus becomes more memorable. This is especially because most people are multimodal in their learning style [17] and use their kinesthetic senses with a mix of others, such as visual senses will strengthen their learning. Thus, being able to grab an object in the immersive environment can feel more memorable and give a feeling of realism and presence, and the users can feel like they have more control in the virtual world.

In terms of interactions, the sustainable future city prototype ***allows users to interact with and navigate through the virtual environment***. The design decisions that went into these interactions were informed by studies mentioned in chapter 2. For instance, the study by Bazargani *et al.* [29] used grab interactions in their immersive learning experience, where participants could grab hidden objects, as well as hold a brush to paint different shapes. Additionally they made use of the teleportation and continuous movement locomotion techniques.

Grab interactions could be considered a base interaction in mixed or virtual reality experiences which suggested it should be interaction to include in the sustainable future city prototype to ***give the users control of tangible interactions which could lead to a higher sense of presence***. Teleportation is more of an optionable feature, where the benefit is that it can help prevent cybersickness symptoms [99]. Some immersive experiences may not require to travel a large distance, thus teleportation might not be needed. However, in the sustainable future city prototype there are large areas to explore, and a lot of distance between them. This meant that a decent amount of time would be spent walking to each area, which gives more time for cybersickness to set in. Therefore, ***implementation of a locomotion technique such as teleportation*** was deemed an important design decision to lower the chance of cybersickness induced symptoms.

The study by Markowitz *et al.* [30] also utilized grab interactions, as well as hand movements to simulate swimming. These simple interactions combined with an underwater reef virtual environment showed highly positive results for the participants' knowledge gained from the experience. In their study, they included a future underwater environment that had suffered from ocean acidification to visualize the consequences of climate change. In a less somber sense, the sustainable future city prototype also ***visualizes a future where sustainable food production is commonplace so that users can see it for themselves and make meaningful connections to understand how it works***. The study by Markowitz *et al.* [30] supported this design decision. One of the four smaller studies therein also introduced some exploration where participants could use their hands to swim to an underwater reef. In the sustainable future city prototype, this idea was taken further to allow full exploration of the environment.

To make input for the interactions, ***hand tracking was implemented in place of controller units***. Hand tracking could be easier for beginners as there is no need to learn a controller scheme. Instead, users can use their hands which they already know how to use, and gestures to interact with the environment for tangible interactions. This design decision was supported by design principle 1, 9 and 10, as well as the study by Ogunseiju *et al.* [31], mentioned in chapter 2. They used the HoloLens 2 which has hand tracking and had positive findings in regard to hand tracking and how easy it was for participants to manipulate and move objects [31].

Visualization

Another important design element to make effective active learning are visualizations of the immersive environment. There are many different active learning strategies. A traditional one is to go and explore real environments in real world experiences, instead of reading from a textbook. The mixed and virtual reality immersive experience may not be a real world experience such as going to a real vertical farm, and therefore may not be able to measure fully up to such an experience. However, it still has value as it can be quite similar. Here it is therefore important to design concepts as realistically as possible, which can become difficult due to technical constraints. However, on the other side, there is not always a need to make active learning realistic, such as for example in the context of learning through storytelling where the story can be based on the real world but still have fantasy elements which can still have value. Therefore, for the immersive experience, there was a need to find a balance between what should be as close to realism as possible, such as the concepts for vertical farming, hydroponics, aeroponics, and aquaponics systems, and what could include some fantasy design elements to improve the overall experience. Design principle 4 supports the design decision to ***focus on realism for the concepts and topics that are part of the learning material for the immersive experience, while other parts can have more fantasy elements***. For instance, the future city environment was designed like this to make it more appealing and interesting for users. Further, ***the screen has no constant UI elements that follow the user's head movements*** to minimize distractions from the visualizations of concepts and topics, as suggested by design principle 2.

The design decision to focus on realism was supported by the study by Slater *et al.* [32] in chapter 2, where they found that a more realistic environment resulted in higher levels of presence experienced by participants. Additionally, the visualization in the sustainable future city prototype should be accurate and reflect real life applications of the technology so that it contributes to how the user learns about it in addition to the text they can read. In the case of vertical farming and usage of LED lights, it was particularly important to display colors of the lights that are actually used in real world facilities, as they have direct implications on growth factors in the plants. This decision was again supported by design principle 4, as realism is important for the concepts and topics that are part of the learning material. Similarly to how Asgary *et al.* [33] created a realistic visualization of volcano activity, the sustainable future city prototype teaches contextually as users can see the systems in person and make connections themselves to understand how they work.

Text

Immersive mixed and virtual reality experiences are great for visualizations and interactions in a virtual environment however it can be difficult to convey information accurately and avoid misinterpretations with only visualization. In the immersive experience, text was used to provide further information and contextualize the visual experience. Further, text could help prevent confusion, as was seen in the study by Salman *et al.* [21] where the lack of text and proper feedback led to confusion from the participants. The design decision to ***use simple and concise language, as well as to use a moderate amount of text*** on each concept was supported by design principles 1 and 5, which include making the experience easy to use and understand for beginners, as well as limit the amount of reading that has to be done in VR to avoid straining the user's eyes. Additionally, it was supported by studies such as one by Hunvik and Lindseth [34] mentioned in chapter 2, where they found that too much text negatively impacted the user experience, and it was suggested to include more visual and audio elements.

Audio
In terms of audio, important implementations were narration and environmental sounds. A ***narrator that reads the text out loud for the user makes the information easier to digest, while sound effects when buttons are pushed or background ambience such as wind or birds help make the environment feel more alive and creates a higher sense of presence***. These design decisions were supported by design principle 1 to make it easier for beginners to understand, as well as the study in chapter 2 by Kelling *et al.* [35] where they found that narration and ambience noise in an immersive experience helped make it interesting and had an overall positive impact on the user experience.

5.2 RQ2 - To what extent do user's perceive the level of presence and motivation in the mixed and virtual reality experience?

5.2.1 Summary of findings from user tests iteration one and two

This section presents summaries of the findings from each topic of the user test. Each topic is divided into iteration one and two. The findings are presented in the order of pre-test interview, observation of user tasks, questionnaire, and post-test interview. In total ten participants were involved in the user tests, five for each iteration. Participants will be referred to as P1, P2... P10, where P1 - P5 are participants in iteration one, and P6 - P10 are participants in iteration two. The digitialized findings of the user tests can be found along with the thematic analysis in Appendix B and Appendix C.

Pre-test interview

1. **Topic: Have you taken part in any kind of research study before, or is this the first time?**

   Iteration one: Two out of five participants had not been in a research study before.

   iteration two: Three out of five participants had not been in a research study before.

2. **Topic: Have you tried VR before? How was it?**

   Iteration one: Four out of five participants had tried VR before. P1 who had tried VR said it was fascinating, exciting, and gave a real feeling. P4 had also tried and thought VR was fun. P5 had their own VR headset at home and said they do not get motion sickness while using it, but they feel tired after a while. P3 had not tried VR before.

   iteration two: Three out of five participants had tried VR before. 2 of which said that it was fun. Further, P7 mentioned it is fun to do something they had not done before. P8 tried VR in the context of work and internship as a nurse. P9 had their own Quest 2 VR headset at home and mentioned it has some problems with mixed reality. P6 and P10 who had not tried VR before expected to come into a fictional world and were curious about trying it.

3. **Topic: When you are going to learn something, do you go more in-depth on what you are going to learn about or do you keep it simple? What usually makes you want to learn deeply or superficially about something? Can you give some examples?**

   Iteration one: Two of the participants, P1 and P2, said they like to learn topics in-depth. Two others, P4 and P5, said it depends on the topic, and if it is of interest to them. They prefer to first get an overview or learn at a surface level, and P5 mentioned they look at YouTube videos as an example. P1 said they like to learn by doing something physical or active, while for P3 it depended on the time they had available. If they have little time, they learn more superficially. If they have a lot of time, they like to go more in-depth.

iteration two: Two of the participants, P7 and P9, liked to go in-depth. P9 added however that if something was to be superficial, then it should be made proper. P6 said it depended on the purpose of why they were learning. If it was not so important, they skimmed through. On the other hand, if something was of interest they went in-depth. P8 preferred to keep it simple and use Google a lot, though they go in-depth when it's work related. P10 said they do a combination of where they first do it quickly by skimming through when reading. Afterwards, if they find out it is more interesting, they go in-depth.

Observation of user tasks

4. **Topic: User task - Explore the surroundings to find the bridge and walk across it**

   Iteration one: There were two critical errors with P1. The participant started by walking through an invisible wall in an unintended way. Also, they were quick when selecting spheres. While they were listening to the blue sphere on sustainability, they selected the red sphere to open the door while they were already standing at the bridge, creating another error. The first thing most of the participants did was look at the miniature model of the city and tried to interact with it. Some figured out they were able to grab and rotate it. Most of the participants did not see the 'introduction poster' at first, but read it when they did. Some never noticed it. Many participants thought they were finished with the task when they found the small bridge on the miniature model. When told the task was not finished yet, they started to explore more by clicking on the different spheres. Some were helped and they should look closer at the spheres. Four participants selected first the blue sphere before the red sphere. Some participants, P4 and P5, when selecting the red sphere did not notice that there was a door that opened, and P5 had to be told it was there. P3 referred to the door as a 'tele-portal'. Most of the participants listened to the content of the blue sphere and were observed to be standing still, and read the text while following along with the narrator. P5 seemed to listen but did not follow the text as the narrator spoke, instead they enjoyed rotating the miniature model.

   Iteration two: P6, P7, and P8 started by investigating the miniature model and the spheres above it, while P9 and P10 immediately tried teleportation. Four out of five participants noticed the 'introduction poster' and read it thoroughly, as well as selected the blue sphere before the red sphere. P8 selected the blue sphere then the red sphere after, and immediately went inside the door. However, they decided to go back to explore the MR scene more. They did not seem to listen to the narration on sustainability, but they mentioned that the 'introduction poster' text was exciting. The other participants listened closely to the narration in a calm manner and seemed interested, with the exception of P7 who decided to read it for themselves. P6 experienced an error where the miniature model got stuck to their hand when they rotated it, otherwise most participants had no issues when rotating the miniature model. P8 and P9 tried to point at and select the bridge on the miniature model at first. P8 commented that, even though they knew the miniature model was digital, it felt like it was really there. Most participants immediately noticed the door when it came up after selecting the red sphere, and understood that they should go through and cross the bridge.

5. **Topic: User task - Explore the city to find the entrance to the hangar**

   Iteration one: The participants quickly noticed the hangar but wanted to explore more of the city before entering it. P2 and P3 displayed improvement with teleportation. With the exception of P5, most participants noted that the environment was cool and seemed interested in exploring the city. P3 enjoyed looking up towards the tall buildings and thought it was highly futuristic, and they also said 'Wow' more than once. Multiple participants tried to open the small door on the left of the hangar before they tried to open the main door. Most participants had no issues when they opened the main door, except for P2 who found it difficult.

Iteration two: Three of the participants immediately noticed the hangar. P6 and P8 were positively surprised when they arrived in the city. P8 in particular seemed very excited as they thought it was very cool because the city seemed so real. Most participants had gotten quite good at teleporting and went through the city at high speeds and investigated every corner of the explorable area. Many of them also looked up towards the tall buildings. With the exception of P10, who really disliked the futuristic look of the city, most participants seemed intrigued or fascinated by the city. It should also be noted that P7 noted there were too little greens on the buildings. The participants easily managed to open the hangar door, most on their first try. P6 however experienced an error where they teleported into the doors when they tried to open them.

6. **Topic: User task - Explore the first and second floors of the hangar and learn about the different cultivation concepts found there**

   Iteration one: P1 and P3 went to the LED light sphere first, while the rest went to the CEA sphere. Most participants stood calmly when they listened to the spheres, and seemed to find them interesting. P5 who selected the CEA sphere first listened intently to the narrator before laughing at the voice, then decided to read it themselves. After, on the LED light sphere, they selected it and let the narration play while they continued exploring. All participants quickly figured out how they could press the button to change the color of the lights. P4 and P5 thought it was exciting and cool to change colors, with P4 getting curious if they could press anything else and P5 wondering if it was part of a test. P3 and P4 wanted to read the text on one of the spheres closer and opened the full-text. They had no issues scrolling through, then they closed it after. P1, P3, and P4 found and entered the office before taking the elevator down. P1 tried to use ray select to open the door. P1 also noted that there was a quiz, but stated that they were not ready for it yet and that they instead should come back to it.

   None of the participants experienced issues when taking the elevator down and found themselves intrigued by the disinfection area. All participants inspected the disinfection room when they got off the elevator before they continued. P2 asked if they should change clothes, expecting a task. P3 had an error where they by mistake teleported through the wall behind the lockers into the disinfection room. Once past, participants saw the vertical farming sign and stacks of vertical salad shelves. Some of the participants asked about vertical farming and aeroponic systems. P2, P3 and P5 particularly took an interest in the aeroponic system, with P2 stating they wanted to have such a system at home and P5 surprised that there was no soil.

   P3 and P5 enjoyed the forklift ride, though P5 mentioned they wanted to steer it as well. P2 missed the forklift ride entirely and went straight past it towards the second elevator instead. Most participants with the exception of P2 had no issues working the second elevator and accessing the aquaponics area. P2 had trouble navigating into the elevator, though they were very happy when they got up to the aquaponic system and saw the fish. P3 and P5 inspected the system and figured out how aquaponics work by themselves.

Iteration two: P6 immediately noticed the vertically stacked salads and inspected them and wondered how the plants were growing without the sun, before they selected the hydroponics sphere, followed by the CEA sphere, vertical farm sphere, and LED light sphere. P7 went to the CEA sphere first and preferred to read themselves rather than listen to it, and then went in the order of hydroponics sphere, followed by vertical farming sphere, and then LED lights sphere. P8 and P9 went to the hydroponics sphere first. P8 then explored the whole area, including the office, before they went to the LED lights sphere, vertical farming sphere, and CEA sphere. After the hydroponics sphere, P9 went to vertical farming sphere, LED lights sphere and then the CEA sphere. P10 started with the LED lights sphere, followed by the vertical farming sphere, hydroponics sphere, and CEA sphere. All participants were interested enough to listen to or read all of the available information, and explored the whole area of the first floor. P7 and P8 attempted to solve the quiz before having been downstairs. Additionally, all participants managed to change colors of the LED lights by pushing the button, with P6, P7, and P8 seeming pleasantly surprised by the interaction.

Most participants with the exception of P10 had no issues taking the elevator downstairs. P10 teleported through the door, but they went back out and did it properly after. Once downstairs, most of the participants inspected the changing room before going through the disinfection process. It was clear what type of room it was, as P6 read the signs there out loud. P6 and P8 laughed and thought it was fun to be disinfected. Afterwards, participants entered the large underground area. P6 was a bit disappointed that it was more of the same downstairs in terms of vertical farming, however they were pleasantly surprised when they saw the aeroponics area. P7 went straight to the aeroponic system and were surprised. They wondered if what was said in the text and what they saw was close to how it is in real life. They also tried to grab a potato that grew in the aeroponic system. When P8 entered the underground area and saw the vertical farming sign, they understood that it was vertical farming when the salads were stacked vertically like they saw. P10 paid attention to details and mentioned the LED lights, pipes, mist, and mystic roots in the aeroponic system.

When riding the forklift, P6 got placed backwards and had to adjust, P7 squatted and acted like they were seated on the forklift, P8 said that they almost started rocking back and forth as it felt like they were taken away for real, P9 noted that they were not able to steer, and P10 started to feel dizzy. Afterwards, the participants found the second elevator. With the exception of P10, participants had no issues taking the elevator up to the aquaponics area. P10 struggled to get into the elevator, and ended up inside the walls a few times. In the aquaponics area, participants looked at the environment and seemed to be reflecting on what they were looking at. They selected the aquaponics sphere and listened to it, then closed it. P7 exclaimed 'Wow' when they saw the aquaponic system, and commented on what they heard from the information sphere as they understood how fish waste was utilized as nourishment for the plants. P9 stated they liked the animation on the fish.

7. **Topic: User task - Find the office on the first floor and answer the final quiz to complete**

   Iteration one: On the way back to the office to solve the quiz, all participants encountered an issue where one of the disinfection doors would not open, so they had to teleport through it to progress. Besides this error, all participants were quick to find their way back to the office. Besides P2, there were no issues opening the door to the office, with P3 even stating that they liked the fact that they had to open the door. In the quiz, P1 answered everything right on the first try. P2 had two failed attempts, and P5 had to do the quiz again due to a trick question. None of the participants seemed to have an issue with using the keyboard to answer the quiz.

   Iteration two: With the exception of P10, all participants quickly found their way back to the office. P10 ended up teleporting through the walls and had to find their way back. P6 seemed to be immersed, as they got a little scared when the door closed on their face in the office. In the quiz, there was one accidental button push. When asked if they would rather finish, or answer all 10 questions, they seemed very motivated to answer the quiz. P7 was a bit confused about whether they answered correctly and said "Moving on means that the answer was right?". P8 felt it seemed natural to use their index fingers on the keyboard, and they were surprised that they had to type in the answer on the fourth question. P8 also stated they did not like that they had to start all over again when they got a wrong answer. Most participants had no issues with typing on the keyboard. However, P9 suggested an alternate button solution with only four buttons, rather than a whole keyboard. They also thought it was a bit tedious to have a typewriter at question four. P10 got confused by the fact that wrong answers meant they had to start over, and did not finish the quiz as they began to feel dizzy.

Findings from questionnaire in iteration one and two

Findings from questionnaire for iteration one, translated to English. See Appendix L for original Norwegian version.

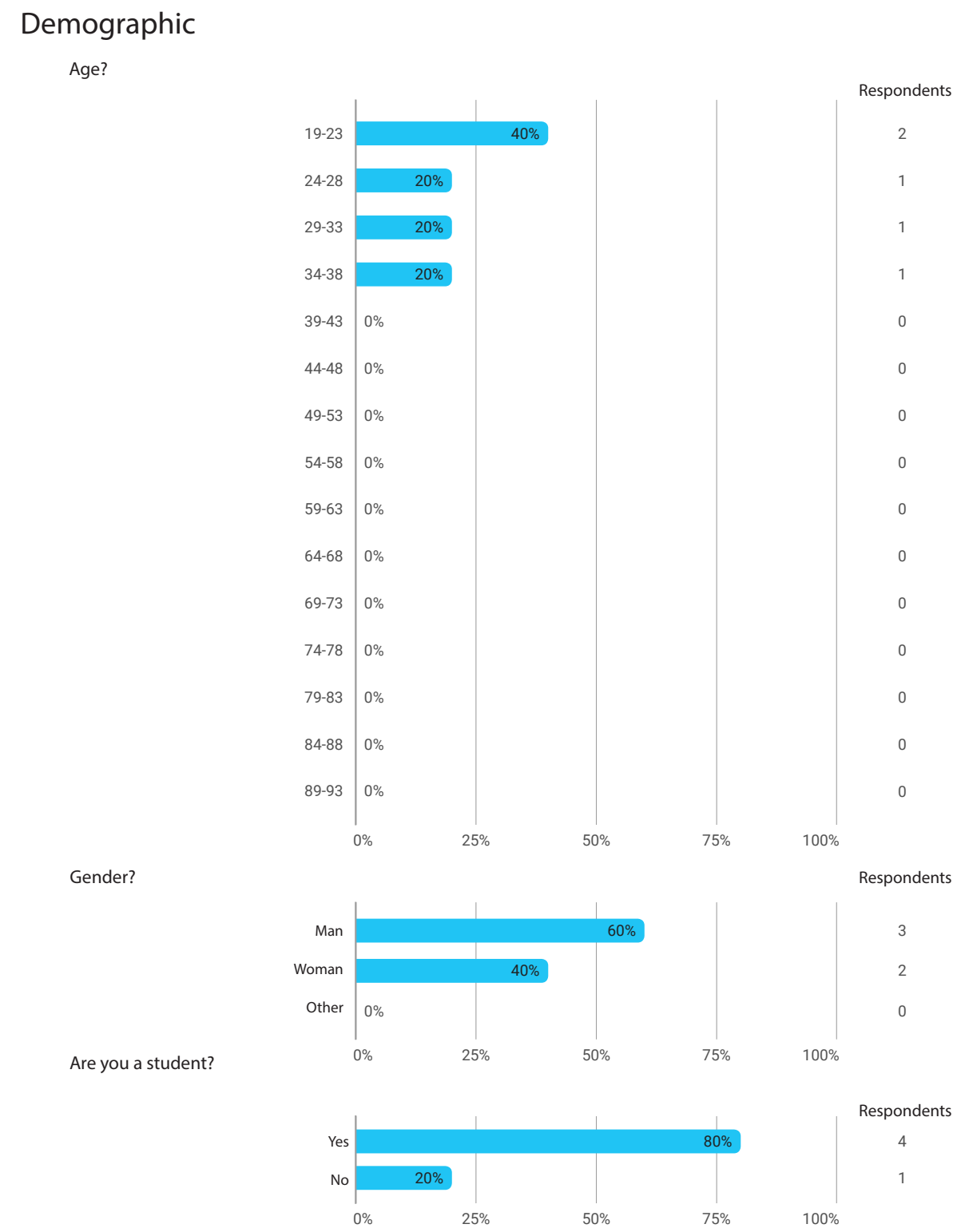


Figure 5.1: Participants demography in iteration one

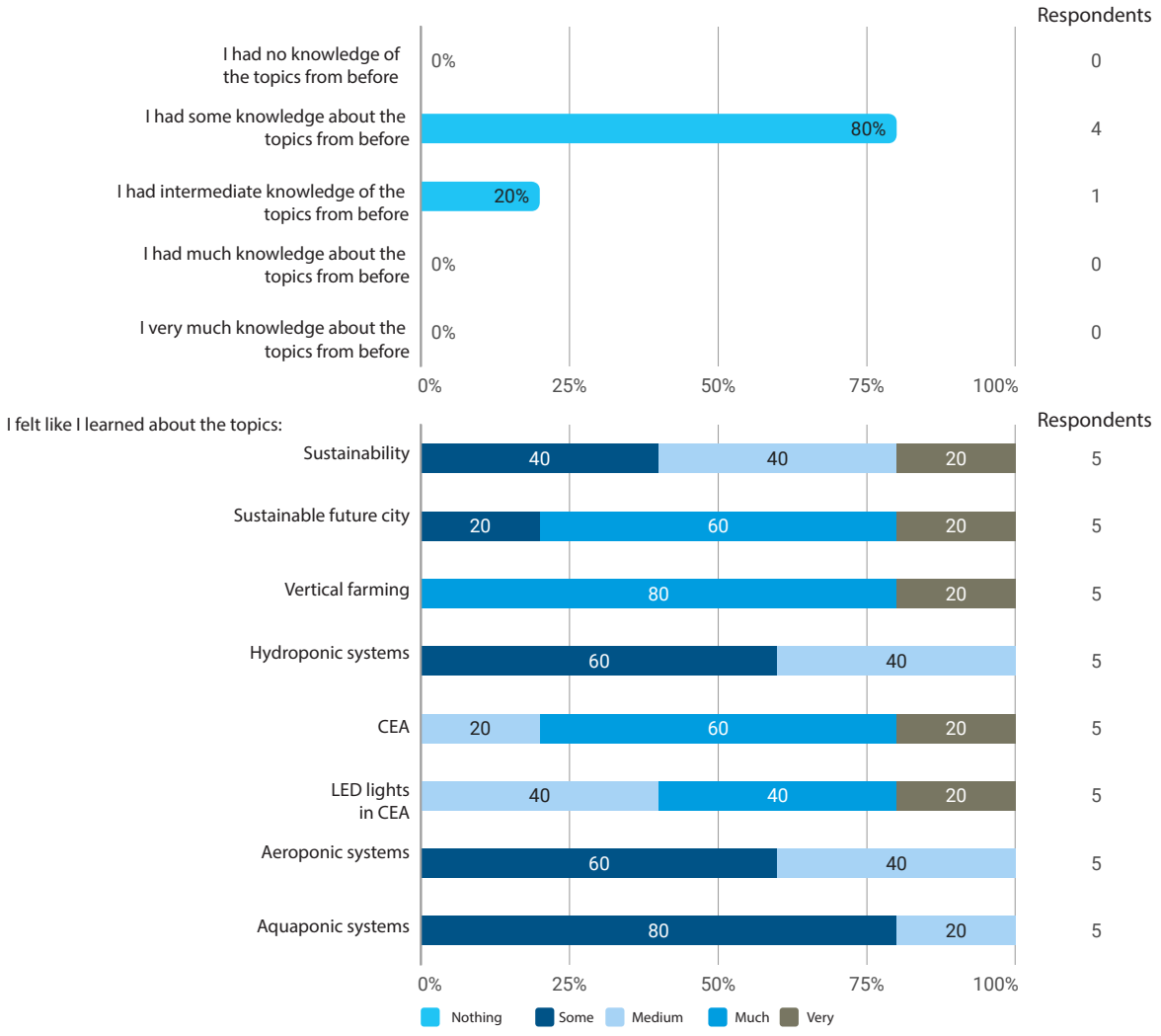


Figure 5.2: Participants' knowledge of the topics in iteration one

Motivation

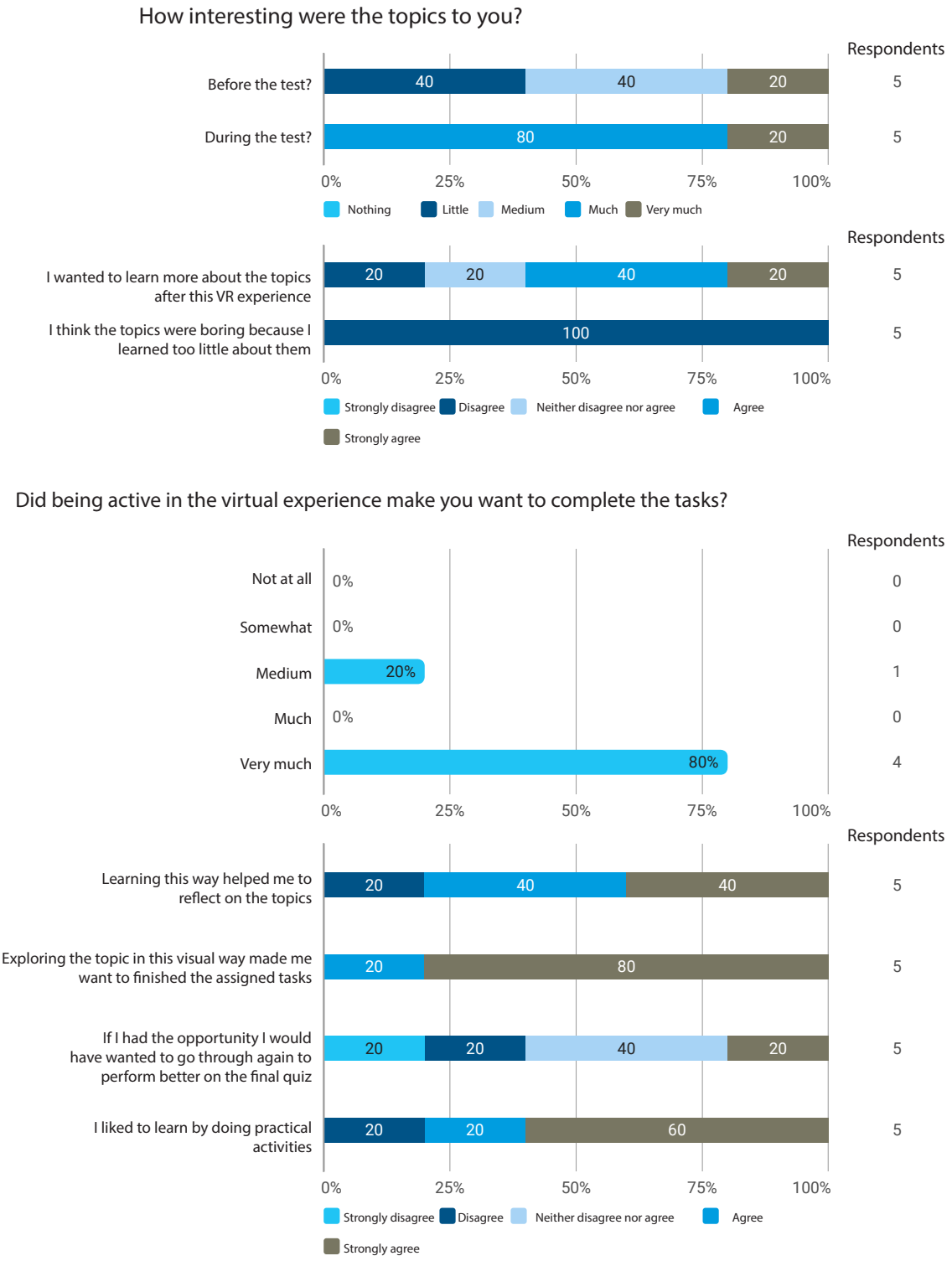


Figure 5.3: Motivation related findings in iteration one

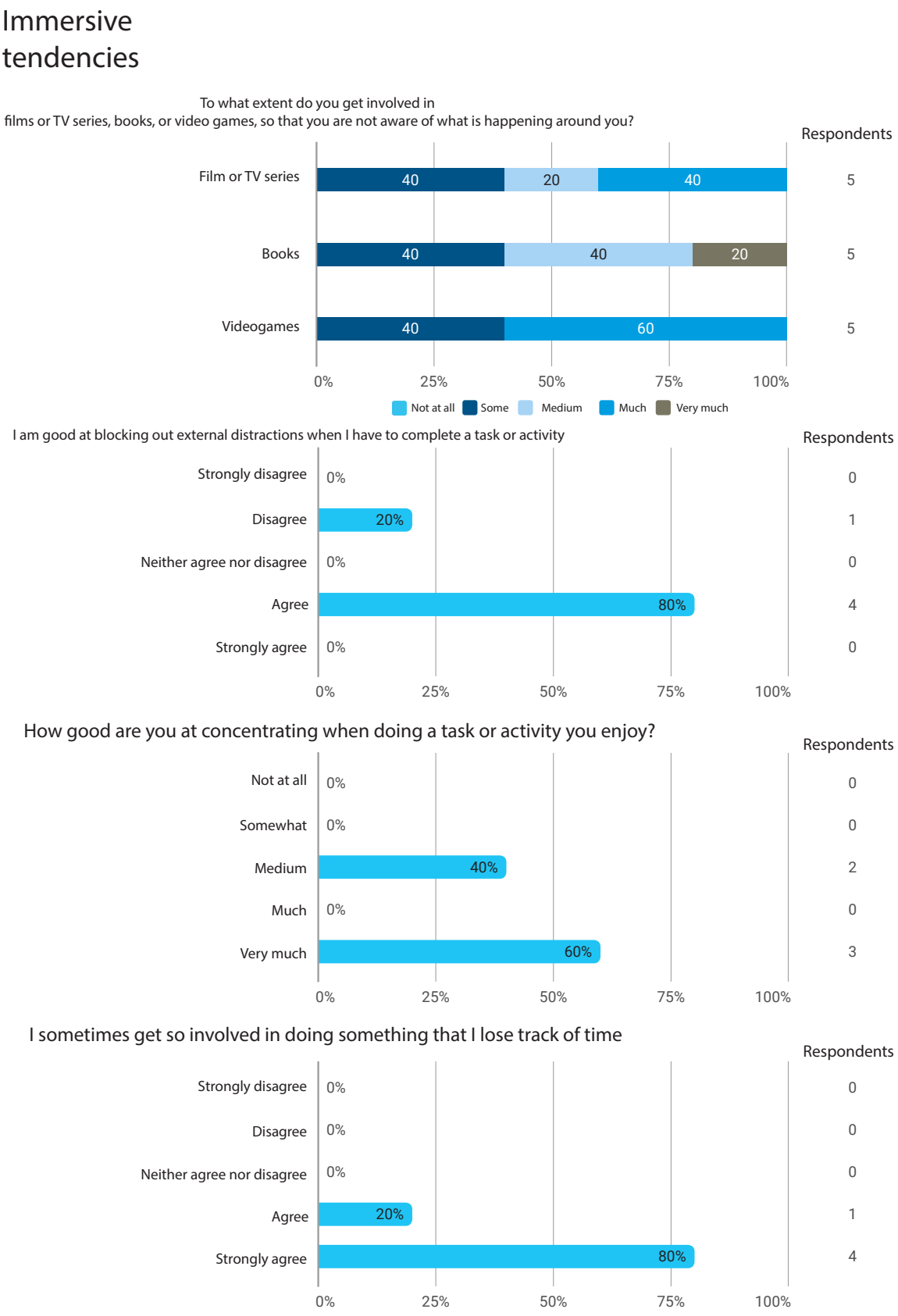


Figure 5.4: Immersive tendencies related findings in iteration one

Presence

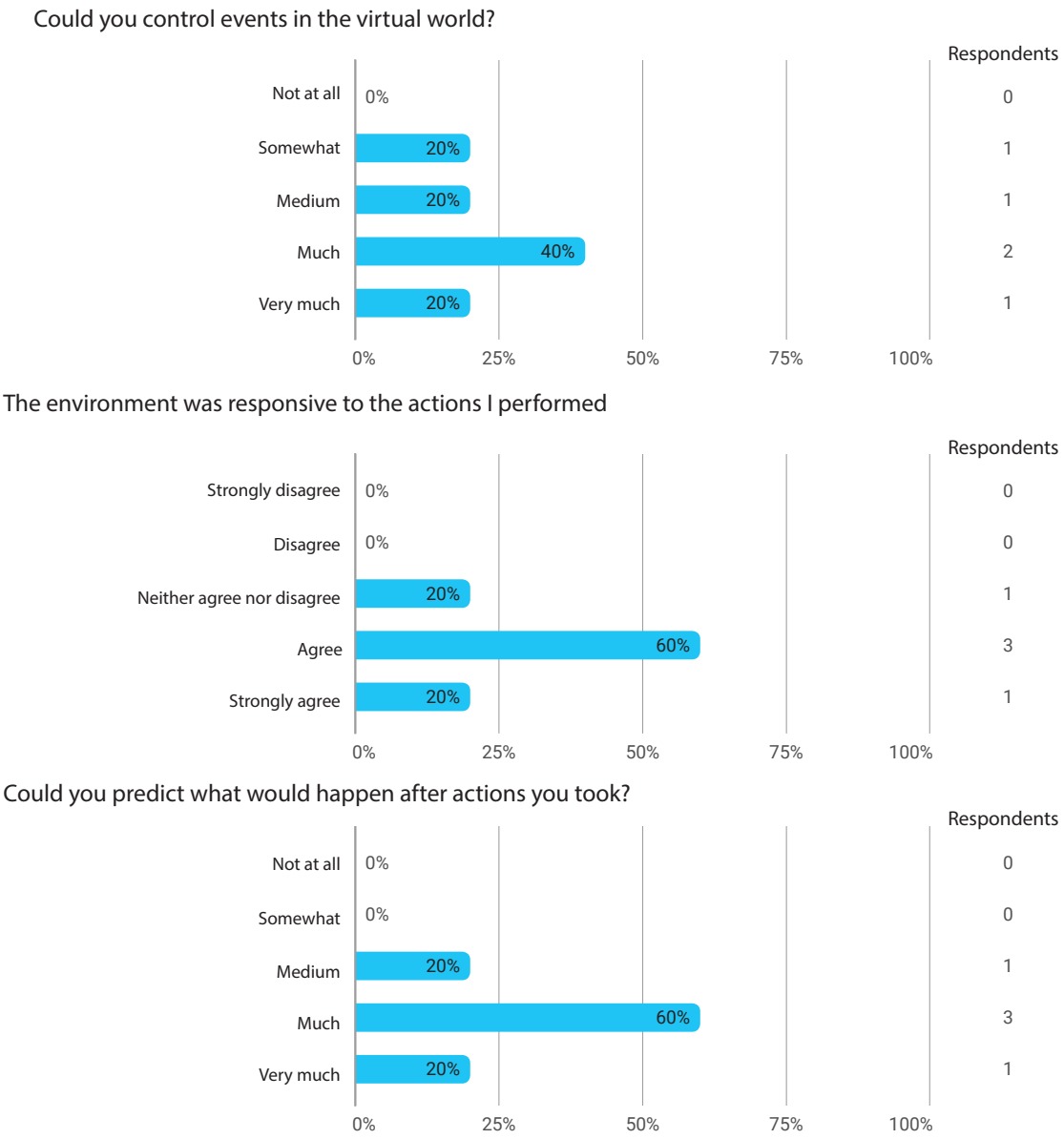


Figure 5.5: Presence related findings in iteration one

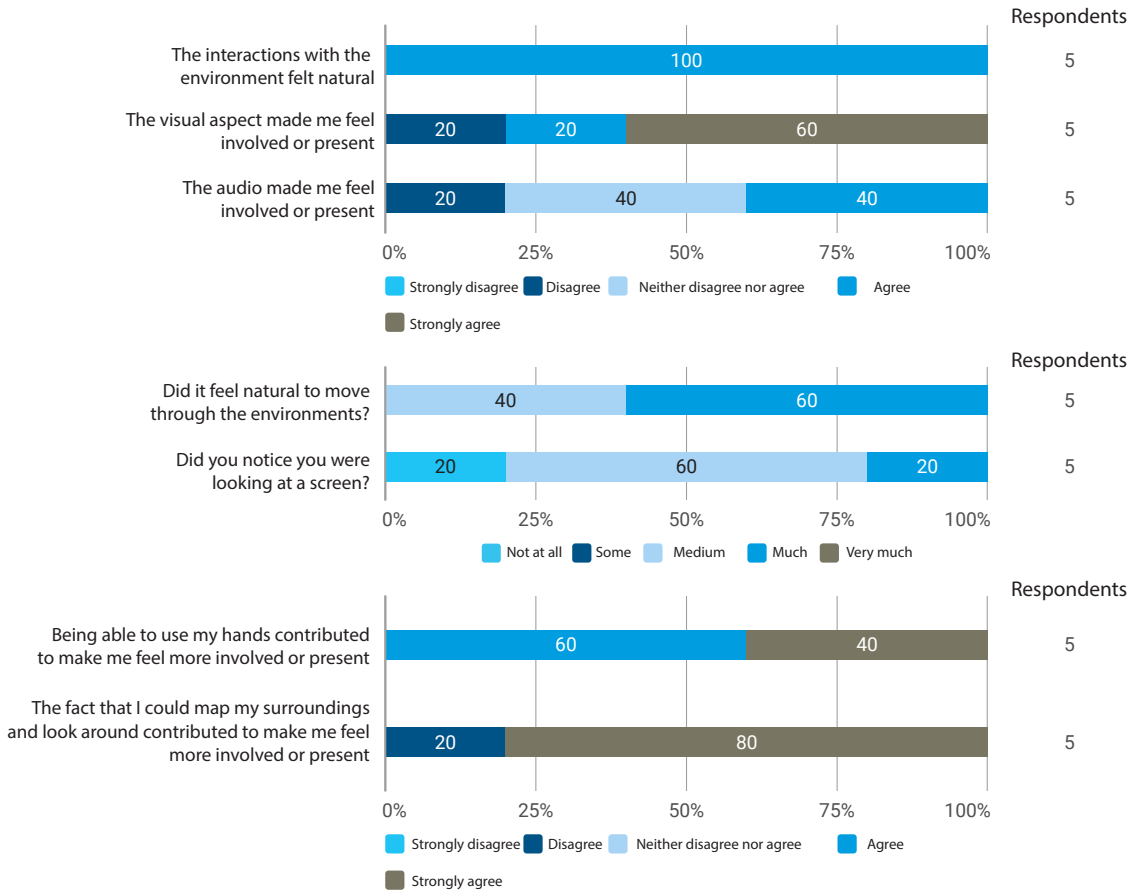


Figure 5.6: Presence related findings in iteration one

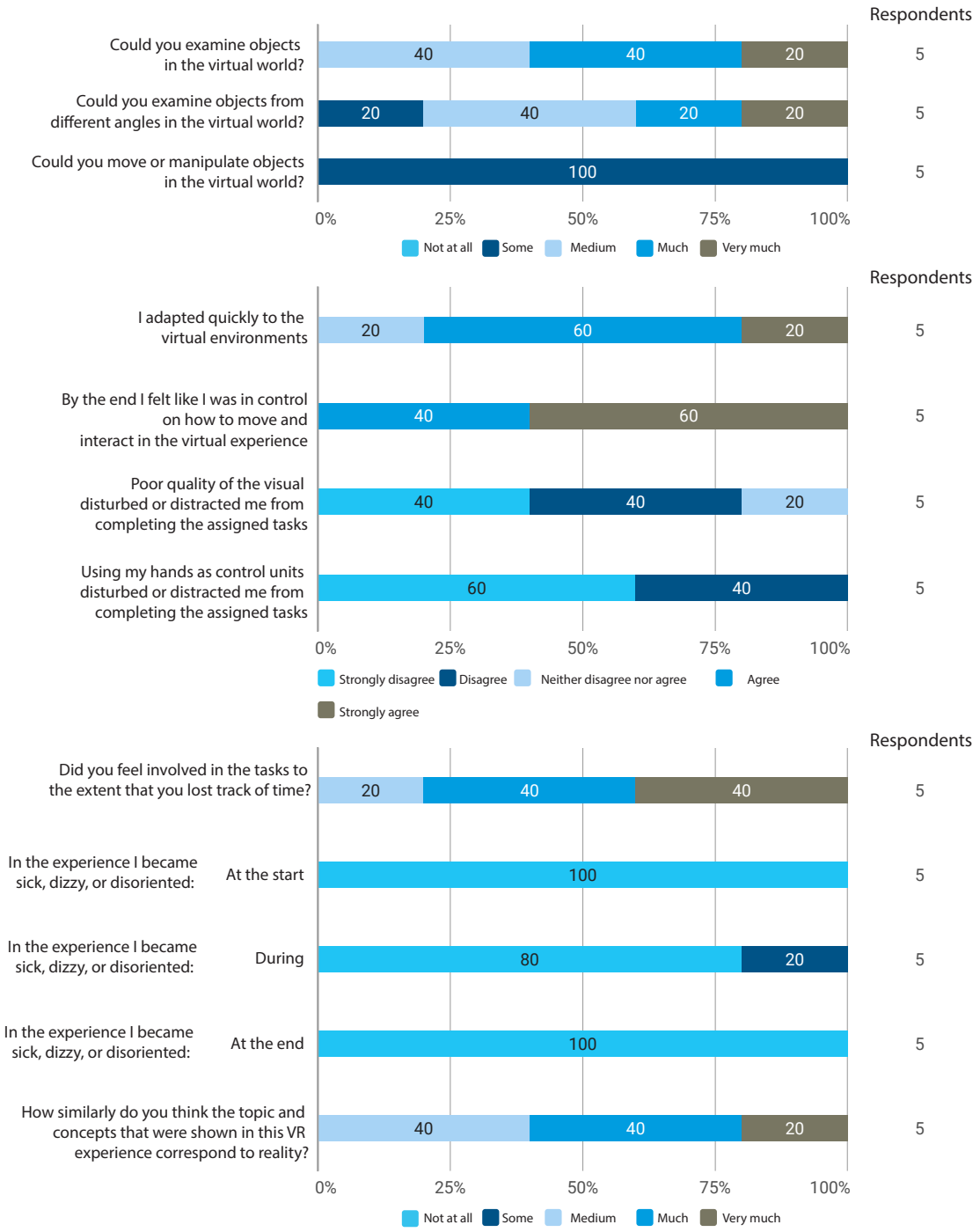


Figure 5.7: Presence related findings in iteration one

Findings from questionnaire in iteration two, translated to English. See Appendix M for original Norwegian version.

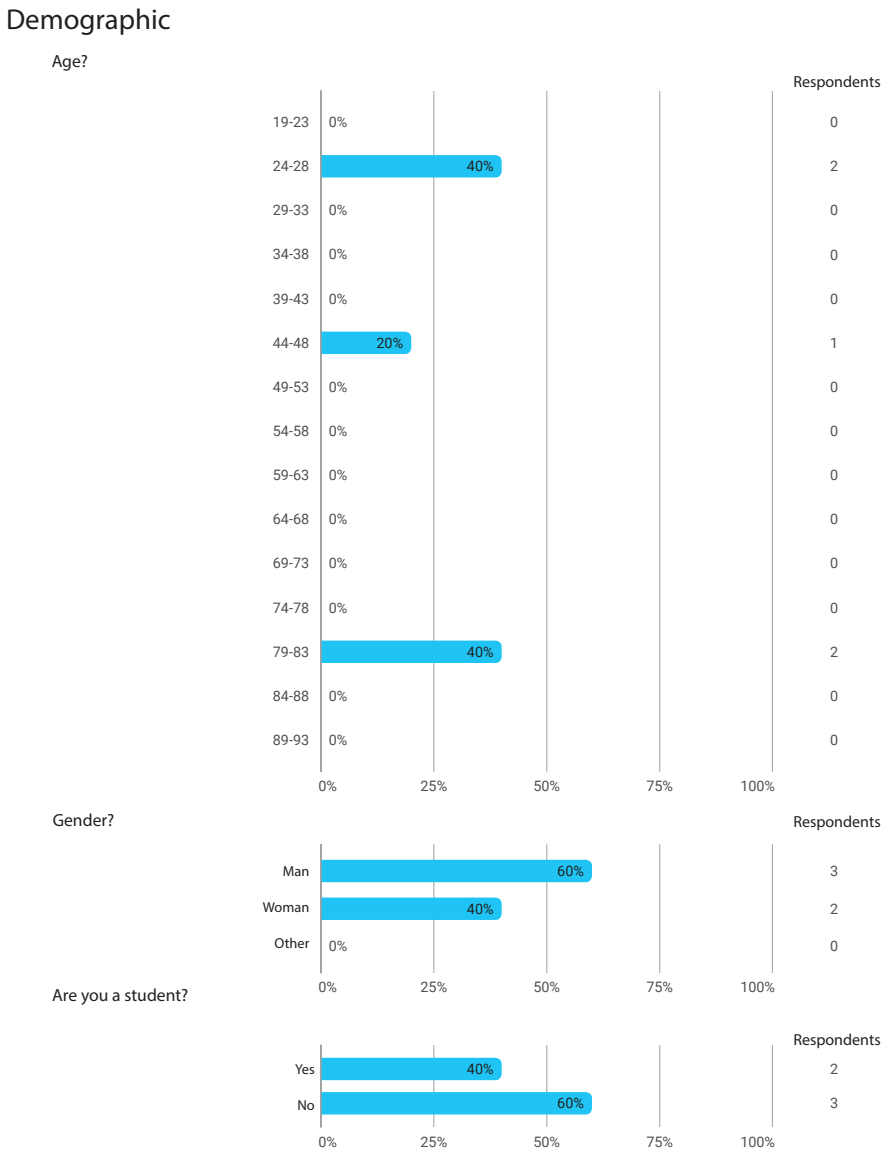


Figure 5.8: Participants demography in iteration two

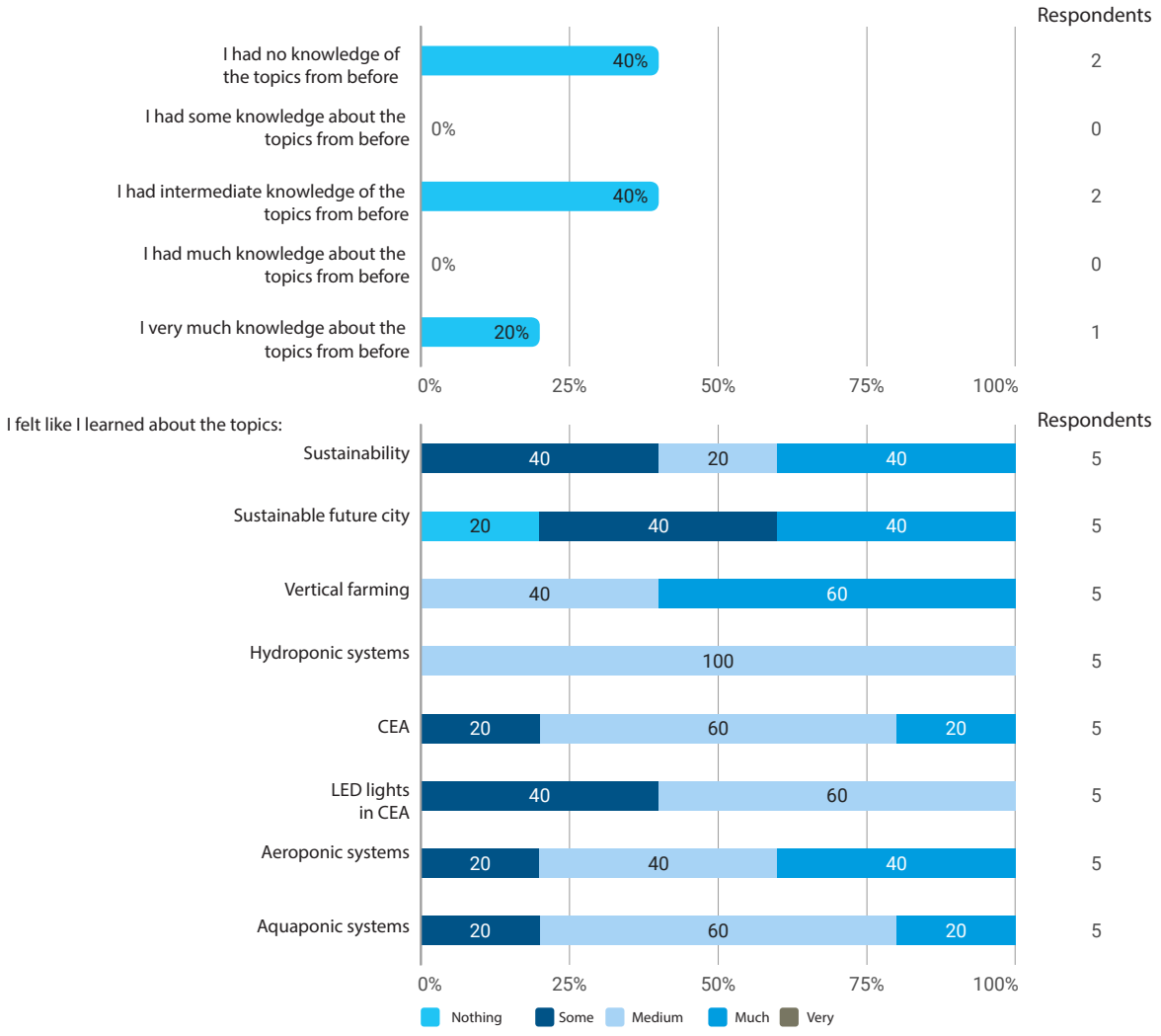


Figure 5.9: Participants' knowledge of the topics in iteration two

Motivation

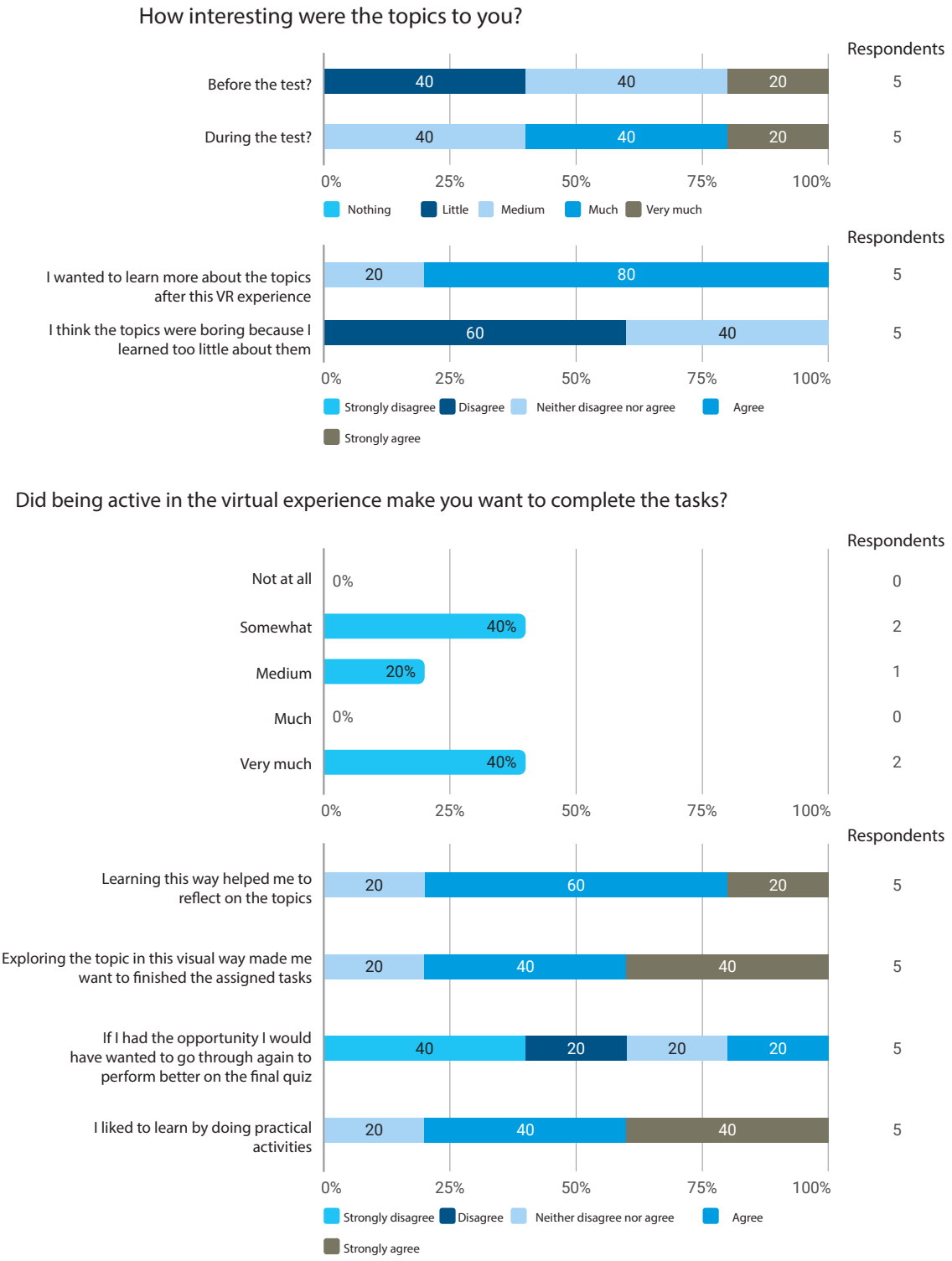


Figure 5.10: Motivation related findings in iteration two

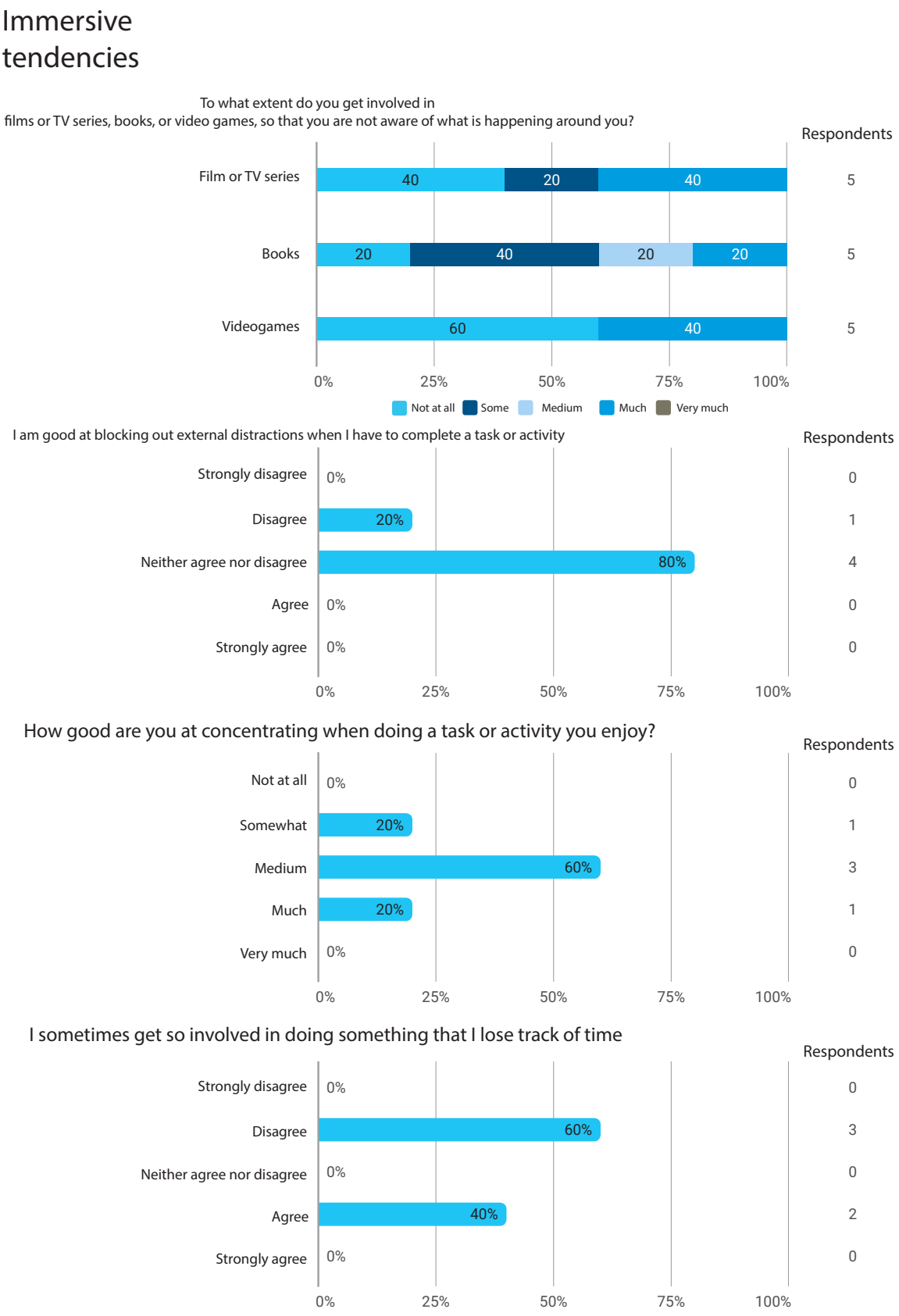


Figure 5.11: Immersive tendencies related findings in iteration two

Presence

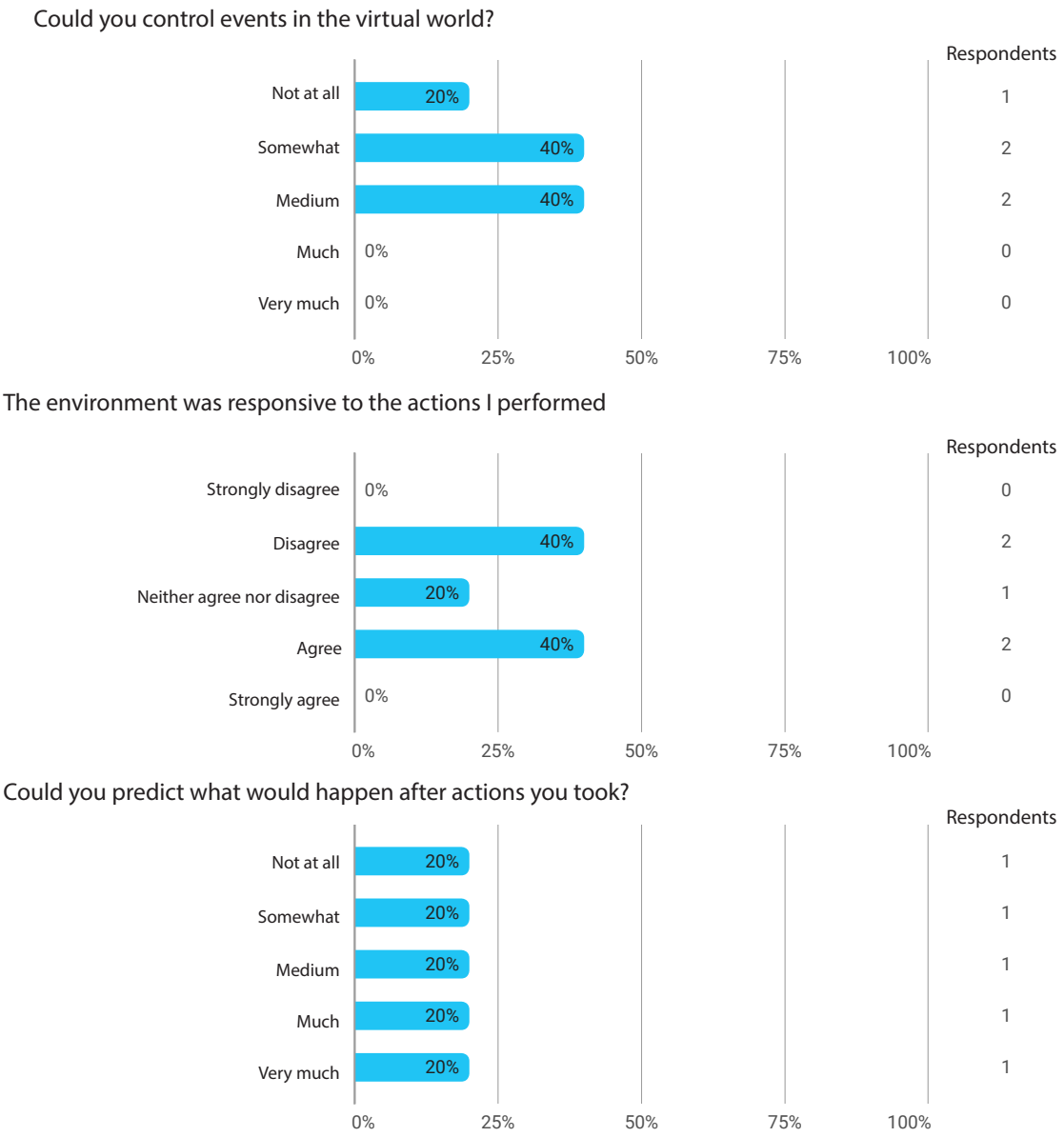


Figure 5.12: Presence related findings in iteration two

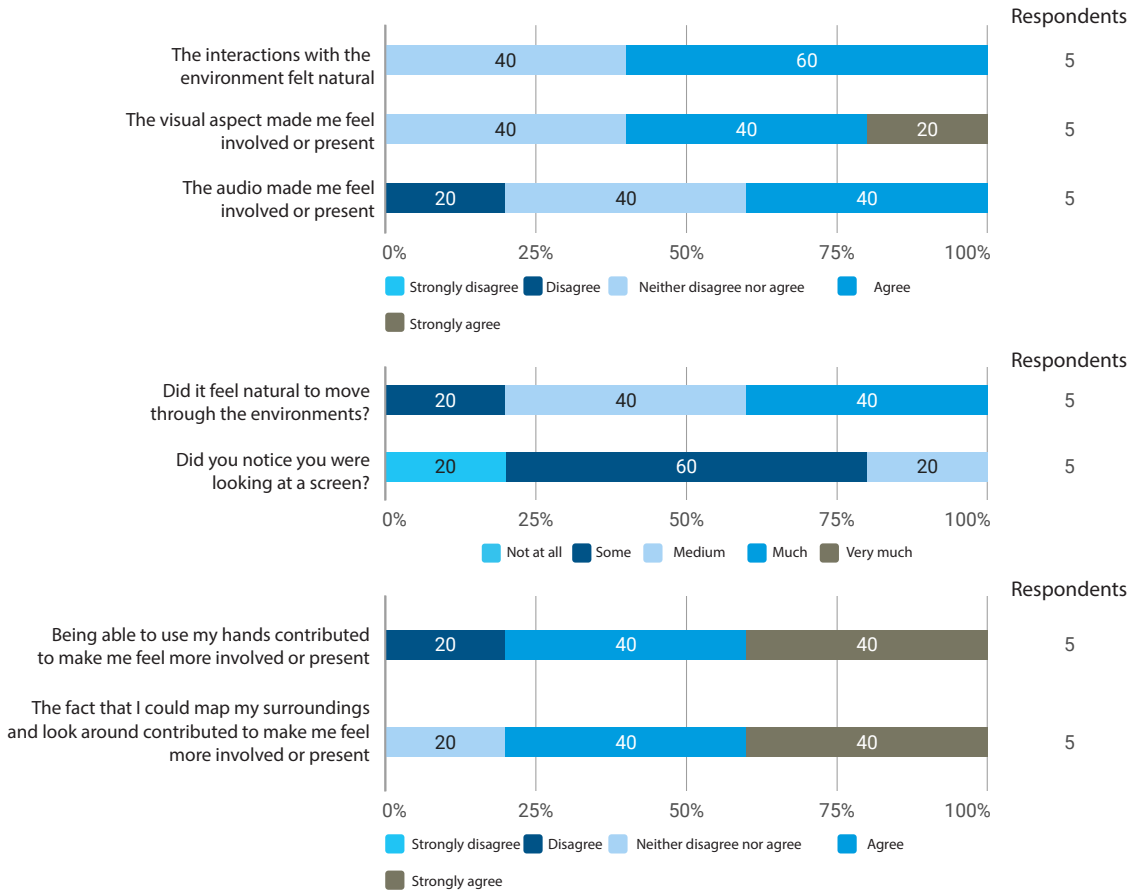


Figure 5.13: Presence related findings in iteration two

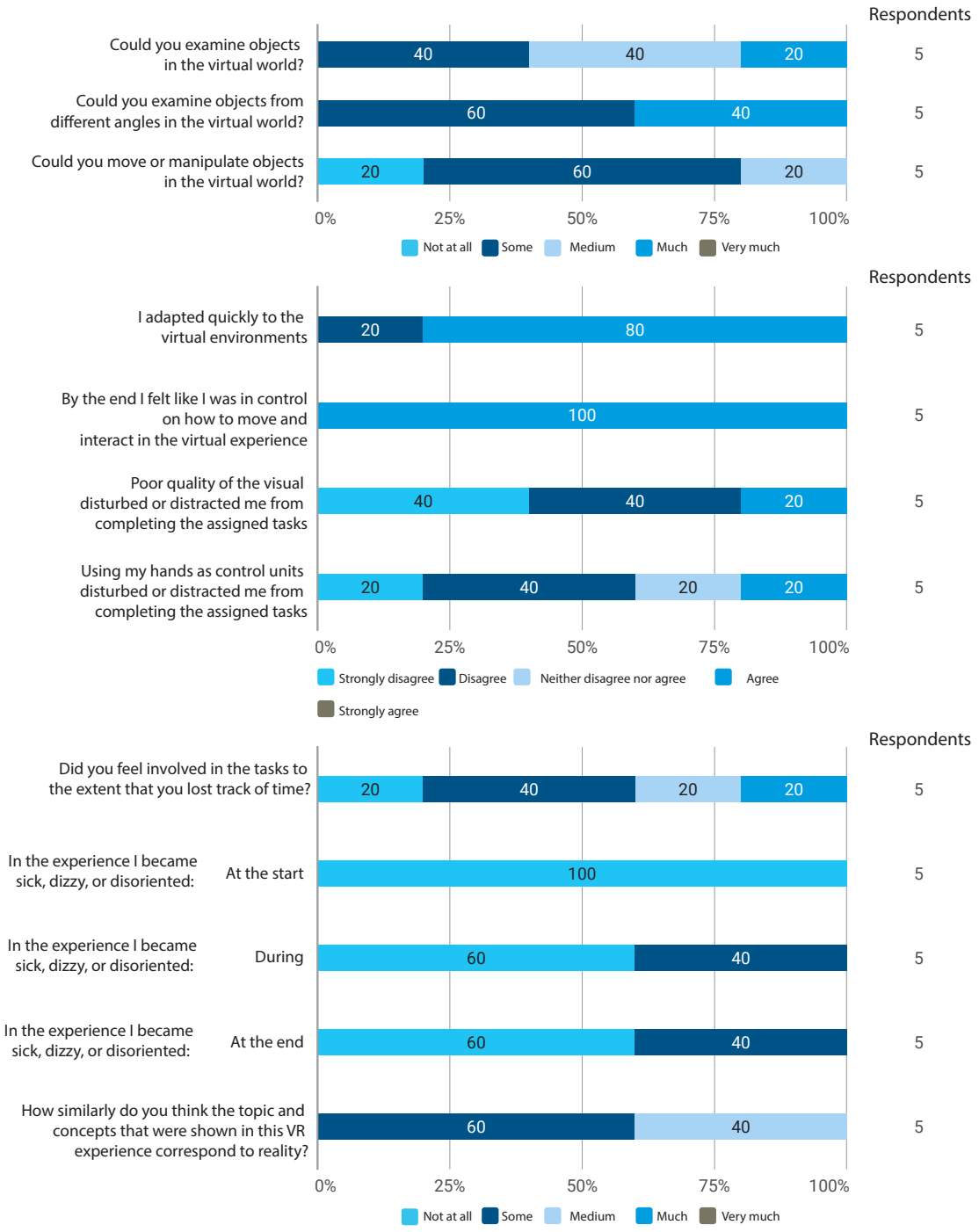


Figure 5.14: Presence related findings in iteration two

Post-test interview

8. **Topic: How was this experience for you? Elaborate?**

   Iteration one: Four out of five participants gave positive feedback. P1 thought it was very fun to learn in such a "hands-on" way. It was preferable to reading a book because it was so visual. P2 thought it was exciting, funny, and that learning through interactions helped make it more exciting. They thought the environment felt real even when they could see that it was not. P3 thought both the virtual reality aspect and the topic were very interesting. They also liked that they could inspect things closely, as well as hear about it. They particularly liked the aquaponics concept with the fish. P4 thought the experience, and the design of the environment, were exciting. They felt it was relevant, which is why they wanted to walk around. They thought the experience was interesting and found themselves reflecting on the potential of such an idea the whole time they were going through. P5 found it to be not very surprising overall. They also thought it was a bit unfamiliar to move, but that it worked fine. It was difficult to find the right tempo. It was a bit weird to understand what they were supposed to do in the beginning. Therefore they would like to have something guide them at the beginning. They suggested adding colliders that prevent the user from going through walls.

   Iteration two: The participants were largely positive about the experience. P6 thought it was unfamiliar and awkward, but otherwise a very interesting experience. P7 thought it was a fun way to learn, and enjoyed walking around. They did admit it was a very resource heavy and expensive way to learn. Further, they thought that people learn more when things are fun. P8 thought it was exciting, informative. They thought it should be added to schools or work, and also that if they were 15 and tired of school, this would have been motivating, and a cool and different way to learn. P9 thought it was alright, but saw areas that could be improved upon. They found it to be kind of irritating with the digital keyboard, and that there was little to interact with. They also thought the spheres should have something written on them to indicate what they are, and to use a real narrator rather than AI for the voice. Overall they thought the experience was very introductory. P10 thought it was completely new, and that there were parts that were interesting. They also felt like they learned something.

9. **Topic: How was it to be able to explore the environment in a virtual world?**

   Iteration one: All participants were positive about the exploration but some wanted there to be more to explore. P1 thought it was nice and fun to explore the environment, but they felt there was too little to learn and explore. P2 enjoyed being able to go so near the plants when inspecting them, as well as how detailed they were. They wished for more variation in what kind of plants were there, as well as additional opportunities to learn more about the plants. P3 thought exploring the environment was very cool. It was cool for them to cross the bridge and enter another world and thought they were another place, in the future. P4 enjoyed walking around and wanted to look at the architecture. They are a very curious person, and felt that the exploration was driving them. P5 thought it was fun to walk around, and that it reminded them of regular games. It felt a bit empty, so they would have wanted more interactions. Additionally, they wanted there to be more information about the areas, and that more spheres were added.

   Iteration two: Likewise to Iteration one, participants were mostly positive but some wished for more. P6 thought it was okay and fun. They suggested having an overview of all the concept words that they could look up. They thought it was a nice city, and that it was fun being disinfected. P7 thought it would have been more fun if there were more objects to pick up. At the same time, they thought the text was helpful. P8 thought it was informative. After a while they understood how to move, and they would have liked it if there was more to explore. P9 thought it was good, but somewhat little to explore. They also wanted to be able to poke the spheres with their fingers, pick up more things, and have the option to use controller units. P10 thought it was exciting and totally unknown to them.

10. **Topic: How did you experience the presentation of the theme?**

    Iteration one: Participants were positive towards the use of both narrator and scrollable full text they could read themselves. P1 felt that the topic was conveyed alright, especially the fact that they could both hear the text and choose to read it themselves. P2 had reflected about the topic after the survey, and thought it was very exciting. They wished for more content in the environment to make it even more exciting. P3 thought it was nice to be able to both read and listen to a voice over, and that they personally preferred to read. Therefore they thought it was nice that they had the possibility to read the text themselves. P4 thought it was interesting, especially the topic. They thought how the topic was conveyed was reasonable, and liked that they could quickly skim through the text. It allowed them to first read the text and then understand what the interaction was, for example with the LED lights. P5 said it reminded them of how information is conveyed in a museum. They thought the voice spoke a bit slow. They made a suggestion to have the possibility to control the talking speed.

    Iteration two: Most participants were satisfied with how the theme was presented. However, some possible improvements were suggested. P6 wanted there to be more of an overview of the concepts. They also wanted to move the descriptions around a bit. P7 thought it was introductory in the text, and that it was interesting. It did not go in-depth, but it was okay, especially if someone using the application is not a professional. They suggested having an animation of someone talking and explaining. P8 thought it was exciting, and that it started at a too high level. There were many words they had not heard of before. It gave them an understanding of the topic, and they were surprised that the visuals matched how the concepts are in reality. P9 thought it could be a bit monotonous with the spheres, and suggested using more lights with them. The visuals were good, but lacked variation and were too similar. P10 thought it was very good to be able to hear and see the text along with the model. They felt it was an enrichment

11. **Topic: How was the depth of what you learned about?**

    Iteration one: Overall participants thought the depth was not so deep, but that it was okay as it gave an introduction for the topic. Some mentioned that they wanted more concept spheres added. P1 thought the depth was ok, but it could have been deeper. They thought the sphere concept was cool, and would have liked there to be more of these spheres added. They suggested adding spheres at the aeroponic system. P1 thought the concept spheres were good and had a suitable amount of text in them. P2 felt there was not a lot of depth, but that what was there still gave them a deep afterthought. They thought the experience could awaken interest. P3 felt that it was deep enough for the time, and that it was like getting a taste of the topic. It was a suitable amount. P4 thought that it did not go very in depth, and that it was conveyed more indirectly through the visuals. They wished for more information, more on the topic of a sustainable city and other topics than food production. They would have liked there to be more spheres added. P5 felt it was quite superficial. However, it was alright because it gave an overview of a topic they were not particularly interested in. They wanted there to be more spheres added on the other concepts such as aeroponics and aquaponics.

    Iteration two: The depth was mostly seen as a suitable amount, and not too deep. P6 felt they got the idea on how the systems worked and that they could reflect after the experience. They felt it helped them remember better and thought it was really good with the voice. They could have gone through again. P7 was interested in learning more. P8 thought it was understandable, and alright in depth and that this was a good starting point or introduction. P9 thought it was surface level, and that it was alright. They prefer seeing the principle, rather than the text, and would want the text as just an extra thing. P10 said it was suitable, concise and clear, without turning it into a long homework. They did not feel the need for more.

12. **Topic: What was it like to learn about the topics in such a virtual experience, as opposed to if you were to learn about it by reading in a book, online, or by watching a video?**

    Iteration one: Most participants preferred the virtual experience, but some noted that it would be a nice addition to traditional means. P1 felt it was a lot more interesting and more fun to be able to see rather than having to imagine. P2 thought it multiplied the impression many times over. Reading and using the body gave another expression than books, and it was very cool to learn in this way. P3 thought it would be a lot easier to remember what they learned. After the experience, they had images in their head which they could recall back to and tie the information to how the environment looked to help them remember. P4 thought it was more fun to move in such a world, and that it gave them a much better understanding. It gave them a very good understanding, having the hands-on visuals to recall back to later. P5 thought it demanded more time, but preferred this way of learning over a book. They felt it was more fun because it felt like visiting a museum.

    Iteration two: P6 saw the experience as something to do first, and then read the book. They thought the experience provided curiosity. P7 compared the experience to a book, which has a start and an end, and that they are in control in the immersive experience. Here, they could miss something when going through. P8 thought it was like night and day. There was no doubt that they would have put the book away. They thought it was better than video, because they could explore, inspect things, and push things. P9 thought it was better to do this than a video and made a suggestion of making it easier to know where they are supposed to go, by having more signs. P10 would have preferred this, because it is something completely new. They felt they got the topic explained in a concise and good amount.

13. **Topic: Do you think that learning this way will help you remember the topics longer afterwards? Why?**

    Iteration one: All participants thought yes, because they had gotten an experience to look back on rather than just reading about it. P2 liked to use a mapping method with the environments when they remember things. P4 thought it was valuable to learn from their mistakes.

    Iteration two: Most participants thought they would because they can make visual connections to the topic. P7 thought yes because it was an exciting topic and because of how much was put into the environment. They also said that being active made it easier. They had been on a memorization course, and mentioned they used a strategy of visualizing a room to make remembering things easier.

14. **Topic: Do you think VR experiences in general can make learning more interesting?**

    Iteration one: All participants thought yes. P1 thought it may not be for everyone but for people like them however, it is great. P2 thought it could make boring subjects a lot more exciting. P3 said that a change in environments and actually walking around to learn was a nice way to remember. P4 mentioned they were not very interested in the topic before, but after the experience they became more interested in it. P5 thought it depends on the topic and how much it fits to do virtually.

    Iteration two: Most participants thought yes. P6 felt it gripped them even as an elderly person. P7 thought it depends on the topic and the quality of the virtual experience. P10 thought it was in the start phase, but they see the potential.

15. **Topic: How did it feel to move around by teleporting?**

    Iteration one: Most participants thought it was difficult at first, but that it got better after a while. Towards the end, they tended to get more skilled. P1 felt it was alright because it reminded them of Google Earth, and P5 had experience with VR teleportation already.

Iteration two: Most participants thought it was alright, where some felt it was natural and others struggled a bit. P6 thought it demanded some effort, and P10 had some issues at the start with pinching and selecting from distance, but they got more control by the end.

16. **Topic: How did it feel to be able to see the digital overlaid on the real?**

    Iteration one: P1 thought it felt natural that the digital and real were shown simultaneously. P2 thought it would have been much easier to not see the real world. P3 thought it was very cool and felt natural to see the miniature model in the real world, but it was a bit difficult to orient themselves. P4 thought it was a nice transition, and liked being able to get an overview first and then seeing the big virtual reality world. P5 thought it felt a bit weird, because the table kept getting in the way.

    Iteration two: P6, P8, and P10 did not even notice it was happening, which P10 suggested meant it felt natural. For P6 it was when they crossed into the city and it got black that they noticed. P7 and P9 thought it felt quite natural and almost like there was a table there, even though they knew it was not.

17. **Topic: How did it feel to go through the door towards the bridge? Did you notice any difference? Elaborate?**

    Iteration one: All participants thought it was cool and liked the effect. P2 did not think much about it at the moment, but when looking back on it they thought it was a very cool effect. P3 said the bridge felt like another world. P5 compared it to a 'Narnia-feeling'.

    Iteration two: P6 and P10 did not think about it. P7 said that was where it became full immersion and that it felt natural, as they did not notice anything. P8 felt like they were in the real world and then went on vacation.

18. **Topic: How did it feel when you walked from the bridge to the city? Did you notice any difference? Elaborate?**

    Iteration one: P1 thought it felt like flying. P2 thought it went okay, and that it was fun. P3 thought it was nice and fascinating to see a new world, and it felt like they were in the future. P4 thought it was alright, and understood that they were in the city they had seen as a miniature model. P5 did not notice much of a difference.

    Iteration two: P6 thought everything felt a lot bigger, and that they were in the city. P7 did not notice anything so they thought it felt natural. P8 and P9 were impressed and assumed they were in the city they had seen in the miniature model. P10 felt they were there, but they strongly wanted it to have looked different.

19. **Topic: How did it feel when you sat on the forklift? Did you notice any difference? Elaborate?**

    Iteration one: P1 was not very impressed, and would have liked there to be more interaction and to have been able to drive it. P3, P4, and P5 thought it was alright even if they could not steer it.

    Iteration two: P6 felt it drove backwards, and that they did not have control. P7 and P8 were a bit disappointed and wanted to steer it, while P9 thought it was okay not to steer. P10 got unwell and confused from the camera movements.

20. **Topic: What would you like to get more out of this VR experience? For example, do you have any suggestions for change? Is there anything that stood out to you that you liked or didn't like?**

    Iteration one: P1, P3 and P4 would have liked for more spheres to be added. P2 would have wanted it to be more realistic. P4 also would have wanted more interactions and other sustainability concepts added. P5 thought it felt a bit empty, and would have wanted there to be more interactions and content.

Iteration two: P6 wanted there to be more plant diversity. P7 thought that the more stuff that fits with the purpose of what users are supposed to learn is put in, the more fun it will get. P8 thought it would have been fun to hear about other topics within sustainability as well as be able to pick up more objects. P9 thought there should be more meaningful interactions, and P10 thought that the city should look different and be more lively.

21. **Topic: Do you have anything else that you feel should be mentioned?**

    Iteration one: P5 thought there could be more environmental sounds to make it more realistic and immersive.

    Iteration two: P7 would have wanted a more guided experience.

5.2.2 Design changes after feedback from iteration one & interpretations

This section lists the design changes made from feedback from user testers in iteration one, reasons why, and if they made an impact in iteration two.

- Moved the poster from the left to the top of the future city mini-model. The reason: to make it more visible because most user testers overlooked it, which was an issue found in iteration one, see 5.2.1., observation of user tasks, no. 4. In iteration two the change did what it was intended to do, as 'four out of five participants noticed the 'introduction poster' and read it thoroughly'. This change was important as the 'introduction poster' is meant to be the start of the guided exploration and an introduction to the experience.
- Put in three name description posters; 'skifterom', 'til desinfisering' og 'vent litt for å bli desinfisert'. The reason: There was some confusion in iteration one as to what type of room it was. Participant three thought it was a laundry room, and participant two thought it was there for them to change clothes. This finding can be seen in 5.2.1., observation of user tasks, no. 6. In iteration two, it was more clear what type of room it was. Participant 6 was observed reading the sign 'skifterom' out loud.
- Fixed critical errors in the changing room and disinfection area; The colliders on the disinfection area were fixed. A button was also added which could be used to open the door. The reason: So that users could not teleport through it anymore and instead had to push the button. This error was spotted in iteration one when participant 3 mistakenly teleported through the wall and got confused as to how they ended up in the disinfection room. This finding can be seen in 5.2.1., observation of user tasks, no. 6. In iteration two, this error was fixed so that it did not occur with any of the participants.
- Fixed critical errors in MR environment: The door to the bridge in the MR scene was fixed to be inactive until the user selects the red sphere, and when they deselect it. Additionally, the whole door and bridge were moved closer to the miniature model, and a magenta sign was placed on top of the door which said 'gå inn her'. The reason: It was changed to prevent users from going through the invisible wall-shader and ending up at the bridge before selecting the red sphere, which happened to participant 1 in iteration one. The change to move it was done to make it easier for users to spot, and the sign was added to guide them to go through it because they often did not see or understand that they needed to go through the door, which was identified as an issue with participants 4 and 5. In iteration two, this was not an issue as users noticed the door immediately due to its new location and sound effect, and understood they should go inside because of the sign. These findings can be seen in 5.2.1., observation of user tasks, no. 4.
- Added mist to the aeroponics model. The reason: Because it was an important detail of the concept itself and to up the realism of the visualization.
- Added many more environment sound effects and ambience such as button pushes, menu hover and selections, nature sounds, winds, hum of LED lights, elevator sounds, as well as hydroponics, aeroponics, and aquaponics sounds. For a full overview, see Appendix G. The reason: To make it more immersive and give users a higher sense of presence. This was due to

previous feedback from participant 5 in iteration one who said that it was too quiet, as well as the questionnaire where one participant disagreed that the audio helped them feel immersed. In iteration two, sound effects and ambient audio were implemented, however it received the same results in the questionnaire, where one participant disagreed again. On the other hand, there was no mention of missing audio in the post-test interviews. These findings can be seen in 5.2.1., post-test interview, no. 21, and questionnaire findings in iterations 1 and 2.

- Added the text script and spheres on the concepts of aquaponic systems, hydroponic systems, vertical farming, and aeroponic systems. The reason: Feedback from multiple users in iteration one, participants 1, 2, and 3 asked for more concept spheres to be included to have more to explore and learn. In iteration two, there were no requests for more concept spheres to be added. These findings can be seen in 5.2.1., post-test interview, no. 20. This change was important as it introduced more content to the experience and more to learn and do for users.

- Added more quiz questions. In iteration one there were three quiz questions, and nr. 4 to 10 were added in iteration two. The reason: As there were more text scripts and spheres added, there also needed to be more questions related to them so that knowledge gathered could be tested and practiced for the new parts as well.

5.2.3 Interpretation of data for measuring presence

Presence is subjective & data from the VR environment

Presence is subjective as it is about cognitive processes for the individual, as well as the immersive environment itself [2]. As mentioned in chapter 2, high or low levels of presence can be determined by where users place their attention, whether it is placed on the virtual world or the real world, respectively [2]. Users can know that they are physically in the same location, but if their attention is fully on what happens in the virtual environment, then they can be said to experience high levels of presence. As seen in the findings of this research, while most participants were observed to experience presence as expected, participant 10 in iteration two's responses indicate that they had a rather low sense of presence and were too distracted by the environment and unfamiliarity with the technology. This suggests that users can feel low levels of presence even when they are fully involved in the virtual environment, because of the cognitive process required to experience presence. While participant 10 admitted to have the feeling of being there, which can be seen in 5.2.1., post-test interview, no. 18, they were strongly critical of the way the future city looked, and struggled to maneuver themselves in the virtual world which could be observed disturbed their sense of presence and pointed their attention to themselves in the real world, which can be seen in 5.2.1., Observation of user tests and user tasks, no. 5, 6 and 7. As for the other participants, presence was observed more as expected, where the virtual environment, explorations, and interactions therein resulted in higher levels of presence experienced. Responses that indicate this level of presence include those observed in 5.2.1., Observation of user tests and user tasks, no. 4, 5, 6, and 7 where participants were active as they explored the environment and responded as if they were there in the virtual environment. For instance, participant 8 mentioned they almost started rocking back and forth on the forklift ride due to that it seemed so real in 5.2.1., Observation of user tests and user tasks, no. 6. Further, the questionnaire revealed that participants mostly picked answers that indicated higher levels of presence, which can be seen in the findings under 5.2.1., questionnaire findings in iterations 1 and 2. Users felt high levels of presence, even though they knew the world was a virtual world and they were still physically in the same location, as mentioned by participant 8 in 5.2.1., Observation of user tests and user tasks, no. 4. On the other side, users were also observed to feel presence in the sense that their body responded to the environment, as seen when participant 6 seemed to be scared when the door closed in their face in 5.2.1., Observation of user tests and user tasks, no. 7, and participant 10 started to feel dizzy when on the forklift ride, as seen in 5.2.1., Observation of user tests and user tasks, no. 6.

Connections between immersive tendencies and presence & implications on data

As mentioned in chapter 2, presence can be influenced by immersion [2]. Therefore, it was of interest to find out what the immersive tendencies of the participants are, as it can impact the data if individuals are more or less likely to feel immersed in activities in general. As can be seen in the findings under 5.2.1., questionnaire findings in iterations 1 and 2, there was a significant difference in reported immersive tendencies between iterations. In iteration one, the reported immersive tendencies were all in the high end, suggesting that participants 1-5 in are all highly likely to become immersed in activities, and therefore are more prone to experience higher levels of presence in the virtual environment. On the other side, participants 6-10 in iteration two reported much lower probabilities to become immersed, with the majority selecting options in the questionnaire that suggest quite low immersive tendencies. This could be an explanation as to why reported levels of presence in the iteration two group were lower than that of iteration one, as changes made between iterations were intended to increase the sense of presence, and not lower it. It should then be said that this is only a possible explanation, and there could be other factors that impacted this result.

Presence in MR & differences compared to the VR environment

Presence in MR seems similar to how it is in VR, even when it is not a full immersion in the sense that one still can see the real world in addition to the digital. Although, there are some design decisions that need to be taken into consideration that are more prevalent in MR, such as making the digital content feel natural in the real environment. However, this does not mean that the digital content needs to be realistic. Findings that substantiate these claims can be seen under 5.2.1., post-test interview, no. 16 and 17, where participants 3, 6 and 10 all mentioned that the digital miniature model of the city felt natural and like it was there, even when they knew in actuality that it was not. When asked how it was to see the digital overlaid on the real, participant 10 was one of those who did not notice it was happening. However, they suggested that this meant they also felt it was natural.

So, realism does not need to play a role here. On the other hand, the digital content in MR instead needs to be able to interact with both the real environment, as well as the users in a 'natural' way, to reach high levels of presence, as seen by the findings seen under 5.2.1., observation of user tasks, no. 4, and 5.2.1., post-test interview, no. 16 and 17, where most participants managed to interact with the miniature model and enjoyed rotating it around. The exceptions were participants 2 and 5, where participant 2 would have preferred to not see the real world, and participant 5 thought it was weird due to the miniature model getting in their way. Additionally, participant 6 had an issue where the model got stuck to their hand as they rotated it. These issues with the interactions seemed to lower their feeling of presence in the MR environment.

Furthermore, another consideration that is more prevalent in MR than in VR, is to think about the real environment MR will be experienced in. In other words, it is also important to consider what physical locations the MR immersive experience can be set up by the user in, so that levels of presence will not be broken in MR. In the case of the experiment, it was set up in a controlled environment. However, that may not always be the case, so design solutions such as spatial anchors could solve this issue.

Overall, the findings suggest that there is a high sense of presence, as presence seemed to be based on whether users get a feeling of naturality. Thus, a high level of presence was reported as most users' attention were placed on the mixed reality environment parts in the MR and its natural feeling and interactions with the real world environment and themselves, and not just the real world in the MR itself.

Combining MR and VR in one immersive experience & data on transition from MR environment to VR environment

It was relevant to combine MR and VR in one immersive experience, because it seems that it was not done like this before. Furthermore, the technique to make a transition from an MR environment to VR environment does also seem that it has not been done much research on either. So there was interest to see if it did something for the level of presence. Findings under 5.2.1., post-test interview, no. 17 show that participants mostly felt it was a natural transition or did not think about it there and then. However, some said it was a cool effect, see findings in 5.2.1., post-test interview, no. 17 and 18 and that it was like a portal or doorway to another world and full immersion, see findings 5.2.1., post-test interview, no. 17.

5.2.4 Motivation for learning with MR & VR tools

MR & VR as a new tool & different type of experiences lead to motivation

It generally can be fun and interesting to use tools that support learning and learning material such as mixed and virtual reality due to its novelty and immersive nature. For many, it is a new experience and feeling, and there is enjoyment in trying something new that they have not tried before. As seen in the findings under 5.2.1., post-test interview, no. 12, 13 and 14, all participants were positive towards the use of immersive virtual experiences, both as an addition to and as a replacement for traditional means such as books. As participants 1 and 4 stated, it was more interesting to see the concepts visualized and more fun to be active in the virtual world than it would be by reading about it in a text book. Overall, participants felt that the experience gave them a deep understanding, that it was concise, fun, interesting, and made the topic easy to remember, which can be seen as factors that would provide users motivation to continue learn more about the topics.

To do something active is more interesting & fun than for example reading a text book about the topics

Being active in the exploration of the environment, finding the concept spheres, observing the visualizations, and the interactions all combined to make the immersive experience more fun than it would have been to read a book, as mentioned by participant 8 who saw it as night and day and would have put the book away. This and the fact that for many it was a new experience, as mentioned by participant 10, meant that participants felt more motivated to continue and learn about the topic in the immersive experience than they would have been if they read about the topic from traditional means such as books. This can also be seen under the findings of the questionnaire, in 5.2.1., questionnaire findings in iterations 1 and 2, where participants mostly had little knowledge about the topic ahead of the experience, and their interest in the topic was much higher after. Further, the majority of participants selected options in the questionnaire that related to them wanting to learn more, thinking the topic was interesting, that it was helpful to learn in this way, and that being practical and actively exploring in a visual way made them want to continue, which suggests they had motivation in the experience.

The design of the end quiz could be improved

Additionally, the end quiz could make it so that some competitive users would want to perform well on the quiz. Some participants, such as participants 1, 7 and 8, seen in the findings under 5.2.1., observation of user tasks, no. 6., may also have paid extra attention as they explored, because they had found the office area and quiz before they had explored all areas of the underground farm, and thus knew that they should be attentive and read more as they went through the content. The findings from the questionnaire revealed however that while some participants agreed, most participants either disagreed or were indifferent when asked if they wanted to go through again to perform better on the end quiz, and it was not a source for motivation in most participants. This could be because the quiz annoyed or confused some participants due to the fact that they had to start over if they answered wrongly, as seen with participants 8 and 10 in 5.2.1., observation of user tasks, no. 7. Therefore findings suggest that this would be a design change that needed improvement in the immersive experience if there would be later iterations. However, all in all it seemed like it did not take away from the fun and interest in doing and learning about the topics in the immersive experience. As a whole, all participants were happy they got to experience it.

Chapter 6

Conclusion & future work

6.1 Conclusion

A mixed and virtual reality immersive experience use case that supports active learning with the topic of sustainability where users explore a 'sustainable future city' with focus on learning concepts related to horticulture has been developed. It was done in accordance to presented educational VR design principles, survey of what others have done in the state-of-the-art, and requirements which were validated through street interviews with five randomly sampled participants from the streets of Grimstad as part of a human-centred design approach. It was then tested using mixed research methods approach involving 10 users over two user testing sessions with five participants in each session. Changes were made in iteration two based on feedback from the first group. Testing consisted of observation as the participants completing user tasks, as well as a questionnaire and in-depth interviews. The gathered data was then analyzed to assess the participants' perceived level of presence and motivation as they went through the immersive experience.

The main areas of research were to explore how such an immersive experience that makes use of both mixed and virtual reality should be designed to effectively support active learning, as well as to use this developed use case to find out how users experience presence and motivation, as these are important factors of the user experience. The feeling of presence, that users feel physically present in a virtual environment even when they know it is digital, is indicative of whether users feel that they want to use it, and want to continue. Otherwise, if the experienced presence is low and the users' attention lands on the real environment instead, it could mean that they are bored, or have become uninterested in the application, which suggests it is not a very effective solution to support active learning. Further, the users' motivation also plays a role, as when the user experiences high levels of presence and keeps their attention on the virtual environment, it can be assessed whether the immersive experience is fun, interesting, and thus if it has value and people actually want to use it.

Research question one: ***"How to design an effective mixed and virtual reality experience supporting active learning?"***, has been addressed through a human-centred design approach in the development and implementation of a new learning environment: a mixed and virtual reality immersive experience that supports active learning through visualization, exploration of, and interactions in a sustainable future city to learn about the topic of sustainability. VR design principles, which also seemed to apply for MR, were also supported by related works in the state-of-the-art. The gathered data indicates that the developed use case experience is an effective starting point for such a design when it is based on the described educational-VR principles in chapter 4, and that guided exploration, realistic visualization and hand gesture interactions are key design decisions that were made. They were at a large extent effective in supporting active learning, and the designed tool can be easily used by the general population.

Research question two: ***"To what extent do user's perceive the level of presence and motivation in the mixed and virtual reality experience?"***, has been addressed as user testing was conducted with ten participants to assess their perceived sense of presence and motivation. As presence is subjective, the findings were varied where some participants indicated higher levels of presence than others at times, which could be due to individual immersive tendencies as well as the characteristics of the virtual environment. Overall however, all participants indicated they experienced high levels of presence as they completed the given tasks, with the exception of participant 10 who indicated multiple times that they had a low sense of presence and were distracted by the environment and unfamiliarity with the technology. This suggests that users can feel low levels of presence even when they are fully involved in the virtual environment, because of the cognitive process required to experience presence. Nevertheless, most of the time participants had their attention placed on the virtual environment and thus experienced high levels of presence. Additionally, presence was observed to be experienced equally in both mixed and virtual reality.

As for motivation, the findings repeatedly state that the experience was fun and interesting, and users enjoyed exploring and interacting with the virtual environment. Further, the visualizations helped them understand the topic and sustainable concepts in a contextual manner, and it was largely preferred to learn in this way when compared to traditional methods such as books. With exception of the quiz at the end, which was found to be a source of frustration for some, the gathered data suggests that the participants overall were positively motivated by the immersive experience which supports active learning, and that the exploration, visualization, and interactive aspects were large parts of why participants responded highly in terms of motivation, as it was concluded to make learning more fun and interesting in an active way.

6.2 Future work

This work developed a mixed and virtual reality based learning tool, as a proof-of-concept to implement active learning strategies in immersive learning contexts, however the scope and sample size were limited. In light of human-centred design principles, future work could focus on improving the usability of the developed prototype, through multiple design iterations and user-based testing. It would be interesting to study further the effect of increased levels of presence and attention to learning performance in active learning settings.

Bibliography

[1] S. Butler. *What Is "Presence" in VR, and Why Is it So Important?* Jan. 2022. URL: https://www.howtogeek.com/772410/what-is-presence-in-vr-and-why-is-it-so-important/#:~:text=VR%20Presence%20Defined&text=You%20feel%20physically%20present%20and,the%20virtual%20world%20as%20real. [Accessed: May 01, 2023].

[2] B. G. Witmer and M. J. Singer. "Measuring Presence in Virtual Environments: A Presence Questionnaire." In: *Presence: Teleoperators and Virtual Environments* 7(3) (June 1998), pp. 225–240. DOI: 10.1162/105474698565686.

[3] R. M. Ryan and E. L. Deci. "Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being." In: *American psychologist* 55(1) (Jan. 2000), pp. 68–78. DOI: https://doi.org/10.1037/0003-066X.55.1.68.

[4] H. Greene and S. Campbell. "Learning Techniques in the classroom: A Comparison of Active Learning versus Passive Learning." In: *Interational Journal of Arts and Sciences*. Orlando, Florida, USA, Jan. 2010. URL: https://www.researchgate.net/publication/275335813_Learning_Techniques_in_the_classroom_A_Comparison_of_Active_Learning_versus_Passive_Learning..

[5] G. M. Isabwe, N. Shevchenko, E. Steinsland, and K. Kokogias. *Virtual and Augmented Reality eBook*. University of Agder, 2022. 2nd ed.

[6] P. Milgram, H. Takemura, A. Utsumi, and F. Kishino. "Augmented reality: a class of displays on the reality-virtuality continuum." In: *Telemanipulator and Telepresence Technologies*. Ed. by Hari Das. Vol. 2351. International Society for Optics and Photonics. SPIE, Dec. 1995, pp. 282–292. DOI: 10.1117/12.197321.

[7] C. C. Bonwell and J. A. Eison. *Active learning: Creating excitement in the classroom. 1991 ASHE-ERIC higher education reports*. 1991. URL: https://eric.ed.gov/?id=ED336049.

[8] M. P. Ryan and G. G. Martens. *Planning a college course: A guidebook for the graduate teaching assistant*. Ann Arbor, MI: The National Center for Research to Improve Postsecondary Teaching and Learning, The University of Michigan, 1989. URL: https://eric.ed.gov/?id=ED314998.

[9] P. Pardjono. "Active Learning: The Dewey, Piaget, Vygotsky, and Constructivist Theory Perspectives." In: *Jurnal Ilmu Pendidikan* 9(3) (Aug. 2002), pp. 163–176. DOI: 10.17977/jip.v9i3.487. URL: https://www.neliti.com/publications/105376/active-learning-the-dewey-piaget-vygotsky-and-constructivist-theory-perspectives.

[10] J. Dewey. *How we think*. Boston, NY: Heath and Company, 1933.

[11] D. A. Kolb. *Experiential Learning: Experience As The Source Of Learning And Development*. Englewood Cliffs, NJ: Prentice-Hall, Jan. 1984. ISBN: 0132952610.

[12] I. D. Cherney. "The Effects of Active Learning on Students' Memories For Course Content." In: *Active Learning in Higher Education* 9(2) (July 2008), pp. 152–171. DOI: 10.1177/1469787408090841.

[13] H. Banchi and R. Bell. "The many levels of inquiry." In: *Science and Children* 46(2) (2008), pp. 26–29. URL: https://hal.science/hal-00692073.

[14] B. S. Bloom, M. D Engelhart, E. J. Furst, W. H. Hill, and D. R. Krathwohl. *Handbook I: cognitive domain*. New York, NY: David McKay, 1956.

[15] D. A. Kolb. "Management and the Learning Process." In: *California Management Review* 18(3) (Apr. 1976), pp. 21–31. DOI: https://doi.org/10.2307/41164649.

[16] N. D Fleming. "I'm different; not dumb. Modes of presentation (VARK) in the tertiary classroom." In: *Research and development in higher education, Proceedings of the 1995 Annual Conference of the Higher Education and Research Development Society of Australasia (HERDSA), HERDSA*. Vol. 18. 1995, pp. 308–313.

[17] I. J. Prithishkumar and S. A. Michael. "Understanding your student: using the VARK model." In: *Journal of postgraduate medicine* 60(2) (June 2014), pp. 183–186. DOI: https://doi.org/10.4103/0022-3859.132337.

[18] Z. Zayapragassarazan and S. Kumar. "Active Learning Methods." In: *NTTC Bulletin* 19(1) (2012), pp. 3–5. URL: https://eric.ed.gov/?id=ED538497.

[19] M. A. Kuhail, A. ElSayary, S. Farooq, and A. Alghamdi. "Exploring Immersive Learning Experiences: A Survey." In: *Informatics* 9(4) (Sept. 2022), p. 75. DOI: 10.3390/informatics9040075.

[20] C. H. Wu, Y. M. Tang, Y. P. Tsang, and K. Y. Chau. "Immersive learning design for technology education: A soft systems methodology." In: *Frontiers in Psychology* 12 (Dec. 2021), p. 745295. DOI: https://doi.org/10.3389/fpsyg.2021.745295.

[21] E. Salman, C. Besevli, T. Göksun, O. Özcan, and H. Urey. "Exploring Projection Based Mixed Reality with Tangibles for Nonsymbolic Preschool Math Education." In: *Proceedings of the Thirteenth International Conference on Tangible, Embedded, and Embodied Interaction*. TEI '19. Tempe, Arizona, USA: Association for Computing Machinery, Mar. 2019, pp. 205–212. DOI: 10.1145/3294109.3300981.

[22] E. Nersesian, M. Vinnikov, J. Ross-Nersesian, A. Spryszynski, and M. J. Lee. "Middle School Students Learn Binary Counting Using Virtual Reality." In: *2020 IEEE Integrated STEM Education Conference (ISEC)*. Princeton, NJ, USA, Aug. 2020, pp. 1–8. DOI: 10.1109/ISEC49744.2020.9397810.

[23] Y. Georgiou, O. Tsivitanidou, and A. Ioannou. "Learning experience design with immersive virtual reality in physics education." In: *Educational Technology Research and Development* 69 (Nov. 2021), pp. 3051–3080. DOI: https://doi.org/10.1007/s11423-021-10055-y.

[24] G. Chu, I. Humer, and C. Eckhardt. "Special Relativity in Immersive Learning." In: *Immersive Learning Research Network*. Ed. by D. Beck et al. Vol. 1044. Cham: Springer International Publishing, June 2019, pp. 16–29. ISBN: 978-3-030-23089-0. DOI: https://doi.org/10.1007/978-3-030-23089-0_2.

[25] D. Allcoat, T. Hatchard, F. Azmat, K. Stansfield, D. Watson, and A. von Mühlenen. "Education in the Digital Age: Learning Experience in Virtual and Mixed Realities." In: *Journal of Educational Computing Research* 59(5) (Jan. 2021), pp. 795–816. DOI: 10.1177/0735633120985120.

[26] I. Remolar, C. Rebollo, and J. A. Fernández-Moyano. "Learning History Using Virtual and Augmented Reality." In: *Computers* 10(11) (Nov. 2021), p. 146. DOI: 10.3390/computers10110146.

[27] J. Wolfartsberger. "Analyzing the potential of Virtual Reality for engineering design review." In: *Automation in Construction* 104 (Aug. 2019), pp. 27–37. DOI: https://doi.org/10.1016/j.autcon.2019.03.018.

[28] S. van Ginkel et al. "Fostering oral presentation competence through a virtual reality-based task for delivering feedback." In: *Computers & Education* 134 (June 2019), pp. 78–97. DOI: https://doi.org/10.1016/j.compedu.2019.02.006.

[29] J. S. Bazargani, A Sadeghi-Niaraki, and S.-M. Choi. "Design, Implementation, and Evaluation of an Immersive Virtual Reality-Based Educational Game for Learning Topology Relations at Schools: A Case Study." In: *Sustainability* 13(23) (Nov. 2021), p. 13066. DOI: 10.3390/su132313066.

[30] D. M. Markowitz, R. Laha, B. P. Perone, R. D. Pea, and J. N. Bailenson. "Immersive Virtual Reality Field Trips Facilitate Learning About Climate Change." In: *Frontiers in Psychology* 9 (Nov. 2018), p. 2364. DOI: 10.3389/fpsyg.2018.02364.

[31] O. R. Ogunseiju, N. Gonsalves, A. A. Akanmu, D. Bairaktarova, D. A. Bowman, and F. Jazizadeh. "Mixed reality environment for learning sensing technology applications in Construction: A usability study." In: *Advanced Engineering Informatics* 53 (Aug. 2022), p. 101637. DOI: https://doi.org/10.1016/j.aei.2022.101637.

[32] M. Slater, P. Khanna, J. Mortensen, and I. Yu. "Visual Realism Enhances Realistic Response in an Immersive Virtual Environment." In: *IEEE Computer Graphics and Applications* 29(3) (May 2009), pp. 76–84. DOI: 10.1109/MCG.2009.55.

[33] A. Asgary, C. Bonadonna, and C. Frischknecht. "Simulation and Visualization of Volcanic Phenomena Using Microsoft Hololens: Case of Vulcano Island (Italy)." In: *IEEE Transactions on Engineering Management* 67(3) (Aug. 2020), pp. 545–553. DOI: 10.1109/TEM.2019.2932291.

[34] S. R. B. Hunvik and F. Lindseth. "Making Use of Virtual Reality for Artificial Intelligence Education." In: *Bridges and Mediation in Higher Distance Education*. Ed. by L. S. Agrati et al. Cham: Springer International Publishing, Jan. 2021, pp. 56–70. ISBN: 978-3-030-67435-9. DOI: https://doi.org/10.1007/978-3-030-67435-9_5.

[35] C. Kelling, O. Kauhanen, H. Väätäjä, J. Karhu, M. Turunen, and V. Lindqvist Lindqvist. "Implications of Audio and Narration in the User Experience Design of Virtual Reality." In: Mindtrek '18. Tampere, Finland: Association for Computing Machinery, Oct. 2018, pp. 258–261. ISBN: 9781450365895. DOI: 10.1145/3275116.3275153.

[36] ISO 9241-210. *Ergonomics of human-system interaction–Part 210: Human-centred design for interactive systems*. July 2019.

[37] R. B. Johnson, A. J. Onwuegbuzie, and L. A. Turner. "Toward a definition of mixed methods research." In: *Journal of mixed methods research* 1(2) (Apr. 2007), pp. 112–133. DOI: https://doi.org/10.1177/1558689806298224.

[38] J. Byrne and A. M. Humble. "An Introduction to Mixed Method Research." In: *Atlantic research centre for family-work issues* 1 (Jan. 2006), pp. 1–4. URL: https://www.researchgate.net/publication/237658796_An_Introduction_to_Mixed_Method_Research.

[39] D. Natesan, M. Walker, and S. Clark. "Cognitive bias in usability testing." In: *Proceedings of the International Symposium on Human Factors and Ergonomics in Health Care*. Vol. 5(1). SAGE Publications Sage CA: Los Angeles, CA. 2016, pp. 86–88. DOI: 10.1177/2327857916051015.

[40] J. G. Adair. "The Hawthorne effect: a reconsideration of the methodological artifact." In: *Journal of applied psychology* 69(2) (1984), pp. 334–345. URL: https://psycnet.apa.org/fulltext/1984-22073-001.pdf.

[41] A. J. Nederhof. "Methods of coping with social desirability bias: A review." In: *European journal of social psychology* 15(3) (1985), pp. 263–280. DOI: https://doi.org/10.1002/ejsp.2420150303.

[42] B. L. Kintz, D. J. Delprato, D. R. Mettee, C. E. Persons, and R. H. Schappe. "The experimenter effect." In: *Psychological Bulletin* 63(4) (1965), pp. 223–232. URL: https://psycnet.apa.org/fulltext/1965-09078-001.pdf.

[43] S. Klar, T. Leeper, and J. Robison. "Studying Identities with Experiments: Weighing the Risk of Posttreatment Bias Against Priming Effects." In: *Journal of Experimental Political Science* 7(1) (2020), pp. 56–60. DOI: 10.1017/XPS.2019.26.

[44] A. Fontana and J. H. Frey. "The interview: From structured questions to negotiated text." In: *Handbook of qualitative research*. Ed. by N. K. Denzin and Y. S. Lincoln. Thousand Oaks, CA: Sage, 2000, pp. 645–672. 2nd ed.

[45] J. Preece, H. Sharp, and Y. Rogers. *Interaction design: beyond human-computer interaction*. John Wiley & Sons, 2019. 5th ed.

[46] A. Nortje. *Measuring Intrinsic Motivation: 24 Questionnaires & 38; Scales*. Mar. 2021. URL: https://positivepsychology.com/intrinsic-motivation-inventory/. [Accessed: 09.05.2023].

[47] C. Lewis. *Using the" thinking-aloud" method in cognitive interface design*. Yorktown Heights, NY: IBM TJ Watson Research Center, 1982.

[48] M. Sandelowski. "Qualitative analysis: What it is and how to begin." In: *Research in nursing & health* 18(4) (Aug. 1995), pp. 371–375. DOI: https://doi.org/10.1002/nur.4770180411.

[49] V. Braun and V. Clarke. "Using thematic analysis in psychology." In: *Qualitative Research in Psychology* 3(2) (2006), pp. 77–101. DOI: 10.1191/1478088706qp063oa.

[50] M. C. Johnson-Glenberg. "The Necessary Nine: Design Principles for Embodied VR and Active Stem Education." In: *Learning in a Digital World: Perspective on Interactive Technologies for Formal and Informal Education*. Ed. by Paloma Díaz, Andri Ioannou, Kaushal Kumar Bhagat, and J. Michael Spector. Singapore: Springer Singapore, 2019, pp. 83–112. ISBN: 978-981-13-8265-9. DOI: 10.1007/978-981-13-8265-9_5.

[51] National Geographic. *This is what the future's sustainable cities could look like*. URL: https://www.nationalgeographic.com/magazine/graphics/see-sustainable-future-city-designed-for-people-and-nature. [Accessed: Mar. 25, 2023].

[52] ARLOOPA Augmented Reality / Virtual Reality. *A Virtual Door to Vincent van Gogh's Bedroom in Arles*. URL: https://www.youtube.com/watch?v=JjqlZQxiitc. [Accessed: Mar. 27, 2023].

[53] Wikimedia Commons. *Vertical farm Finland.jpg*. URL: https://commons.wikimedia.org/wiki/File:IFarm.fi_Vertical_farm_Finland.jpg. [Accessed: Mar. 28, 2023].

[54] Wikimedia Commons. *verticalfarming1.png*. URL: https://commons.wikimedia.org/wiki/File:Sgverticalfarming1.png. [Accessed: Mar. 28, 2023].

[55] N. Farm. *Aeroponics Potato Farming - Potato Chip Process Factory - Modern Potato Agriculture Technology*. URL: https://www.youtube.com/watch?v=9ck5iEP03g4. [Accessed: Mar. 28, 2023].

[56] Wikimedia Commons. *Aquaponics with catfish.jpg*. URL: https://commons.wikimedia.org/wiki/File:Aquaponics_with_catfish.jpg. [Accessed: Mar. 28, 2023].

[57] Meta. *Meta Connect 2022: Meta Quest Pro, More Social VR and a Look Into the Future*. Oct. 2022. URL: https://about.fb.com/news/2022/10/meta-quest-pro-social-vr-connect-2022/. [Accessed: Mar. 26, 2023].

[58] Meta. *Meta Quest Pro*. URL: https://www.meta.com/no/en/quest/quest-pro/. [Accessed: Mar. 26, 2023].

[59] Unity Technologies. *Unity Real-Time Development Platform*. URL: https://unity.com/. [Accessed: Mar. 08, 2023].

[60] Microsoft. *Visual Studio: IDE and Code Editor for Software Developers and Teams*. URL: https://visualstudio.microsoft.com/. [Accessed: Mar. 26, 2023].

[61] Blender Foundation. *Blender*. URL: https://www.blender.org/. [Accessed: Mar. 26, 2023].

[62] Unity Technologies. *Manual: Unity User Manual 2021.3 (LTS)*. URL: https://docs.unity3d.com/Manual/index.html. [Accessed: Apr. 08, 2023].

[63] Unity Technologies. *Scripting API: Component*. URL: https://docs.unity3d.com/ScriptReference/Component.html. [Accessed: Apr. 13, 2023].

[64] Unity Technologies. *Unity Asset Store*. URL: https://assetstore.unity.com/. [Accessed: Apr. 13, 2023].

[65] Unity Technologies. *Packages and feature sets*. URL: https://docs.unity3d.com/Manual/PackagesList.html. [Accessed: Apr. 13, 2023].

[66] Oculus Integration SDK. *Meta Quest Developer Center*. URL: https://developer.oculus.com/downloads/package/unity-integration/. [Accessed: Mar. 23, 2023].

[67] Unity Technologies. *Manual: Prefabs*. URL: https://docs.unity3d.com/Manual/Prefabs.html. [Accessed: Apr. 08, 2023].

[68] Oculus. *Oculus Integration - Unity Asset Store*. URL: https://assetstore.unity.com/packages/tools/integration/oculus-integration-82022. [Accessed: Apr. 08, 2023].

[69] Meta. *Add Camera Rig Using OVRCameraRige*. URL: https://developer.oculus.com/documentation/unity/unity-add-camera-rig/. [Accessed: Apr. 13, 2023].

[70] Blender Foundation. *Blender Features*. URL: https://www.blender.org/features/. [Accessed: Apr. 19, 2023].

[71] BlenderKit. *BlenderKit*. URL: https://www.blenderkit.com/. [Accessed: Apr. 19, 2023].

[72] Blender Documentation Team. *BlenderKit - Blender Manual*. URL: https://docs.blender.org/manual/en/2.92/addons/3d_view/blenderkit.html. [Accessed: Apr. 19, 2023].

[73] R. F. Dam and T. Y. Siang. *Personas – A Simple Introduction*. URL: https://www.interaction-design.org/literature/article/personas-why-and-how-you-should-use-them. [Accessed: Apr. 23, 2023].

[74] M. Rehkopf. *User stories with examples and a template*. URL: https://www.atlassian.com/agile/project-management/user-stories. [Accessed: Apr. 23, 2023].

[75] K. Pernice. *User Interviews: How, When, and Why to Conduct Them*. Oct. 2018. URL: https://www.nngroup.com/articles/user-interviews/. [Accessed: Apr. 23, 2023].

[76] J. Robertson and S. Robertson. *Volere Requirements Specification Template Version 16*. First published 1995, 2012.

[77] Meta. *Interaction SDK Overview*. URL: https://developer.oculus.com/documentation/unity/unity-isdk-interaction-sdk-overview/. [Accessed: Apr. 17, 2023].

[78] J.-N. Voigt-Antons, T. Kojic, D. Ali, and S. Möller. "Influence of Hand Tracking as a Way of Interaction in Virtual Reality on User Experience." In: *2020 Twelfth International Conference on Quality of Multimedia Experience (QoMEX)*. 2020, pp. 1–4. DOI: 10.1109/QoMEX48832.2020.9123085.

[79] Meta. *Set Up Hand Tracking*. URL: https://developer.oculus.com/documentation/unity/unity-handtracking/. [Accessed: Apr. 19, 2023].

[80] Meta. *Ray Interactions*. URL: https://developer.oculus.com/documentation/unity/unity-isdk-ray-interaction/. [Accessed: Apr. 17, 2023].

[81] Meta. *Hand Grab Interactions*. URL: https://developer.oculus.com/documentation/unity/unity-isdk-hand-grab-interaction/. [Accessed: Apr. 18, 2023].

[82] Meta. *Poke Interactions*. URL: https://developer.oculus.com/documentation/unity/unity-isdk-poke-interaction/. [Accessed: Apr. 18, 2023].

[83] DMGregory. *How to hide objects behind an invisible plane?* June 2019. URL: https://gamedev.stackexchange.com/questions/172656/how-to-hide-objects-behind-an-invisible-plane. [Accessed: Feb. 01, 2023].

[84] Blender Documentation Team. *Decimate Modifier — Blender Manual*. URL: https://docs.blender.org/manual/en/latest/modeling/modifiers/generate/decimate.html. [Accessed: Apr. 19, 2023].

[85] scifijunk. *Miami 2525*. Dec. 2013. URL: https://www.turbosquid.com/3d-models/free-obj-model-city-scifi-fantasy/788958. [Accessed: Feb. 03, 2023].

[86] Procedural Worlds. *Gaia 2021 - Terrain & Scene Generator*. Apr. 2023. URL: https://assetstore.unity.com/packages/tools/terrain/gaia-2021-terrain-scene-generator-193509. [Accessed: Feb. 17, 2023].

[87] Unity Technologies. *Scripting API: VideoPlayer*. URL: https://docs.unity3d.com/ScriptReference/Video.VideoPlayer.html. [Accessed: Apr. 24, 2023].

[88] Clipchamp. *Quick and easy video editor | Clipchamp*. URL: https://clipchamp.com/en/. [Accessed: Apr. 24, 2023].

[89] Clipchamp. *Text to speech*. URL: https://clipchamp.com/en/features/ai-voice-over-generator/. [Accessed: Apr. 24, 2023].

[90] Adobe. *Adobe Premiere Pro*. URL: https://www.adobe.com/products/premiere.html. [Accessed: Apr. 24, 2023].

[91] Adobe. *Adobe After Effects*. URL: https://www.adobe.com/products/aftereffects.html. [Accessed: Apr. 24, 2023].

[92] Oculus VR. *Mixed Reality with Passthrough*. July 2021. URL: https://developer.oculus.com/blog/mixed-reality-with-passthrough/. [Accessed: Apr. 24, 2023].

[93] Meta. *Meta Quest Pro Tech Specs*. URL: https://www.meta.com/no/en/quest/quest-pro/tech-specs/. [Accessed: Apr. 16, 2023].

[94] Meta. *Passthrough API Overview*. URL: https://developer.oculus.com/documentation/unity/unity-passthrough/. [Accessed: Apr. 16, 2023].

[95] Unity Technologies. *Manual: Render pipelines*. URL: https://docs.unity3d.com/Manual/render-pipelines.html. [Accessed: Apr. 16, 2023].

[96] Unity Technologies. *Universal Render Pipeline overview*. URL: https://docs.unity3d.com/Packages/com.unity.render-pipelines.universal@16.0/manual/index.html. [Accessed: Apr. 16, 2023].

[97] Unity Technologies. *Unity - Manual: Using the Built-in Render Pipeline*. URL: https://docs.unity3d.com/Manual/built-in-render-pipeline.html. [Accessed: Apr. 17, 2023].

[98] E. Bozgeyikli, A. Raij, S. Katkoori, and R. Dubey. "Point & Teleport Locomotion Technique for Virtual Reality." In: *Proceedings of the 2016 Annual Symposium on Computer-Human Interaction in Play*. CHI PLAY '16. Austin, Texas, USA: Association for Computing Machinery, Oct. 2016, pp. 205–216. ISBN: 9781450344562. DOI: 10.1145/2967934.2968105.

[99] F. Buttussi and L. Chittaro. "Locomotion in Place in Virtual Reality: A Comparative Evaluation of Joystick, Teleport, and Leaning." In: *IEEE Transactions on Visualization and Computer Graphics* 27(1) (2021), pp. 125–136. DOI: 10.1109/TVCG.2019.2928304.

[100] D. Heaney. *Meta Interaction SDK Gets Hand Tracking Teleport Gesture With Demo Game*. Feb. 2023. URL: https://www.uploadvr.com/meta-interaction-sdk-hand-tracking-teleport/. [Accessed: Apr. 16, 2023].

[101] Oculus. *First Hand*. Aug. 2022. URL: https://www.oculus.com/experiences/quest/5030224183773255/. [Accessed: Apr. 16, 2023].

[102] Unity Technologies. *Manual: Optimizing draw calls*. URL: https://docs.unity3d.com/Manual/optimizing-draw-calls.html. [Accessed: Apr. 18, 2023].

[103] Meta. *Testing and Performance Analysis*. URL: https://developer.oculus.com/documentation/unity/unity-perf/. [Accessed: Apr. 18, 2023].

[104] Unity Technologies. *About FBX Exporter*. URL: https://docs.unity3d.com/Packages/com.unity.formats.fbx@4.1/manual/index.html. [Accessed: Apr. 18, 2023].

[105] Blender Documentation Team. *Join*. URL: https://docs.blender.org/manual/en/latest/scene_layout/object/editing/join.html. [Accessed: Apr. 18, 2023].

[106] Unity Technologies. *Manual: Occlusion culling*. URL: https://docs.unity3d.com/Manual/OcclusionCulling.html. [Accessed: Apr. 18, 2023].

[107] FN-sambandet. *Bærekraftig utvikling*. URL: https://www.fn.no/tema/fattigdom/baerekraftig-utvikling. [Accessed: Mar. 15, 2023].

[108] College of Agricultural and Environmental Sciences. *Controlled Environment Agriculture*. July 2021. URL: https://caes.ucdavis.edu/research/initiative/controlled-environment-agriculture. [Accessed: Mar. 15, 2023].

[109] S. Solberg. *Hvorfor landbruk med kontrollert miljø (Controlled Environment Agriculture) er fremtiden for landbruket*. Apr. 2022. URL: https://www.danthermgroup.com/nn-no/dantherm/hvorfor-landbruk-med-kontrollert-milj%C3%B8-controlled-environment-agriculture-er-fremtiden-for-landbruket. [Accessed: Mar. 15, 2023].

[110] L. Alter. *Behold the Revolution: LED Bulbs Are Now as Cheap as Incandescents*. Feb. 2021. URL: https://www.treehugger.com/behold-revolution-led-bulbs-are-now-cheap-incandescents-4855845. [Accessed: Mar. 22, 2023].

[111] E. Yılmaz. *How Do Different Colors of Light Affect Plant Growth?* URL: https://www.aydinlatma.org/en/how-do-different-colors-of-light-affect-plant-growth.html. [Accessed: Mar. 22, 2023].

[112] P. Pinho, K. Jokinen, and L. Halonen. "The influence of the LED light spectrum on the growth and nutrient uptake of hydroponically grown lettuce." In: *Lighting Research & Technology* 49(7) (Aug. 2017), pp. 866–881. DOI: 10.1177/1477153516642269.

[113] National Agricultural Library. *Hydroponics*. URL: https://www.nal.usda.gov/farms-and-agricultural-production-systems/hydroponics#:~:text=Hydroponics%20is%20the%20technique%20of,%2C%20hobbyists%2C%20and%20commercial%20enterprises. [Accessed: Mar. 22, 2023].

[114] Bowery. *Vertical Farming: Why Growing Up Can Make a Difference*. Feb. 2023. URL: https://boweryfarming.com/vertical-farming/. [Accessed: Mar. 22, 2023].

[115] Vertical farming. *English meaning - Cambridge Dictionary*. URL: https://dictionary.cambridge.org/dictionary/english/vertical-farming. [Accessed: Mar. 22, 2023].

[116] Aquaponics. *HarperCollins Publishers Ltd*. URL: https://www.collinsdictionary.com/dictionary/english/aquaponics. [Accessed: Mar. 22, 2023].

[117] What is Aquaponics and How Does it Work? *Go Green Aquaponics*. URL: https://gogreenaquaponics.com/blogs/news/what-is-aquaponics-and-how-does-it-work. [Accessed: Mar. 22, 2023].

[118] B. Barth. *How Does Aeroponics Work?* URL: https://modernfarmer.com/2018/07/how-does-aeroponics-work/. [Accessed: Mar. 22, 2023].

[119] Mixkit. *Download Free Hum Sound Effects*. URL: https://mixkit.co/free-sound-effects/hum/. [Accessed: Mar. 22, 2023].

[120] Mixkit. *Download Free Doors Sound Effects*. URL: https://mixkit.co/free-sound-effects/doors/. [Accessed: Mar. 22, 2023].

[121] Mixkit. *Download Free Engine Sound Effects*. URL: https://mixkit.co/free-sound-effects/engine/. [Accessed: Mar. 22, 2023].

[122] Mixkit. *Download Free Engine Sound Effects Page 2*. URL: https://mixkit.co/free-sound-effects/engine/?page=2.. [Accessed: Mar. 22, 2023].

[123] Mixkit. *Download Free Ding Sound Effects*. URL: https://mixkit.co/free-sound-effects/ding/. [Accessed: Mar. 22, 2023].

[124] Mixkit. *Download Free Bubbles Sound Effects*. URL: https://mixkit.co/free-sound-effects/bubbles/. [Accessed: Mar. 22, 2023].

[125] Mixkit. *Download Free Ocean Sound Effects*. URL: https://mixkit.co/free-sound-effects/ocean/. [Accessed: Mar. 22, 2023].

[126] Mixkit. *Download Free Wind Sound Effects*. URL: https://mixkit.co/free-sound-effects/wind/. [Accessed: Mar. 22, 2023].

[127] Mixkit. *Download Free Ambience Sound Effects*. URL: https://mixkit.co/free-sound-effects/ambience/?page=2. [Accessed: Mar. 22, 2023].

[128] Valem. *How to make a door in VR - Unity tutorial*. Aug. 2019. URL: https://www.youtube.com/watch?v=3cJ_uq1m-dg. [Accessed: Apr. 06, 2023].

[129] RealaryVR. *VR Keyboard | Unity Tutorial for Oculus Quest*. Jan. 2022. URL: https://www.youtube.com/watch?v=PyKW9kecyqg. [Accessed: Apr. 06, 2023].

[130] James OOI. *BlenderKit: Download the FREE Wooden Crate Storage Box model*. URL: https://www.blenderkit.com/asset-gallery-detail/da872f30-6d88-4c46-b7d1-e600a052efab/. [Accessed: Feb. 01, 2023].

[131] Z. Balogh. *BlenderKit: Download the FREE Bench model*. URL: https://www.blenderkit.com/asset-gallery-detail/72501fa0-5725-4b18-b994-c0ee798275d9/. [Accessed: Feb. 02, 2023].

[132] RokReef. *Free commuter bike 3D - TurboSquid 1577631*. URL: https://www.turbosquid.com/3d-models/commuter-bike-3d-1577631. [Accessed: Feb. 07, 2023].

[133] D. Tirindelli. *Modern Street Bin #05v2 by Davide Tirindelli - Blender model*. URL: https://www.blenderkit.com/asset-gallery-detail/3e435ed2-255d-4e83-9a9e-06b6d585d51d/. [Accessed: Feb. 07, 2023].

[134] polygoniq. *Concrete column by polygoniq - Blender model*. URL: https://www.blenderkit.com/asset-gallery-detail/c04787fb-3e52-4806-a0f2-de2fe13268ff/. [Accessed: Feb. 07, 2023].

[135] M. Xavier. *Madeka fish by Melvin Xavier - Blender model*. URL: https://www.blenderkit.com/asset-gallery-detail/f7b3a69f-d92f-4d5f-9435-50b49e9f7778/. [Accessed: Feb. 07, 2023].

[136] A. Novgorodtsev. *Forklift Truck by Alexander Novgorodtsev - Blender model*. URL: https://www.blenderkit.com/asset-gallery-detail/e130bcae-b9cd-43d5-a1ba-46a1654a7749/. [Accessed: Feb. 07, 2023].

[137] A. Novgorodtsev. *Greenhouse 3D model by Alexander Novgorodtsev - Blender model*. URL: https://www.blenderkit.com/asset-gallery-detail/f40d3432-36f1-44fb-8ee8-5f38b664980f/. [Accessed: Feb. 07, 2023].

[138] A. Samusenko. *Arched hangar by ALEX SAMUSENKO - Blender model*. URL: https://www.blenderkit.com/asset-gallery-detail/16ce132d-e808-479a-8699-dfb8c09bb0b8/. [Accessed: Feb. 07, 2023].

[139] 3DModelsCC0. *Fluorescent Lamp 3D Model Free Download*. URL: https://www.3dmodelscc0.com/model/fluorescent-lamp. [Accessed: Feb. 08, 2023].

[140] RvveSplit. *2 Ways to Make Water in Unity Game Engine WITHOUT SHADERS*. July 2022. URL: https://www.youtube.com/watch?v=EVYR9VGyDZw. [Accessed: Feb. 08, 2023].

[141] ShareTextures. *Shelf by ShareTextures - Blender model*. URL: https://www.blenderkit.com/asset-gallery-detail/eedcbf8c-b380-45d5-abc9-76a4ae800307/. [Accessed: Feb. 08, 2023].

[142] Venik. *Metal insect steel max free*. URL: https://www.turbosquid.com/3d-models/metal-insect-steel-max-free/204245. [Accessed: Feb. 08, 2023].

[143] L. Call. *Pack arvores e pedras model - TurboSquid 1310160*. URL: https://www.turbosquid.com/3d-models/pack-arvores-e-pedras-model-1310160. [Accessed: Feb. 08, 2023].

[144] ibotpl. *Bridge by ibotpl - Blender model*. URL: https://www.blenderkit.com/asset-gallery-detail/b75e09de-6ba4-4035-9fe4-f20632d4e1b4/. [Accessed: Feb. 08, 2023].

[145] at1012. *3D commercial steel doors model - TurboSquid 1575549*. URL: https://www.turbosquid.com/3d-models/3d-commercial-steel-doors-model-1575549. [Accessed: Feb. 08, 2023].

[146] P. Hee. *Modern Luxury Arch by Pinkpink Hee - Blender model.* URL: https://www.blenderkit.com/asset-gallery-detail/5162e3ee-d503-4f84-9573-14744899b166/. [Accessed: Feb. 09, 2023].

[147] M. Rabiee. *Street Lights Pack.* URL: https://assetstore.unity.com/packages/3d/props/exterior/street-lights-pack-31644. [Accessed: Feb. 09, 2023].

[148] 0Hideout_. *3D door - TurboSquid 1365093.* URL: https://www.turbosquid.com/3d-models/3d-door-1365093. [Accessed: Feb. 09, 2023].

[149] Nobiax / Yughues. *Yughues Free Bushes.* URL: https://assetstore.unity.com/packages/3d/vegetation/plants/yughues-free-bushes-13168. [Accessed: Feb. 09, 2023].

[150] SineVFX. *Translucent Crystals.* URL: https://assetstore.unity.com/packages/3d/environments/fantasy/translucent-crystals-106274. [Accessed: Feb. 09, 2023].

[151] JeffK. *Elevator - Low Poly Animated - Download Free 3D model by JeffK (jeffkolada).* URL: https://sketchfab.com/3d-models/elevator-low-poly-animated-3a9cc99aeb284a4080c033742772 [Accessed: Feb. 09, 2023].

[152] ALP8310. *Grass Flowers Pack Free.* URL: https://assetstore.unity.com/packages/2d/textures-materials/nature/grass-flowers-pack-free-138810. [Accessed: Feb. 09, 2023].

[153] DEXSOFT. *Garden Vegetables 2. Update.* URL: https://assetstore.unity.com/packages/3d/vegetation/plants/garden-vegetables-2-update-2581. [Accessed: Feb. 10, 2023].

[154] ShareTextures. *Potatoes 2 by ShareTextures - Blender model.* URL: https://www.blenderkit.com/asset-gallery-detail/3771222b-f9b6-4e9d-8e30-1434d5f8c43d/. [Accessed: Feb. 10, 2023].

[155] R. K. Dilipkumar. *Conference Table by Ramprasath Kochi Dilipkumar - Blender model.* URL: https://www.blenderkit.com/asset-gallery-detail/4c441b1c-d330-4207-aa06-1eff5e8599f3/. [Accessed: Feb. 10, 2023].

[156] PhixerArt. *Wooden Armchair by PhixerArt - Blender model.* URL: https://www.blenderkit.com/asset-gallery-detail/48005672-06d9-476a-869a-3d01510df930/. [Accessed: Feb. 10, 2023].

[157] D. Demi. *Chair by Dario Demi - Blender model.* URL: https://www.blenderkit.com/asset-gallery-detail/d920d9ea-1f3d-4ab1-b25d-220c8d288ac0/. [Accessed: Feb. 10, 2023].

[158] The Doctor. *Cupboard 900 450 1800 mm by The Doctor - Blender model.* URL: https://www.blenderkit.com/asset-gallery-detail/e289408f-0584-4a2a-8613-af0fa367f2f8/. [Accessed: Feb. 10, 2023].

[159] The Doctor. *Credenza 1200 450 mm by The Doctor - Blender model.* URL: https://www.blenderkit.com/asset-gallery-detail/ddf1e3f9-041b-4f2b-8060-f6d1e565b672/. [Accessed: Feb. 10, 2023].

[160] The Doctor. *Office Desk 1200 * 600mm by The Doctor - Blender model.* URL: https://www.blenderkit.com/asset-gallery-detail/1195c9d1-0609-47dc-bfca-56601ddc2cc6/. [Accessed: Feb. 10, 2023].

[161] M. Fidor. *Dark Narrow Bookshelf by Maciej Fidor - Blender model.* URL: https://www.blenderkit.com/asset-gallery-detail/be6c358c-2655-495c-9b0d-4d84459a5400. [Accessed: Feb. 10, 2023].

[162] BlenderKit Community. *Books by BlenderKit Community - Blender model.* URL: https://www.blenderkit.com/asset-gallery-detail/8fe7a893-a603-4a6d-86cd-70d6c12913e2/. [Accessed: Feb. 11, 2023].

[163] Re Models. *Porcelain Vase by Re Models - Blender model.* URL: https://www.blenderkit.com/asset-gallery-detail/b3ec3bf1-b028-4fd8-a4f8-784a582e2090/. [Accessed: Feb. 11, 2023].

[164] R. Hans. *Carton Box by Rex Hans - Blender model*. URL: https://www.blenderkit.com/asset-gallery-detail/9d203439-bc91-4653-8401-f6a4475c6f42/. [Accessed: Feb. 11, 2023].

[165] R. Hans. *Peaking Birds by Rex Hans - Blender model*. URL: https://www.blenderkit.com/asset-gallery-detail/0f19d754-960f-4d31-8e00-a1481407579a/. [Accessed: Feb. 11, 2023].

[166] Nico. *Wireless Mouse by Nico - Blender model*. URL: https://www.blenderkit.com/asset-gallery-detail/f8436d7d-800c-4bc1-b1cf-28c72f7315ee/. [Accessed: Feb. 11, 2023].

[167] A. Samusenko. *Monitor Samsung U28D590D by ALEX SAMUSENKO - Blender model*. URL: https://www.blenderkit.com/asset-gallery-detail/5130be17-6622-4c08-8e89-03a4d267bc5e/. [Accessed: Feb. 11, 2023].

[168] Blenderkit Community. *A4 paper pile by BlenderKit Community - Blender model*. URL: https://www.blenderkit.com/asset-gallery-detail/41aebdc7-0c53-4197-98eb-5f6d4a80116a/. [Accessed: Feb. 11, 2023].

[169] Blenderkit Community. *Books by BlenderKit Community - Blender model*. URL: https://www.blenderkit.com/asset-gallery-detail/ca64a2fd-5ea5-4359-956a-9d615132b3f8/. [Accessed: Feb. 11, 2023].

[170] ibotpl. *Pencil by ibotpl - Blender model*. URL: https://www.blenderkit.com/asset-gallery-detail/0a5c6d79-cd5f-4dc1-8e80-6532f3923bd2/. [Accessed: Feb. 11, 2023].

[171] J. Maycon. *Vivacious arabesque rug by jhon maycon - Blender model*. URL: https://www.blenderkit.com/asset-gallery-detail/6593f151-3e5f-4dad-bcda-2dc0a6704274/. [Accessed: Feb. 11, 2023].

[172] Blenderkit Community. *White porcelain mug by BlenderKit Community - Blender model*. URL: https://www.blenderkit.com/asset-gallery-detail/feefe419-a50b-48e9-bc83-be1ce579aa4a/. [Accessed: Feb. 12, 2023].

[173] Take Refuge TV. *Noodle Cup by Take Refuge TV - Blender model*. URL: https://www.blenderkit.com/asset-gallery-detail/13a6023b-abd3-466a-b89e-aa8033016ea2/. [Accessed: Feb. 12, 2023].

[174] S. Mahmoudiz. *Cup of Coffee by Soheil Mahmoudi - Blender model*. URL: https://www.blenderkit.com/asset-gallery-detail/5f57a50e-7906-4768-894d-2ee8175062ea/. [Accessed: Feb. 12, 2023].

[175] BlenderKit Community. *Bowl by BlenderKit Community - Blender model*. URL: https://www.blenderkit.com/asset-gallery-detail/6bd92939-0d93-49e8-bbf6-0a8beda6de0e/. [Accessed: Feb. 12, 2023].

[176] L. Hai. *Cocacola can by Le Hai - Blender model*. URL: https://www.blenderkit.com/asset-gallery-detail/f43e93d2-8f01-4a95-bed0-06fd0ee60874/. [Accessed: Feb. 12, 2023].

[177] R. K. Dilipkumar. *Cup & Saucer Set White 2 by Ramprasath Kochi Dilipkumar - Blender model*. URL: https://www.blenderkit.com/asset-gallery-detail/9c6dcf09-35ef-4c30-b230-a9eee73f7165/. [Accessed: Feb. 12, 2023].

[178] L. E. Paludo. *Moka coffee maker by Lucas E. Paludo - Blender model*. URL: https://www.blenderkit.com/asset-gallery-detail/44decb6a-f7fc-4069-8232-88e0baa0ed6a/. [Accessed: Feb. 12, 2023].

[179] Nobody. *Paper Stack by Nobody - Blender model*. URL: https://www.blenderkit.com/asset-gallery-detail/33572ba6-801b-4e4e-8006-54189c45a079/. [Accessed: Feb. 12, 2023].

[180] D. Alytas. *Cupboard var 2.3 by Dovydas Alytas - Blender model*. URL: https://www.blenderkit.com/asset-gallery-detail/2156e59b-3ce4-46b7-861e-b90f1e4b6be4/. [Accessed: Feb. 12, 2023].

[181] D. Alytas. *Cupboard var 2.2 by Dovydas Alytas - Blender model.* URL: https://www.blenderkit.com/asset-gallery-detail/954b18d5-fab8-4ab2-887a-0cff1c1975a4/. [Accessed: Feb. 12, 2023].

[182] D. Alytas. *Cupboard var 2.6 by Dovydas Alytas - Blender model.* URL: https://www.blenderkit.com/asset-gallery-detail/a003f965-b4f4-47ba-a23f-f4f6ff45e127/. [Accessed: Feb. 12, 2023].

[183] A. Machin. *Microwave by Andy Machin - Blender model.* URL: https://www.blenderkit.com/asset-gallery-detail/47f8452d-fe20-45c0-8a85-85b6849c6cd5/. [Accessed: Feb. 12, 2023].

[184] A. Wiese. *Fridge by Adam Wiese - Blender model.* URL: https://www.blenderkit.com/asset-gallery-detail/d2d659c7-d916-451e-9247-79445f9f225b/. [Accessed: Feb. 12, 2023].

[185] R. Hans. *Trash Bin by Rex Hans - Blender model.* URL: https://www.blenderkit.com/asset-gallery-detail/082bdb7d-2ab9-42b6-a196-0c38a3403b25/. [Accessed: Feb. 12, 2023].

[186] R. Hans. *Whiteboard by Rex Hans - Blender model.* URL: https://www.blenderkit.com/asset-gallery-detail/a1996f29-d7fe-44a6-8949-3d34ca15a089/. [Accessed: Feb. 12, 2023].

[187] FriskyTater. *Sticky Notes by FriskyTater - Blender model.* URL: https://www.blenderkit.com/asset-gallery-detail/c8b24498-de7d-4bfe-ae5e-93ed1a0d4636/. [Accessed: Feb. 12, 2023].

[188] P. Jerzak. *Alcohol marker box by Patryk Jerzak - Blender model.* URL: https://www.blenderkit.com/asset-gallery-detail/8bb80a36-d604-4cd2-b8b9-48ba1168d1f8/. [Accessed: Feb. 12, 2023].

[189] Nico. *Cat Figurine by Nico - Blender model.* URL: https://www.blenderkit.com/asset-gallery-detail/b349c584-2667-46ff-94e2-3b598d7a362f/. [Accessed: Feb. 12, 2023].

[190] J. Cooper. *LG Dryer by Josh Cooper - Blender model.* URL: https://www.blenderkit.com/asset-gallery-detail/8ec6d215-3906-47b5-92b2-baaf096d5c42/. [Accessed: Feb. 14, 2023].

[191] ArtAmin. *Plastic Landry Basket by ArtAmin - Blender model.* URL: https://www.blenderkit.com/asset-gallery-detail/40552801-1b12-4f60-832a-765d79c32aea/. [Accessed: Feb. 14, 2023].

[192] J. Maycon. *Corner table-01 by jhon maycon - Blender model.* URL: https://www.blenderkit.com/asset-gallery-detail/d7d1d47f-9ee8-411c-b84f-18fd111c9e4b/. [Accessed: Feb. 14, 2023].

[193] A. R. Siddhu. *Dish Washer Sink by Abdul Rouf Siddhu - Blender model.* URL: https://www.blenderkit.com/asset-gallery-detail/fad44c9e-d98f-472e-b553-e227a198368c/. [Accessed: Feb. 14, 2023].

[194] R. Hans. *Folded Towel by Rex Hans - Blender model.* URL: https://www.blenderkit.com/asset-gallery-detail/755a9a16-d738-44ab-9ab6-07d35db05e47/. [Accessed: Feb. 14, 2023].

[195] Nobody. *Paper Towel Stand by Nobody - Blender model.* URL: https://www.blenderkit.com/asset-gallery-detail/9a346431-c2eb-46fa-acb6-0941ab7a99a6/. [Accessed: Feb. 14, 2023].

[196] S. Fuchs. *Towel Crumpled by Silas Fuchs - Blender model.* URL: https://www.blenderkit.com/asset-gallery-detail/a71b4afd-25d4-49d8-8aa0-9eb6d8f45034/. [Accessed: Feb. 14, 2023].

[197] P. Wałasiewicz. *Skateboard Shoes by Paweł Wałasiewicz - Blender model.* URL: https://www.blenderkit.com/asset-gallery-detail/bf8054d6-8c8f-41b0-9c51-ee553fc82c1e/. [Accessed: Feb. 14, 2023].

[198] P. Hee. *School Locker by Pinkpink Hee - Blender model*. URL: https://www.blenderkit.com/asset-gallery-detail/332998e7-1b8e-474e-8076-cc50b6c43d7b/. [Accessed: Feb. 14, 2023].

[199] H. Zhang. *ShuFan Chair by Helena Zhang - Blender model*. URL: https://www.blenderkit.com/asset-gallery-detail/846eb219-9fa6-4773-9947-1ecaa5c4ccdf/. [Accessed: Feb. 14, 2023].

[200] H. Zhang. *Shufan Bench by Helena Zhang - Blender model*. URL: https://www.blenderkit.com/asset-gallery-detail/e590cb1d-754e-462e-b121-e9edda9c5387/. [Accessed: Feb. 14, 2023].

[201] M. Mons. *Free 3D Free Classic Mini Temple model - TurboSquid 1888572*. URL: https://www.turbosquid.com/3d-models/3d-free-classic-mini-temple-model-1888572#. [Accessed: Feb. 14, 2023].

[202] edikm1. *3d branch rotten wood model*. URL: https://www.turbosquid.com/3d-models/3d-branch-rotten-wood-model/936976#. [Accessed: Feb. 14, 2023].

[203] leonelrajoy. *Plastic water tanks model - TurboSquid 1792657*. URL: https://www.turbosquid.com/3d-models/plastic-water-tanks-model-1792657. [Accessed: Feb. 14, 2023].

[204] Dreamsoft Innovations. *Herbs and Plants*. URL: https://assetstore.unity.com/packages/3d/vegetation/herbs-and-plants-226970. [Accessed: Feb. 07, 2023].

[205] A dog's life software. *Outdoor Ground Textures*. URL: https://assetstore.unity.com/packages/2d/textures-materials/floors/outdoor-ground-textures-12555. [Accessed: Feb. 15, 2023].

[206] S. Seeliger. *Hexagonal Concrete Paving Texture • Poly Haven*. URL: https://polyhaven.com/a/hexagonal_concrete_paving. [Accessed: Feb. 15, 2023].

[207] AmbientCG. *Metal 046 A on ambientCG*. URL: https://ambientcg.com/view?id=Metal046A. [Accessed: Feb. 15, 2023].

[208] AmbientCG. *Plastic 010 on ambientCG*. URL: https://ambientcg.com/view?id=Plastic010. [Accessed: Feb. 15, 2023].

[209] D. Barresi. *Gravel Concrete Texture • Poly Haven*. URL: https://polyhaven.com/a/gravel_concrete. [Accessed: Feb. 16, 2023].

[210] AmbientCG. *Painted Plaster 017 on ambientCG*. URL: https://ambientcg.com/view?id=PaintedPlaster017. [Accessed: Feb. 16, 2023].

[211] D. Barresi. *Clean Pebbles Texture • Poly Haven*. URL: https://polyhaven.com/a/clean_pebbles. [Accessed: Feb. 16, 2023].

[212] C. Baglioni and D. Barresi. *Wooden Planks Texture • Poly Haven*. URL: https://polyhaven.com/a/wooden_planks. [Accessed: Feb. 16, 2023].

[213] AmbientCG. *Wood 018 on ambientCG*. URL: https://ambientcg.com/view?id=Wood018. [Accessed: Feb. 16, 2023].

[214] AmbientCG. *Concrete 016 on ambientCG*. URL: https://ambientcg.com/view?id=Concrete016. [Accessed: Feb. 16, 2023].

Appendix A

Interview guide for user tests in usability lab

Intervjuguide for brukertesting av MR og VR opplevelse

Før brukertesting - 10 min

Ønske velkommen, og samtykkeskjema
Brukertesten starter med å ønske deltakeren velkommen og å gi dem samtykkeskjema for å signere. For å sikre personopplysningene, slik at ingen uvedkommende får tilgang, vil personopplysninger bli anonymisert. Deltakere vil bli erstattet med tall (eks. deltaker 1, deltaker 2, … osv.). Deltakerne vil ikke kunne bli gjenkjent.

Før-test intervju
1. Har du vært med på noe slags forskningsundersøkelse før, eller er dette første gang?
2. Har du prøvd VR før? Hvordan var det?
3. Når du skal lære noe, går du mer i dybden på det du skal lære om eller holder det å gjøre det enkelt? Hva gjør vanligvis at du ønsker å lære dypt eller overflatisk om noe? Kan du gi noen eksempler?

Introduksjon på hvordan VR-en fungerer
Lære deltakeren håndbevegelsene som trengs for å orientere seg i VR miljøet.

Brukertesting - 30 minutter

Deltakeren utfører oppgaver inne i MR og VR opplevelsen mens det observeres i samtid på hva deltakerne gjør via VR strømming til skjerm. Det skal ikke tas opptak.

Deltakerne skal bruke 'think aloud teknikken', altså si hva de gjør og tenker høyt - hvis det glemmes skal observatørene minne deltakerne på dette.

Videre, så skal observatørene ta notater på papir underveis, fordi det kan være aktuelt å skrive ned hva deltakeren sier og gjør.

Brukeroppgaver

- Utforsk omgivelsene for å finne broen og gå over den
- Utforsk byen for å finne inngangen til hangaren
- Utforsk første og andre etasjen av hangaren og lær om de forskjellige konseptene innenfor dyrking som finnes der
- Finn kontoret i første etasje og svar på sluttquiz for å fullføre

Etter brukertesting - spørreskjema på SurveyXact, intervju og avslutning

Spørreskjema på SurveyXact (10 min)

Et spørreskjema med følgende spørsmål vil bli besvart ut fra en **likert scale** på SurveyXact.

1. **Alder?**
   Angi egen alder

2. **Er du student?**
   Ja/nei

3. **Kjønn?**
   Kvinne/mann/annet

4. **Velg hva som passer deg**
   Jeg hadde ingen kunnskaper om temaene fra før
   Jeg hadde noe kunnskaper om temaene fra før
   Jeg hadde middels med kunnskaper om temaene fra før
   Jeg hadde mye kunnskaper om temaene fra før
   Jeg hadde veldig mye kunnskaper om temaene fra før

5. **Jeg følte at jeg lærte om temaene;**
   Bærekraft
   Bærekraftig Framtidig By
   Vertikalt Landbruk
   Hydroponiske systemer
   CEA
   LED lys i CEA
   Aeroponiske systemer
   Akvaponiske systemer

Motivasjon

6. Hvor interessante var temaene for deg?
   Før selve testen
   Under selve testen
7. Jeg fikk lyst til å lære mer om temaene etter denne VR opplevelsen
8. Jeg syns temaene var kjedelige fordi jeg lærte for lite om de
9. Gjorde det å være aktiv i den virtuelle opplevelsen at du hadde lyst til å fullføre de tildelte oppgavene?
10. Å lære på denne måten hjalp meg å reflektere rundt temaene
11. Det å utforske temaet på denne visuelle måten gjorde at jeg fikk lyst til å fullføre de tildelte oppgavene
12. Hvis jeg hadde fått muligheten ville jeg hatt lyst til å gå gjennom igjen for å prestere bedre på sluttquizen
13. Jeg likte å lære ved å gjøre praktiske aktiviteter

Generell Innlevelse

14. I hvilken grad blir du involvert i filmer/tv serier, bøker eller videospill slik at du ikke er klar over hva som skjer rundt deg;
    Filmer/tv serier
    Bøker
    Videospill
15. Jeg er flink til å blokkere eksterne distraksjoner når jeg må gjøre ferdig en oppgave eller aktivitet
16. Er du flink til å konsentrere deg når du gjør en oppgave eller aktivitet du liker?
17. Jeg blir noen ganger så involvert i å gjøre noe at jeg mister all oversikt over tid

Tilstedeværelse

18. Kunne du kontrollere hendelser i den virtuelle verden?
19. Omgivelsene var responsive for handlingene jeg utførte
20. Kunne du forutse hva som ville skje etter handlinger du utførte?
21. Interaksjonene med omgivelsene føltes naturlig
22. Det visuelle aspektet gjorde at jeg følte meg involvert/tilstede/levde meg inn
23. Lyden gjorde at jeg følte meg involvert/tilstede/levde meg inn
24. Føltes det naturlig å bevege deg gjennom omgivelsene?
25. Merket du at du så på en skjerm?
26. Å kunne bruke hendene bidro til å føle meg mer involvert/tilstede/levde meg inn
27. Det at jeg kunne kartlegge omgivelsene mine og se meg rundt bidro til at jeg følte meg involvert/tilstede/levde meg inn
28. Kunne du undersøke objekter i den virtuelle verden?
29. Kunne du undersøke objekter fra forskjellige vinkler i den virtuelle verden?
30. Kunne du flytte eller manipulere objekter i den virtuelle verden?
31. Jeg tilpasset meg raskt i de virtuelle omgivelsene
32. På slutten følte jeg at jeg hadde kontroll på hvordan man skulle bevege seg og interagere i den virtuelle opplevelsen
33. Dårlig kvalitet på det visuelle forstyrret eller distraherte meg fra å utføre de tildelte oppgavene
34. Det å bruke hendene mine som kontrollenheter forstyrret eller distraherte meg fra å utføre de tildelte oppgavene
35. Følte du deg involvert i oppgavene til den grad at du mistet oversikt over tid?
36. Når det gjelder opplevelsen så ble jeg kvalm, svimmel eller desorientert;
    - på starten
    - under
    - på slutten
37. Hvor likt tror du temaet og konseptene som ble vist i denne VR opplevelsen samsvarer med virkeligheten?

Intervju og avslutning (10 min)

Et intervju holdes etter deltakeren har utført oppgavene i opplevelsen, hvor det spørres om deres opplevelse etter å ha testet den. Deretter avsluttes testen.

1. Hvordan var denne opplevelsen for deg? Utdyp?
2. Hvordan var det å kunne utforske omgivelsene i en virtuell verden?
3. Hvordan opplevde du formidlingen av tema?
4. Hvordan var dybden på det du lærte om?
5. Hvordan var det å lære om temaene i en slik virtuell opplevelse, i motsetning til hvis du skulle lært om det ved å lese i en bok, på nett, eller se en video?
6. Tror du at å lære på denne måten kommer til å hjelpe deg å huske temaene lengre i ettertid? Hvorfor?
7. Tror du VR opplevelser generelt kan gjøre det mer interessant å lære?
8. Hvordan følte du det var å bevege deg rundt ved å teleportere?
9. Hvordan føltes det å kunne se det digitale lagt over det virkelige?
10. Hvordan føltes det å gå gjennom døra mot broen? Merket du noen forskjell? Utdyp?
11. Hvordan føltes det da du gikk fra broen til byen? Merket du noen forskjell? Utdyp?
12. Hvordan føltes det da du satt på gaffeltrucken?Merket du noen forskjell? Utdyp?
13. Hva ville du ønsket å fått ut mer av denne VR opplevelsen? For eksempel har du noen forslag til endring? Er det noe som stakk ut for deg som du likte eller ikke likte?
14. Har du noe annet som du føler burde bli nevnt?

Appendix B

Thematic analysis iteration one

User testing for iteration one were held between 17.03.2023 and 22.03.2023.

List of themes and subthemes used for the thematic analysis:

Presence
- Presence in subjective
- Connections between immersive tendencies and presence
- Beginner friendly
- Control
- showing / visualization
- Attention)
- Presence in VR
- Presence in MR
- Presence in combination of MR and VR
- Break in presence

Motivation
- Interesting
- Fun
- Active
- Surprising
- (Guided) exploration path
- Want to perform because of end quiz

INTERVJUGUIDE: NOTATER - INTERVJUER OG OBSERVASJON AV BRUKERTESTING

FØR-TEST INTERVJU

1. Har du vært med på noe slags forskningsundersøkelse før, eller er dette første gang?

Participant no.	Notes/Codes	Translation to english & coding	Participate background / extra data
1	Første gang	First time	
2	Første gang	First time	
3	Ikke ordentlig → bare digital spørreundersøkelse	Only a digital survey	
4	Har vært	Have been before	

5	Ha vært før → en annen masteroppg.	Have been before	

Findings/summary
- 2 out of 5 participants have not been in a research study before

Interpretation
- How can this affect the findings/results of a study? Find sources for 'first time participants' and 'participants that have done a study before?'

2. Har du prøvd VR før? Hvordan var det?

Participant no.	Notes	Translation to english & coding	Participate background / extra data
1	Ja har prøvd, som underholdning • Var fasinerende • Var spennende • Reelt følelse	Yes the participant has used VR as entertainment before. They said VR was fascinating, exciting, and gave a real feeling	
2	Du to gang, veldig kort, spilte lightsaber, oljeplatform	Participant has tried it two times, but only very briefly.	
3	Aldri	Never	
4	Ja, noen få ganger. Var gøy	They have tried VR a few times and thought VR was fun.	
5	Ja → har egen → blir ikke motionsick → men blir litt sliten etterhvert	They have their own VR device. They do not get motion sick while using it, but they feel tired after a while.	

3. Når du skal lære noe, går du mer i dybden på det du skal lære om eller holder det å gjøre det enkelt? Hva gjør vanligvis at du ønsker å lære dypt eller overflatisk om noe? Kan du gi noen eksempler?

Participant no.	Notes	Translation to english & coding	Participate background / extra data
1	• Liker detaljer, liker å gå i dybde • Fysiske og aktiv type • "Hvis jeg skal lære noe, jobbsammenheng → fisker → forskjellig vær → fleksibel tenker • Interessert i teknologi	The participant enjoys details and going in-depth, for example when they are to learn something work-related. They are a physical and an active person, with an interest in technology.	
2	• Dybde person → hvis kunne → i senere tid	They are a depth person.	
3	• Kommer ann på tid • Hvis dårlig tid → så overfladisk • Hvis mer tid → liker å spørre andre om det	For them it depends on time. If they have little time, they learn more superficially. If they have a lot of time, they like to go more in-depth, as well as ask others about it.	
4	• Avhengig hva jeg skal lære	It depends on what they are to learn.	

	• Først oversikt deretter i dybden	Firstly they go over the topic superficially, then they go in-depth.	
5	• Spørs i hvilken grad • Hvis nysgjerrig, ser på overflaten først f.eks. Youtube videoer	For them it depends on to what degree they are curious. If so, they will first look at surface level material such as Youtube videos.	

BRUKERTESTING OG BRUKEROPPGAVER

- Utforsk omgivelsene for å finne broen og gå over den

Participant no.	Notes	Finalized code	Themes & Subthemes
1	• Prøvde å gå først → critical error → kom til broen på en anna måte enn tenkt → trykte veldig for på kulene → fikk samtidig hørt det som var i den blåe kulen, mens røde kulen ble trykt og døra åpnet seg → stod allerde i døra/broa	The participant started by walking through an invisible wall in an unintended way.This was an error. Also, they were quick when selecting spheres. While they were listening to the blue sphere on sustainability, they selected the red	Presence: Beginner friendly Presence: Break in presence

		sphere to open the door while they were already standing at the bridge, creating another error.	
2	- Ser broa på mini-broen → prøver å trykke på alt og broa på → mini-modellen → trykte fort på blå kula, så på og trykte på røde kula → ville Zoome inn tekst → leste på plakaten → lurte på hva "Zukunft betydde" - Syns overgangen fra MR til brua g broa til byen "veldig kult" → ble overrasket	The participant started by inspecting the miniature model of the city and tried selecting all over its surface, including the small bridge model. They then quickly selected the blue sustainability sphere, followed by the red sphere. When reading the text in the blue sustainability sphere, they wanted to zoom in by making hand gestures, which does not work. Soon after, they noticed the introduction poster and wondered what "Zukunft" meant. When going through the door from mixed reality to virtual reality, they were surprised and thought it was very cool.	Presence: Beginner friendly Presence: Beginner friendly Motivation:Interesting
3	• Prøver forsiktig å teleportere • Ser mini-broen → prøver å trykke på den → trykte på blå kule → står stille og hører på → trykte på "les mer" → litt forvirrett å	The participant started by carefully experimenting with the teleportation mechanic. When looking for a	

	både kunne lese og høre det → ler mye → virker mye overrasket → Veldig overrasket å se plakaten "Hadde ikke lagt merke til dette" → Ville gjerne kunne flyttet mini-modellen → trengte hjelp med rød kule → overrasket at kunne gå over	bridge to cross, they found the mini bridge on the table model and tried to select it. After, they selected the blue sustainability sphere and stood still while listening to it. Once finished, they selected to read the full text, and seemed confused by being able to both read and listen to the text. During this time, the participant was laughing a lot and seemed to be surprised by the experience. They were very surprised by the introduction poster and had not noticed it before. They wanted to be able to move the miniature model. They needed help when selecting the red sphere, and were surprised that they could go over the bridge.	Motivation: Fun Presence: Beginner friendly Presence: Control Motivation: Surprising
4	• Står først helt stille og prøver å trykke på mini-modellen - lurer på om modellen kan vries → vrir modellen fordi vil ha overblikk → den roterer rundt	The participant started by standing still and selecting the surface of the miniature model, which did nothing.	

	• Tester ut ting på en rolig måte • "Var kult å stå midt i den" (modellen) → syns byen → trykte på rød kule først → såg seg rundt fant plakaten og brua deretter → trykte deretter på blå kulen → trykte på rød igjen → såg seg tilbake en tur	They found that they could rotate the model and used it to get an overview of the city. They were testing in a calm manner. At one point, they stood inside the miniature model and thought it was cool to stand there. First they selected the red sphere and were unsure what it did. They only noticed the introduction poster when looking around for what the red sphere did. Shortly after they found it raised the door. After, they selected the blue sphere and listened to it, before selecting the red sphere again and went over the bridge. They looked back at the mixed reality environment, before crossing the bridge.	Presence: Control Presence: Beginner friendly Presence: Presence in combination of MR and VR
5	• Leser på plakaten. Finner ut med samme om teleportering • Veldig kjapt tester minimodellen • Finner blå kule med det samme og → tar seg ikke tid til å høre	The participant started by reading the introduction poster. Shortfy after they figured out how the telportation worked.	Presence: Beginner friendly

	på • Liker veldig godt å snu på minimodellen og prøver å trykke på broen på modellen • Går litt frem og tilbake • Stiller spm. Om "Forstår ikke hvor broen er" så får hjelp/tips • Finner broen og ser seg tilbake	They were quick to start testing what they could do with the miniature model. Immediately after, they found the blue sustainability sphere and selects it, but they do not take the time to listen to it. Instead, they enjoyed turning the miniature model. They tried multiple times to select the bridge on the miniature model. They spent some time pacing back and forth, before asking for help and that they did not understand where the bridge was. With some help, they managed to find it, and looked back at the door before crossing the bridge.	Presence: Beginner friendly

- Utforsk byen for å finne inngangen til hangaren

Participant no.	Notes	Finalized code	Themes & Subthemes
1	• Trengte tips for å gå til bysentrum	The participant needed help to get to	

	• Syns det var tøft • Spør hvor inngangen er • Syns det var kult å åpne døra	the city center. When they got there, they thought it was cool. They also asked where to find the hangar entrance, and thought it was cool when they opened the door.	
2	- Ble veldig flink til å teleportere - Fant hangaren, men dro en tur til byområdet - Hadde vansker med å komme seg inn i hangaren	The participant had become very good at teleporting when entering the city. They were quick to find the hangar, but wanted to explore the city area. They had difficulties with entering the hangar door.	Presence: Beginner Friendly Motivation: (Guided) exploration path Presence: Break in presence
3	→ Sier "jeg vil bare se litt rundt først" → fokuser på sykkelne → ser hangaren men sier vil utforske mer → "byen er veldig futuristisk" → fokusere på statuen → sier mye "wow" → gikk rundt i sentrum → virker å bli mer og mer flink på teleportering → Liker ser opp ih immelen → Finner lett tilbiake til hangaren → prøver først lille døra	The participant wanted to explore a bit more of the city before going to the hangar. They thought the city was very futuristic, and say "wow" out loud many times. As they go through the city center, they seem to become more and more proficient at teleporting. They enjoy looking up towards the sky, at the tall buildings.	Motivation: (Guided) exploration path Motivation: Interesting Presence: Beginner friendly Motivation: Interesting

		They easily found their way back to the hangar, first tried to enter the small door on the side, before trying the large ones.	
4	• Overrasket over å havne i byen • Ser hangaren med det samme → men spør å utforske mer → går først til høyre "der var det sperret" → deretter til bydelen → "planmessig liker jeg byen" → syns det er gøy å gå rundt → drar automatisk til hangaren etter bysentrum → overrasket	They were surprised to arrive in the city They immediately spotted the hangar, but wanted to explore more before going there. Firstly they tried to go right, but found it was blocked. Instead, they went to the city center. They liked the layout of the city, and thought it was fun to walk around. After having been in the center, they automatically went back to the hangar and were surprised when they could open the doors.	Motivation: surprising Motivation: (Guided) exploration path Motivation: Fun
5	• Ser hangaren med det samme prøver å åpne "fake døra" deretter går og utforsker bysentrum → "litt rart å bevege seg" → men funker • Virker ikke overraskene om miljøet • Kommer seg inn på hangaren lett	The participant immediately spotted the hangar and tried to open the small door, but when it failed to open, they instead explored the city center. They thought it was a bit weird to move, but that it worked.	

		When going through, they did not seem to be surprised by the environment. They then easily got into the hangar.	

- Utforsk første og andre etasjen av hangaren og lær om de forskjellige konseptene innenfor dyrking som finnes der

Participant no.	Notes	Finalized code	Themes & Subthemes
1	● Trykte først på LED-lys kulen → Stod rolig og hørte på beskrivelsen av den, syns var interessant → har hørt litt om det før ● Trykte på CEA kulen → stod stille og hørte på ● Prøver å selektere	The participant selected the LED-lights sphere at first. They stood calmly and listened to it, and found it to be interesting. They had heard about this topic before	Motivation: Interesting

	kontordøra med pekeren → går inn → legger merke til quizen, sier "Tror ikke jeg kan nok til å ta den enda" → går ned til etasje 2 i heis → error → kommer ut av heisen en tur → ser skoene først → åpner døra med knapp → syns det er artig å bli desinfisert, → legger merke til "Vertikal Landbruk", finner, stiller spm. Hva aeroponisk systemer er for noe →	They then selected the CEA sphere, and again stood still and listened to it. They found the office door and tried to select it with the ray selector. When that did not work, they instead opened it by grabbing the handle and went inside. There they spotted the quiz and thought they were not ready for it yet, so instead they went to the elevator. They inspected the disinfection room when they got off the elevator, and thought it was funny to be disinfected. When in the underground area, they noticed the vertical farming sign. They also asked questions when about what aeroponics were.	Motivation: Want to perform because of end quiz Motivation: Fun Motivation: Interesting
2	- Fant CEA kula og trykte på den med det samme → syns stemmen leser for sakte. - Trykte på led lys kula, så trykte på ledlys for å forandre på farger → prøvde å plukke en salat → gikk til heis og inn → gikk bra å trykke → men kom seg en tur av heisen	When entered the hangar, the participant started by selecting the CEA sphere immediately. They thought its voice was speaking too slow. After, they selected the LED light sphere and pressed the	Motivation: Active

	→ dro til vaskemaskinen og spurte om hun skulle skifte klær → bruker hodet aktivt for å se seg rundt → spør om vertikal farming → liker veldig godt aeroponics "vil ha dette hjemme" sa hun vil i tillegg ha fisk der → drar inni andre heisen → overser gaffeltrucken → vanskelig med heis 2 → blir glad når hun ser det er fisk i aquaponics området → prøvde fake døra i aquaponics-området	button nearby to change LED colors. They tried to pick up a salad. They went into the elevator and had no issues pressing the button to go down, apart from briefly going through the elevators walls. When in the disinfection area, they went straight for the washing machine and asked if they should change clothes. While going through, the participant was actively turning their head to look around. They asked about vertical farming when passing it in the underground area. They really liked aeroponics, and wanted to have such a system at home. Additionally, they wanted there to be fish in the water. When going to the second elevator, they miss the forklift. They had some difficulties navigating into the second elevator.	Motivation: Active Motivation: Interesting Motivation: Interesting

		When arriving at the aquaponics area, they were happy to see fishes. Before leaving, they tried to open the fake door that is there.	Motivation: Fun
3	● Går først mot led lys kulen og hører spent på hva som sies. Sier "kult" og "dette visste jeg ikke" "syns dette var veldig interessant" ● Går til CEA-kulen og hører spent på, blir stille og konsentrert for å høre på teksten → går nærmere og sier "okay denne vil jeg lese nærmere" → skroller teksten → trykker krysset → prøver åk omme i kontoret → positivt overrasket over at rommet er veldig stort Kommer seg inn ih eis → sier "vaskerommet", error → kom inn gjennom veggen via kleskapet → alt er så svært → "Ser ut at det kan produseres vledig mye mat" → syns det var veldig kult med potetene → Syns temaene er veldig relevant → kjører gaffeltrucken "kult" → går inni heis to → reflekterer over aquaponics → "så det er fiskene som lager gjødsel til plantene", dette var "favoritten"	The participant first went to the LED light sphere and eagerly listened to what was said. They thought it was cool and very interesting. They had not heard of it before. After, they went to the CEA sphere and eagerly listened to that as well. They became quiet and concentrated on hearing what was said. At this sphere they said they wanted to read it closer, and opened the full-text. They had no issues scrolling the text, and closed it after. After, they went to find the office. It was surprising how big the room was. They then take the elevator down with no issues. Once down, they explored what was thought to be a laundry room. An error occurred when	Motivation: Interesting Motivation: Interesting Motivation: Surprising Presence: Beginner friendly

		they were to enter the disinfection room, as they went through the wall by the lockers to get in. They thought the underground area was large and figured a lot of food could be produced there. They thought aeroponics was cool, and said they thought the themes were relevant. They also thought it was cool to ride the forklift. They took the second elevator up with no issues, and stood there reflecting over aquaponics. By looking at the fish tank, they figured that the fish help give nourishment to the plants. They proclaimed aquaponics were their favorite system.	Presence: Break in presence Presence: showing / visualization Motivation: Interesting Presence: Beginner friendly Presence: showing / visualization
4	• Gikk til CEA kulen → ville ikke høre på "heller kjapt lese selv" • Veldig rolig står mye stille og bruker teleportering aktivt • "Var veldig høy hangar" • Går rundt hele området, deretter ser ledlys-kulen og leser	The participant first went for the CEA sphere, and wanted to quickly read it themselves rather than listen to it. They were calm, stood still and actively used	

	uten tekst → ser ledlys knappen → finner ut hvordan trykker selv uten hjelp → ble overrasket å få annet lys → slår gul → "nå blir jeg mer nygjerrig hva annet man kan trykke" → finner kontoret → prøver å ta kaffe, prøver å åpne kjøleskapet → "der var det quiz" → trok heisen → trykker først øvre deretter nederste "handler om bedriften tenker jeg → må være rent" → ser trukken → "den kan kjøres → men vil først finne ut mer området → finner elevatoren → går opp andre heis → går ned igjen" fordi ville finne ut om det var noe mer" → virket skuffet over at det ikke var en kule med beskrivelse Error → gikk ut	teleportation. They thought the hangar was very tall. They explored the whole area before spotting and selecting the LED light sphere and read it without the voice. After, they noticed the LED button and figured they could press to change colors. It was surprising to change the light's color. They got curious what else they could press. When in the office, they tried to grab a coffee, open the fridge, and interact with the objects there. They noticed the quiz before leaving. They went into the elevator, first selecting button to go up, before correcting it and going down. They deduce from the disinfection area that the company wants to keep it clean. They spotted the forklift, but wanted to explore more of the area before riding it.	Presence: Control Motivation: Active Motivation: Surprising Presence: showing / visualization Motivation: (Guided) exploration path

		They found the second elevator and took it up with no issues, before taking it down again to check if they had missed anything. They seemed to be disappointed that there were no more spheres with descriptions. Before leaving, there was an error where they briefly went through the walls of the elevator.	Motivation: (Guided) exploration path
5	• Trykker på CEA og hører på nøye → flirer av CEA og stemmen → venter ikke på å høre, trykker seg til å lese selv • Trykker på ledlyskula → hører på ved å samtidig utforske området → tester lyset → trykker uten hjelp → "Spennende" og lurer på om det var en test → lese på teskten igjen • Bruker lett heisen → overrasket at det var et vaskerom → går aktivt og utforsker området → kommer seg kjapt gjennom til underground delne → litt overrasket over aeroponiks "wow ikke noe jord i bakken" → Flira og blir litt skuffet over at det ikke kan styres selv → fant heis 2 → gikk veldig bra uten noe problem → da det stilles spm. Om hva de ser → → aquaponics → vet med edt samme hva det er	The participant first selected the CEA sphere and listened intently. They laughed at the voice over and did not wait for it to finish, instead selecting to read it themselves. After, they selected the LED light sphere and listened to it simultaneously as they were exploring the area. They found the button to change color of the LED light, and figured out they could press it without any help. They thought it was exciting to change colors, and wondered if it was a test. They then read the text again.	Presence: Control Motivation: (Guided) exploration path Presence: Beginner friendly Motivation: Fun

	→ er direkte på vei tilbake til etasje 1 uten at noe blir sagt	They had no issues taking the elevator down, and were surprised to find themselves in a laundry room. They actively explored the area, and quickly got through disinfection to the underground area. They were surprised by aeroponics and mentioned how there was no soil involved. When riding the forklift, they laughed. They were also a little disappointed hat they could not steer it themselves. After, they found the second elevator and took it up without issue. They asked questions about what they were seeing in the aquaponics area, but figured out what it was when they inspected it. They then started going back to the first floor without being told to do so.	Presence: Beginner friendly Motivation: Surprising Presence: showing / visualization Presence: Beginner friendly

- Finn kontoret i første etasje og svar på sluttquiz for å fullføre

Participant no.	Notes	Finalized code	Themes & Subthemes
1	Kjører bilen, spør om arkitekturen "hva er vinduene" → tok heis 2 → visste om def. Til akvaponic → lurte på hva slags fisker dette var "er det ferskvannssild?" → finner greit tilbake til første etasje til kontoret → critical error: desfinfiseringsdøra åpner seg ikke, må teleportere gjennom → Går rett til quizen; stiller spm. Om bærekraft → glemte å trykke på kula om bærekraft,	They rode the forklift without issues. They were curious about the architecture of the underground area. They took the second elevator without issues. The definition of aquaponics was	Presence: Beginner friendly Motivation: Interesting

	men greide å ta riktig svar likevel → alt riktig → fikk ikke trykket på røde boble → prøvde nå → åpnet døra	already familiar to them, and they wondered if the tank contained freshwater herring. After, they easily found their way back to the first floor. There was an error where the disinfection door would not open, which was solved by teleporting through instead. They went straight for the quiz, and got everything right, even when they had missed the sustainability sphere. Before exiting, they tried to select the red sphere and opened the door to the bridge, which they had missed earlier.	Presence: Beginner friendly
2	- Husket og var veldig kjap med å finne første etasjen - Kom seg gjennom til kontoret uten å åpne døra → drar rett til quizen på pc-en → hopper tilbake 2 forsøk feil	The participant remembered their way back to the first floor and were quick to get there. There was an error where they got through the office door without opening it. They went straight for the quiz and finished with two failed attempts.	Presence: Beginner friendly

3	• Kommer seg lett til første etasjen → error → i desinfiseringsromsdøra → liker at man tar i døra → går rett til pc-en for → → en ulempe "lure spm." ha ha	They easily found their way back to the first floor. There was an error with the disinfection door on the way back, as it would not open. They liked that they had to grab the office door to open it. They went straight for the pc to do the quiz. During the quiz, they laughed about there being trick questions.	Presence: Beginner friendly Motivation: Active
4	• Finner lett veien tilbake til kontoret, men drar først en tur og prøver en av de fake dørane på hangaren • Veldig smooth trykking på knappene (ingen problem med) → ser tastaturet nøye quiz lesning	The participant easily found their way back to the office. But before entering, they tried to open the fake doors in the hangar. They had no issues when using the keyboard to answer the quiz.	Presence: Beginner friendly Presence: Beginner friendly
5	• Finner kjapt veine til kontoret, ikke noe problem med ødra → ser seg først rundt • Deretter finner quizen og uten problemer forstår tastaturet → siste spm. Lure spm. → måtte ta om igjen • Tester mer på MR området → tester lilla kulene og trykker på blå kulen	The participant were quick to find their back to the office, and had no issues opening the door. They looked around, then found the quiz and understood immediately how to use the keyboard. Their first attempt ended by failing on the last question, which was a trick	Presence: Beginner friendly Presence: Beginner friendly

		question, and they had to do it again. After having returned to the mixed reality area, they tried selecting the different spheres again before ending.	Motivation: Interesting

SPØRRESKJEMA - SKJER ONLINE PÅ SURVEYXACT

SLUTT-TEST INTERVJU

1. Hvordan var denne opplevelsen for deg? Utdyp?

Participant	Notes	Finalized code	Themes &

no.			Subthemes
1	• Veldig gøy å lære på denne måten "hand ånd" • Passet bedre for meg isteder for ål ese bok • Fordi kan se det	The participant thought it was very fun to learn in such a "hands-on" way. It was preferable to reading a book because it was so visual.	Motivation: Fun Presence: showing / visualization
2	- Spennende - Artig - lær interactiv med ting gjør ting mer spennende → at du går nært på ting → hjelper f.eks. Selv om jeg ser det er uekte ting føles det virkelig → fikk ikke registrert lyden på heisen → var så god at ikke fikk med meg	They thought it was exciting, funny, and that learning through interactions helped make it more exciting. Being able to closely inspect the environment helped. They thought it felt real even when admitting they could see that it was not. They did not notice the sound effects when clicking the buttons in the elevator.	Motivation: Fun Motivation: Active Presence: showing / visualization Presence: Presence in subjective
3	• Veldig interessant, både VR og temaet • Det at man kunne gå til ting og høre om det → likte veldig odt konseptet om fiskene	They thought both the virtual reality aspect and the topic were very interesting. They also liked that they could inspect things closely, as well as hear about it. They particularly liked the aquaponics concept with the fish.	Motivation: Interesting Motivation: (Guided) exploration path

4	• Var spennende • Var spennende hvordan designet omgivelsene • "Relevant å se hvordan vi lagde byen" • Derfor gikk jeg også rundt → syns løsningen var interessant → reflekterte hele tiden underveis → potensialet	The participant thought the experience, and the design of the environment, were exciting. They felt it was relevant, which is why they wanted to walk around. They thought the experience was interesting and found themselves reflecting on the potential of such an idea the whole time they were going through.	Motivation: Fun Motivation: (Guided) exploration path Motivation: Interesting
5	• Ikke veldig overraskende • Litt uvant å beveg seg men gikk greit → litt vanskelig å finne rett tempo • Litt rart å forstå hva jeg skal gjøre på starten • Kunne gjerne hatt noe guide på starten ○ (Når de snakker om opplevelsen, kaller de det spill) • Kunne gjerne at noe kolliders som ikke lar deg gå gjennom	The participant found it to be not very surprising overall. They also thought it was a bit unfamiliar to move, but that it worked fine. It was difficult to find the right tempo. It was a bit weird to understand what they were supposed to do in the beginning. Therefore they would like to have something guide them at the beginning. The participant refers to the experience as a game when they talk about it. They suggested adding colliders that prevent the user	

		from going through walls.	

2. Hvordan var det å kunne utforske omgivelsene i en virtuell verden?

Participant no.	Notes	Finalized code	Themes & Subthemes
1	• Fint • Artig • Litt lite å lære om "skulle ønske det var litt mer"	They thought it was nice, and fun to explore the environment, but they felt there was too little to learn. They wanted there to be more to learn and explore.	Motivation: Fun Motivation: (Guided) exploration path
2	Liker veldig godt å gå nært planter → liker at det er detaljert → inspisere de → mer variasjon på planter → ting for å lære litt mer om planter	They enjoyed being able to go so near the plants when inspecting them, as well as how detailed they were. The participant did wish for more variation in what kind of plants there were however, as well as	Presence: showing / visualization

		additional opportunities to learn more about the plants.	Motivation: (Guided) exploration path
3	• Var veldig kult → Kult å gå over bro go det å komme inn i verden og tenke "nå er et annet sted" dette er framtiden.	They thought exploring the environment was very cool. It was cool for them to cross the bridge and enter another world. They thought they were another place, the future.	Motivation: (Guided) exploration path Presence: Presence in combination of MR and VR
4	• Likte å gå rundt → ville gå å se på akitekturen • Veldig nygjerrig person → utforskingen drev meg	The participant enjoyed walking around and wanted to look at the architecture. They are a very curious person, and felt that the exploration was driving them.	Motivation: Active Motivation: (Guided) exploration path
5	• Var gøy å gå rundt • "Minner meg veldig vanlig spill" • Føltes litt tomt → gjerne flere interaksjoner • Litt mer info om rommene → flere info kuler	The participant thought it was fun to walk around, and that it reminded them of regular games. It felt a bit empty, so they would have wanted more interactions. Additionally, they wanted there to be more information about the areas, and that more spheres were added.	Motivation: Fun Motivation: Active

3. Hvordan opplevde du formidlingen av tema?

Participant no.	Notes	Finalized code	Themes & Subthemes
1	Det som ble formidla var på en grei måte, spesielt å kunne se tekst o høre på samme måte	The participant felt that the topic was conveyed alright, especially the fact that they could both hear the text and choose to read it themselves.	Presence: Control
2	• et spm. Om refleksjon i surveyen → fikk meg til å reflektere om temaet → veldig spennende → flere ting for å gjøre miljøet mer spennende	The participant started reflecting about the topic after the survey, and thought it was very exciting. They wished for more content in the environment to make it even more exciting.	Motivation: Interesting Motivation: (Guided) exploration path
3	- Syns det var fint at det både var lesing og stemme, personlig liker best å lese → synd det var fint å ha muligheten til å lese på teksten på egenhånd	The participant thought it was nice to be able to both read and listen to a voice over, and that they personally preferred to read. Therefore they thought it was	Presence: Control

		nice that they had the possibility to read the text themselves.	
4	• Var interessant → veldig interessant om bærekraft → er fornuftig → kunne kjapt skumme de → ville først lese og deretter forstodt interaksjonen eks. ledlys	The participant thought it was interesting, especially the topic. They thought how the topic was conveyed was reasonable, and liked that they could quickly skim through the text. It allowed them to first read the text and then understand what the interaction was, for example with the LED lights.	Motivation: Interesting Presence: Control
5	• Var litt som type museums-aktig • Stemmen snakker litt tregt → f.eks. Høre hele teksten → vil ha en mulighet på å kontrollere speed	It reminded them of how information is conveyed in a museum. They thought the voice spoke a bit slow. They made a suggestion to have the possibility to control the talking speed.	Presence: Control

4. Hvordan var dybden på det du lærte om?

Participant no.	Notes	Finalized code	Themes & Subthemes
1	• Var ok, kunne vært litt mer, syns bole konseptet var kult, trenger mer detaljer om temaene f.eks. Potetre og dens vannløsning • Kulene var bra → passende mengde tekst i de, men ville gjerne hatt flere	The participant thought the depth was ok, but it could have been deeper. They thought the sphere concept was cool, but that it needs more detail about topics such as with the potatoes and its water solution. The information spheres were good and had a suitable amount of text in them. The participant would have liked there to be more of these spheres added.	Motivation: (Guided) exploration path Presence: Beginner friendly Motivation: (Guided) exploration path
2	• Følte ikke så mye dybde, men “gav meg en veldig dyp ettertanke” → interessevekker → har hørt om temaene før → har masse planter selv • Satte pris på det → lysene var veldig spennende	The participant felt there was not a lot of depth, but that what was there still gave them a deep afterthought. They thought it could wake interest. They had heard about the topics before, and own a lot of plants themselves.	Presence: Beginner friendly Motivation: Interesting

		They appreciated the experience, and mentioned how the lights were exciting.	Motivation: Fun
3	Nok i dybden for tiden → får “smakebit” av ting → var passelig	The participant felt that it was deep enough for the time, and that it was like getting a taste of the topic. It was a suitable amount.	Presence: Beginner friendly
4	• Gikk ikke veldig i dybden → mer indirekte → ser det mer visuelt • Ville gjerne hatt mer informasjon → mer om “bærekraftig by” og mer temaene innenfor det istedet for matproduksjon • Ville gjerne hatt flere kulene	The participant thought that it did not go very in depth, and that it was conveyed more indirectly through the visuals. They wished for more information, more on the topic of a sustainable city and other topics than food production. They would have liked there to be more spheres added.	Presence: showing / visualization Motivation: (Guided) exploration path
5	• Føltes ganske overflatisk/middels • Syns det var greit slik da fordi å ha oversikt over det, og lære det overflatisk slik på et tema jeg ikke er veldig interessert i • Savner overflate-kunnskap/mer kuler på de andre tingene	The participant felt it was quite superficial. However, it was alright because it gave an overview of a topic they were not particularly interested in. They wanted there to be more spheres added on the other concepts such as aeroponics and aquaponics.	Presence: Beginner friendly

5. Hvordan var det å lære om temaene i en slik virtuell opplevelse, i motsetning til hvis du skulle lært om det ved å lese i en bok, på nett, eller se en video?

Participant no.	Notes	Finalized code	Themes & Subthemes
1	Mye mer interessant, mer gøy → det å kunne se det istedet for å måtte bruke fantasien var veldig bra	They felt it was a lot more interesting and more fun to be able to see rather than having to imagine. They felt it was very good.	Motivation: Interesting Motivation: Fun
2	• Tror "mange ganger inntrykker" → lese, bruke kroppen osv. Gav et annet uttrykk → veldig kult å lære slik	The participant thought it multiplied the impression many times. Reading and using the body gave another expression than books, and it was very cool to learn in this way.	Motivation: Active
3	Tror det er mye enklere å huske i ettertid → nå har jeg bilder i hodet av det → husker enklere → hvordan det såg ut da /omgivelsene	The participant thought it would be a lot easier to remember what they learned. After the experience, they had images in their head which they could recall back to,	Motivation: Interesting Presence: showing / visualization

		tie the information to how the environment looked, to help them remember.	
4	• Var morsjommere å kunne bevege seg i en slik verden • For mye bedre forståelse • inføring/løsning i hvordan hengaren og farmen er satt opp • Bedre utgangspunkt → god innføringen i tema • Veldig fint startpunkt og deretter kunne sener sett og lært fortere om temaet senere • Velig god forståelse, håndfast visuelt for at det hjelpe senere	The participant thought it was more fun to move in such a world, and that it gave them a much better understanding. It gave them an understanding of how the hangar and the underground farm are set up. It gave them a better starting point and introduction to the topic, which could then lead to a better and faster understanding if they were to dive deeper in the topic themselves later. It gave them a very good understanding, having the hands-on visuals to recall back to later.	Motivation: Fun Presence: showing / visualization Presence: Beginner friendly Motivation: Active Presence: showing / visualization
5	• Litt mer tidskrevende → men likte det istedet for en bok • Følte det var gøy fordi det føltes som en museumsbesøk	The participant thought it demanded more time, but preferred this way of learning over a book. They felt it was more fun because it felt like visiting a museum.	Presence: showing / visualization Motivation: Fun

6. Tror du at å lære på denne måten kommer til å hjelpe deg å huske temaene lengre i ettertid? Hvorfor?

Participant no.	Notes	Finalized code	Themes & Subthemes
1	Ja "Fordi for min del er en beste måten å lære på er å se og høre det" istedet for å lese det i en bok	The participant thought yes, it would help them remember after, because for them the best way to learn is to see and hear it, rather than reading about it in a book.	Presence: showing / visualization
2	Ja, fordi helhetsinntrykk Ofte når skal huske ting Liker mapping aka ha en omgivelse → sammenligning med butikk mapping → huskes bedre slik med disse omgivelse	The participant thought yes, because of the overall impression the experience left. When they are to remember something, they like to use a mapping method with the environments. They compared it how we map a supermarket in our minds, where we know where the products are thanks to having a mental mind map of the layout from having been there before. The participant	Presence: showing / visualization Motivation: (Guided) exploration path

		remembers better with these environments.	
3	Ja → "fordi nå har fått en opplevelse av det enn å lese på det" → en historie å se tilbake til → mer minnerverdig inntrykk	The participant thought yes, because they have gotten an experience rather than just reading about it. The experience can be looked back to, and left a more memorable impression.	Presence: showing / visualization
4	• Ja fordi visuelt gjør det enklere å huske ting • Kan alltid refere tilbake til den virtuelle modellen etter senere læring → god kobling tilbake → gjennom denne erfaring og koble det til det teoretiske • Lære av dine feil. "Dette er gull vært å lære det slikt"	The participant thought yes, because visually it makes it easier to remember. They could recall back to the virtual model if learning about the topic at a later point, which would be a good connection point to the theoretical. The participant also thought it was worth its weight in gold to learn by their mistakes.	Presence: showing / visualization Presence: showing / visualization Motivation: Want to perform because of end quiz
5	Ja, fordi det visuelle hjelper meg å huske tilbake på ting	The participant thought yes, because the visuals will help them recall.	Presence: showing / visualization

7. Tror du VR opplevelser generelt kan gjøre det mer interessant å lære?

Participant no.	Notes	Finalized code	Themes & Subthemes
1	Ja, 100 prosent, "kanskje ikke for alle, men ihvertfall folk som meg syns det er top"	The participant thought yes, although it may not be for everyone. For people like them however, it was great.	Presence: showing / visualization
2	Ja, f.eks. Kan gjøre kjedelige fag mye mer spennende → aka kunsthistorie fra en kjedelig bok eller kunne gå i en VR opplevelse i denne historien → huske bedre	The participant thought yes, and that it could make boring subjects a lot more exciting. As an example, they mention learning about art history from a boring book or being able to go through a virtual reality experience of the history. They thought it can help them remember better.	Motivation: Fun Presence: showing / visualization
3	Ja → fordi litt annerledes → bare at noe er nytt er engasjerende → skift i omgivelse og faktisk å gå rundt å lære → fin måte å huske på	The participant thought yes, because it is a bit different, and that it being something new makes it engaging. A change in environments and actually walking	Motivation: Fun Motivation: (Guided) exploration path

		around to learn is a nice way to remember.	
4	• Det tror jeg • Spesielt dette temaet(matproduksjon) som ikke interesse meg like mye → ble plutselig litt mer interessert • Ville ikke lest det i en bok → fikk mer inntrykk	The participant thinks so, particularly the theme of food production, as they were not very interested in it. After the experience however, they became more interested. They would not have read about it in a book, and got more of an impression from the immersive experience.	Presence: Beginner friendly Presence: Beginner friendly
5	• Ja spørs hva det er • Temaet har mye å si f.eks. En opplevelse om norskfaget ville vært vanskelig, men andre fag/praktiske fag der man gjør noe f.eks. Kemifaget, også tryggere	The participant thought yes, but it depends on what it is. The topic is very important, as an experience on norwegian would be difficult, while other more practical topics where you do something are more appropriate. For example, chemistry, which could also be safer to do virtually.	Motivation: Active Presence: showing / visualization

8. Hvordan følte du det var å bevege deg rundt ved å teleportere?

Participant no.	Notes	Finalized code	Themes & Subthemes
1	Funker greit fordi minner meg om google earth	The participant felt it was alright because it reminded them of Google Earth.	Presence: Beginner friendly
2	Når du blir vant med det så går det lettere, men vanskelig med uvant først, men gikk bra → vanskelig å åpne døra	The participant thought that once they got used to it, that it became easier. However, it was difficult and unfamiliar at first, but it worked. They thought it was difficult to open the door.	Presence: Beginner friendly
3	Var litt vanskelig først → bedre etterhvert → mot slutten føltes det naturlig	The participant thought it was difficult at first, but that it got better after a while. Towards the end, it felt natural.	Presence: Control
4	• Gikk greit → tok litt tid → deretter følte at jeg hadde veldig kontroll → mestrer det på slutten	The participant thought it was alright, but it took some time. After which, they felt they had very good control, and by the end they were a master at it.	Presence: Control
5	• Greit → fordi har erfaring med det fra før	The participant thought it was alright,	

	→ ville gjerne hatt valget md å ha håndtrekking (handtracking), og kontrollere • Litt irriterende å alltid måtte ha hendene trekka • Litt unaturlig bevegelse	because they had experience with it. They would have wanted to be able to choose between using hand tracking and controllers. It was a bit annoying always having to have their hands held up. It was a bit of an unnatural movement.	Presence: Control Presence: Break in presence

9. Hvordan føltes det å kunne se det digitale lagt over det virkelige?

Participant no.	Notes	Finalized code	Themes & Subthemes
1	• Var kult men var litt langt unna • Føltes natulig at det digitale var der samtidig som det ekte	The participant thought it was cool but a bit far away. It felt natural that the digital and real were shown simultaneously.	Motivation: Interesting Presence: Presence in MR

2	• Syns det ville ha blitt mye lettere å ikke kunne → noe som sier ifra om plakaten er der	The participant thought it would have been much easier to not see the real world. They also would have liked something to indicate that the introduction poster is there.	Presence: Presence in subjective Presence: Presence in MR
3	Veldig kult → å se dette bordet → men litt vanskelig å orientere seg → føltes naturlig å se digitale objekter	The participant thought it was very cool to see the miniature model in the real world, but it was a bit difficult to orient themselves. It felt natural to see the digital objects.	Presence: Presence in MR
4	• Fin overgang → likte å kunne få overblikk først og deretter se den store VR verden	The participant thought it was a nice transition, and liked being able to get an overview first and then seeing the big virtual reality world.	Presence: Presence in combination of MR and VR
5	Føltes litt rart → fordi bordet var litt i veien / rommer litt smått	The participant thought it felt a bit weird, because the table kept getting in the way, and the room was a little too small.	Presence: Presence in MR

10. Hvordan føltes det å gå gjennom døra mot broen? Merket du noen forskjell? Utdyp?

Participant no.	Notes	Finalized code	Themes & Subthemes
1	• Fint • Kult	The participant thought it was nice and cool.	Presence: Presence in combination of MR and VR
2	• Artig → likte overgangen fra der man ser til • Tenkte ikke over det der og da • Veldig kul effekt i ettertid	The participant thought it was fun, and liked the transition. They did not think much about it in the moment, but when looking back on it they thought it was a very cool effect.	Presence: Presence in combination of MR and VR
3	• Var stilig å kunne ha en slik overgang "en tele portal" • Broa føltes som at det var en annen verden	The participant thought it was cool to have such a transition, and refer to it as a "tele portal" They also said the bridge felt like another world.	Presence: Presence in combination of MR and VR
4	• Føltes veldig merkverdig → likte følelsen fordi MR delen prosjektbord og fikk overordet bildet 3d modellen deretter	The participant thought it felt very noticeable, and liked the feeling of first getting an overview from seeing the projectboard and then going there after.	Presence: Presence in combination of MR and VR
5	• Var en "neat" effekt → føltes unnaturlig/annerledes • Var en sterk kontrast	The participant thought it was a neat effect that felt unnatural and	Presence: Presence in combination of MR and VR

	og se tilbake → var interessant å se fra ekte tli cartoon verden, og se tilbake og være i cartoon verden • "Narnia-feeling"	different. They said it was a strong contrast when looking back, and that it was interesting to see from the real world into the cartoon world, and also when looking back from inside the cartoon world. They compared it to a "Narnia-feeling".	

11. Hvordan føltes det da du gikk fra broen til byen? Merket du noen forskjell? Utdyp?

Participant no.	Notes	Finalized code	Themes & Subthemes
1	Føltes som å fly	They thought it felt like flying.	Presence: Presence in combination of MR and VR
2	• Gikk okay • Var morsomt → såg byen først veldig liten og nå følte meg at jeg plutselig krympet	They thought it went okay, and that it was fun. They saw the city first when it was very little, and then they felt like they had	Motivation: Fun Presence: Presence in VR

		suddenly shrunk.	
3	Var fint og fasinernde og se en ny verden, "føltes at jeg var i framtid → føltes veldig stort -> realistisk perspektiv "følte jeg var et menneske i denne verden"	The participant thought it was nice and fascinating to see a new world. It felt like they were in the future. It felt very big, but that it was a realistic perspective. They felt they were a human in this world.	Presence: Presence in VR
4	Syns det var helt greit, forstodt at jeg var i byen (den jeg såg som mini versjon • Følte at jeg fikk et mer • Kult å se modellen	The participant thought it was alright, and understood that they were in the city they had seen as a miniature model. It was cool to see the model.	Presence: Presence in VR
5	• Ikke veldig • Forslag til endring → Peke på bordet (broen, mini modell) og bli transportert til store verden → da ville det blitt en brå overgang	The participant did not notice much of a difference. They suggested a change to make it so that pointing and selecting a surface on the miniature model transports the user into the city. This would be a steep transition.	Presence: Presence in VR

12. Hvordan føltes det da du satt på gaffeltrucken?Merket du noen forskjell? Utdyp?

Participant no.	Notes	Finalized code	Themes & Subthemes
1	Var ikke så veldig imponert, kunne være litt mer interaksjon / kjøre noe den	The participant was not very impressed, and would have liked there to be more interaction and to have been able to drive it.	Motivation: Active
2	- Gikk forbi den	The participant missed the forklift.	
3	• Var veldig gøy, følte at jeg jobbet • Var fint → fordi kunne se plantenese reise i heisen	The participant thought it was fun, and said it felt like they were working. It was nice because they could see the plants' journey to the elevator.	Motivation: Fun Presence: showing / visualization
4	• Trodde at jeg først skulle styre denne → • Var ikke skuffet over at jeg ikke fikk kjøre den • Trodde jeg kjørte → var usikker også forstodt at det var en simulering → mista bevegelsesansen trodde jeg tilta	The participant thought at first that they would be able to steer it. However, they were not disappointed when they found out the could not. At first they thought they were steering it, and was a bit uncertain about it. They still understood that it was a simulation.	Presence: Control Presence: Presence in VR

		They lost their sense of movement briefly and thought they tilted.	
5	• Føltes som en "cutscene" • Litt kjapt forvirring først, men gikk greit at jeg ikke må styre	The participant thought it felt like a cutscen. At first it was a brief moment of confusion, but it was alright that they did not have to steer.	Presence: Presence in VR

13. Hva ville du ønsket å fått ut mer av denne VR opplevelsen? For eksempel har du noen forslag til endring? Er det noe som stakk ut for deg som du likte eller ikke likte?

Participant no.	Notes	Finalized code	Themes & Subthemes
1	• Flere kuler, savnet ikke noe annet • Kunne gjerne hatt flere boler/kuler for åkunne utforske • "Kunne utfroska de hele dagen"	The participant would have liked for more spheres to be added, and did not really miss anything else. They wanted more spheres to explore They said they could have explored them all day.	Motivation: Interesting Motivation: (Guided) exploration path

2	• Ville ha likt å hatt det mer realistisk • Variasjoner i planter • Ville ha likt å kunne fått noe følelsesmessig → det å kunne føle/haptiks hvis ting holdes osv.	The participant would have wanted it to be more realistic. They wanted more variations of the plants. They would have liked to have more sensory feedback, such as the sense of touch through haptic feedback when holding objects or such.	Presence: showing / visualization
3	Lkte veldig godt informasjonskulene → ville hatt flere kuler litt overalt og kunne gått og utforsket disse	The participant liked the information spheres a lot and would have wanted there to be more spheres added all around so they could have gone exploring them.	Motivation: Interesting
4	• Ser at dette er et tidsbegrenset prosjekt • Kunne gjerne at mer interaksjon → mer inspirasjon Andre bærekraftaspekter dere kunne ha gjort Grønne områder i byen → ville lært litt mer om andre ting → planlegge infrastruktur, solseller, bærekraftig i bedrift, arbeid f.eks. Kildesortering, f.eks. Byggeplasser, effekten av strømsparing, gjenbruk av fasader, få andre til å tenke mer på bærekraft.	The participant understands that the project has a time limit, but they would have wanted more interactions and inspirations. They would have liked other sutsainable aspects to be included, and there could be more green areas in the city. They wanted to learn about other things such as planning of infrastructure, solarcells, sustainable	Motivation: Interesting

		businesses, waste sorting, construction sites, effect of powersaving, re-use of facades, and getting other to think more about sustainability.	
5	• Har sagt litt om det • "Føltes litt tomt" gjerne flere interaksjoner/content • Flere objekter som viser de usynlige veggene f.eks. veggene	The participant had heard a little of the topic before. They thought it felt a bit empty, and would have wanted there to be more interactions and content. They wanted more objects that indicate the invisible walls.	Motivation: (Guided) exploration path

14. Har du noe annet som du føler burde bli nevnt?

Participant no.	Notes	Finalized code	Themes & Subthemes
1	• Forstod oppgavene litt mer underveis	The participant understood their	Presence: Beginner friendly

	• Litt greit å hoppe i det • Var helt top	tasks more as they went. It was alright to jump into it. Overall it was great.	
2			
3			
4	• Surveyen går jo in på dybden på ting → • Litt for enkelt når det gjelder teori	The survey went into depth on things. The participant thought it was too simple on the theory.	
5	- Når det komme inn på immersion → så litt mer realistiske - Spm. om (survey om) lyd → (litt mer) miljølyder som f.eks. Vannlyd, ledlys lyd, lyd for pumper, vil gjerne ha smålyder	The participant thought when it came to immersion, that it could be more realistic. They also wanted more sounds, such as environmentsounds of water, LED lights sound, sound for pumps, and other small sound effects.	Presence: Presence in subjective Presence: Presence in VR

Appendix C

Thematic analysis iteration two

User testing for iteration two were held between 23.03.2023 and 30.03.2023.

List of themes and subthemes used for the thematic analysis:

Presence
- Presence in subjective
- Connections between immersive tendencies and presence
- Beginner friendly
- Control
- showing / visualization
- Attention)
- Presence in VR
- Presence in MR
- Presence in combination of MR and VR
- Break in presence

Motivation
- Interesting
- Fun
- Active
- Surprising
- (Guided) exploration path
- Want to perform because of end quiz

INTERVJUGUIDE: NOTATER - INTERVJUER OG OBSERVASJON AV BRUKERTESTING

FØR-TEST INTERVJU

1. Har du vært med på noe slags forskningsundersøkelse før, eller er dette første gang?

Participant no.	Notes/codes	Translation to english & coding	Participate background / extra data
6	Ja noen småe spørreundersøkelser	Yes they have been part of a few small surveys	-
7	Ja små undersøkelser	Yes afew surveys	-
8	første	The first time	-
9	Nei første gang	No, first ime	-

10	Første gang	First time	-

2. Har du prøvd VR før? Hvordan var det?

Participant no.	Notes/codes	Translation to english & coding	Participate background / extra data
6	Nei, tro at jeg kommer i en fiktiv verden	The participant has not tried VR before. They expect to come into a fictional world.	
7	Ja var gøy, ikke så mye, gøy à gjøre noe man ikke har gjort	The participant has tried some VR before and thought it was fun. They said it is fun to do something they have not done before.	
8	Ja, innenfor jobbrelatert → praksis sykepleier, var veldig spennende og morsomt	Yes, the participant has tried VR before related to work. Internship as a nurse. They thought it was very exciting and fun.	
9	Ja, har egen quest, quest 2 har jo problemer med mixed reality Spill noen spill her og der	Yes, the participant has their own Quest 2 VR headset, which they say has some	

		problems with mixed reality. They play some games here and there.	
10	Nei, forventing → nysgjerrig	No, the participant has not tried VR, but they are curious about trying.	

3. Når du skal lære noe, går du mer i dybden på det du skal lære om eller holder det å gjøre det enkelt? Hva gjør vanligvis at du ønsker å lære dypt eller overflatisk om noe? Kan du gi noen eksempler?

Participant no.	Notes/codes	Translation to english & coding	Participate background / extra data
6	• Kommer an på hva hensikter er • Skumlese hvis det ikke er så viktig • Går i dybden hvis noe interesserer meg	It depends on what the purpose is. If something is not so important, they skim through. If something is of interest to them, they go in-depth.	
7	• Går i dybden på ting, f.eks. Hvis noen sier/mener noe liker jeg å finne det ut etterpå	The participant usually goes in-depth.	

	selv	They gave an example where if someone tells them something or has an opinion, the participant likes to find out for themselves after.	
8	Ja mest enkelt, → veldig mye google, men går i dybden hvis jobbrelatert	The participant prefers to keep it simple. They do a lot of Google, but also in-depth when it is work related.	
9	• Liker å gå i dybde → går til forelesning og les boka • Men hvis det skal være overflatisk da skal det være laget ordentlig • Liker å undersøke	The participant likes to in-depth. They go to lectures and they read the book. However, if something is to be superficial, then it should be made proper. They also like to investigate.	
10	• Kombinasjon → først rask gjennomlesing/skumles ing, deretter hvis mer interessant så mer i dybden	The participant does a combination. First they do it quickly by skimming through when reading. Afterwards, if they find out it is more interesting, they go in-depth.	

BRUKERTESTING OG BRUKEROPPGAVER

- Utforsk omgivelsene for å finne broen og gå over den

Participant no.	Notes/codes	Translation to english & coding	Themes & Subthemes
6	• Ser på mini-modellen → error → mini modellen roterer med hånda, festet seg på den • Går mye rundt fysisk, ser nøye på minimodellen • Leser nøye på plakaten • Trykte først på lila kule → trykker så på nlå og hører og følger nøye med → "sier seg enig med teksten" → virker interessert i det som sies • Rykker på rød kule → legger merke til rødt skilt, beskrivelse og går gjennom døra til broen med det samme	The participant started by looking at the miniature model. An error occurred as they were rotating the miniature model, where the model got stuck to their hand. The participant walked around physically a lot, and looked thoroughly at the miniature model. They also read the introduction poster thoroughly. After, they selected the purple sphere. Then the blue sustainability sphere. They were listening closely, and says they agree with the text they just heard.	Presence: Break in presence Presence: Beginner friendly Motivation: Interesting

		They seem to be interested in what is being said. Lastly, they select the red sphere and notice the red sign above the door. Immediately, they went through the door and crossed the bridge.	Motivation: Interesting
7	• Går fysisk mot mini modellen →klyper direkte på rød kule (uten noe hjelp) • Inni modellen • Stiller inn brillene for å få skarpere bilde → liker fugleperspektiv → ser nøye på mini-modellen for å finne broa → ser skiltet og leser rolig på det "syns det er rart at vi ser på nært hold" → roterer modellen → trykker på blå kulen og hører nøye på teksten → lurer på om speeden kan forandres til å bli fortere → ser på selv → leser tekst → røde kulen igjen → ser skiltet → blir overrasket og kobler med det samme	The participant started by physically walking towards the miniature model and pinching directly at the red sphere, unprompted. They ended up standing inside the model. The VR headset had to be adjusted to get a sharper image. They liked the bird's eye view and look closely at miniature model to find the bridge. They notice the introduction poster and calmly read it. They said it was weird how the poster mentions "looking up close". They rotate the city select the blue sustainability sphere,	Presence: showing / visualization Presence: Beginner friendly Presence: Control

		after which they closely listen to the text. They wonderd if the speed could be adjusted to be faster. They decide to read the full-text themselves. Lastly they select the red sphere again and notice the sign that comes up. They got surprised and immediately understood where to go.	Presence: Control Motivation: Surprising
8	- Lurer på hva ballongene er → trykker med det samme på blå-kulen, deretter på rød → ser døra med det samme og går over → virker veldig overrasket, går tilbake for å utforske MR området litt mer → prøver å trykke på lilla → "der er broa" → sier deltakeren hvis trykker → prøver å roter bordkanten → overrasket over minimodellen → virker som at hører ikke på bærekraftig teksten → Leser på plakaten → syns dette var veldig spennende → går gjennom modellen, følte litt rart å gå, fordi virker som et ekte objekt → Ser mini-broen på modellen → ser nøye på modellen	The participant started by wondering what the balloons were. Immediately they selected the blue sustainability sphere, followed by the red sphere. They noticed the door instantly and go inside it. They seemed to be very surprised, and decided to go back to explore the mixed reality area a little more. They tried to select the purple sphere. They spotted the bridge on the miniature model and	Motivation: Surprising

		said they had found it, then tried to select it. They tried to rotate the table edge. They seemed surprised by the miniature model. They did not seem to be listening to the text about sustainability. They noticed the introduction poster and read it, thinking it was very exciting. They started walking through the miniature model, which they thought was weird as it felt like a real object. Lastly they closely inspected the bridge and miniature model.	Motivation: Surprising Presence: Beginner friendly Presence in MR
9	• Bruker først knappen for å gå • Teleporterer inn i modellen • snur/rotere minimodellen • Prøver å tryke på broen på modellen • Trykker lilla kulen, så grønn → trykker på blå → ser ikke skiltet med det samme men hører på, prøver samtidig gå inn → rød kule → ser seg tilbake	The participant started by trying teleportation. They teleported into the miniature model, and started turning and rotating it. They tried to select the bridge on the miniature model. They selected the purple sphere, then the green, followed by the blue	Presence: Control

		sustainability sphere. They did not see the sign at first, but they were still listening and trying to go in. They selected the red sphere and looked back before crossing the bridge.	Presence: Presence in combination of MR and VR
10	• Øver først på teleportering • Leser plakaten • "Ser ikke broen" • Rolig fysisk • Blir overrasket fordi får øye på mini broen • Klyper grønn-kulen • Trykker på rød → ser ikke døra, trykker igjen, forsvinner • Trykker blå-kule → og hører på (veldig rolig i kroppen) og virker konsentrert (bruker venstre hånda), greier å trykke på krysset • Rød-kule → "gå inn her" "her ja". Gikk med et trykk over broen	The participant started by practicing teleportation. They noticed the introduction poster and read it. They could not see the bridge at this point. They were calm physically. It surprised them when they noticed the miniature bridge. First they tried to pinch the green sphere, then the red sphere. They did not notice the door, and instead selected red sphere again making it go back down. They select edthe blue sustainability sphere and listened to the voice over. They seem to be very calm and	Presence: Beginner friendly Motivation: Surprising

		concentrated, using their left hand. Managed to select the cross to close the sign again. They selected the red sphere again and noticed the sign. They said "Ah, here" before crossing the bridge in one click.	Presence: Presence in MR

- Utforsk byen for å finne inngangen til hangaren

Participant no.	Notes/codes	Translation to english & coding	Themes & Subthemes
6	• Blir overrasket da kom gjennom til byen • Ser hangaren med det samme • Ser sykkelen etterpå • "Rette fine linjer, ganske høye bygg" • Ble flink på telportering, men sier det er litt "uvant" • Virker veldig fasinert av de store bygningene	The participant was surprised when they got through to the city. They immediately noticed the hangar, and then the bicycle after. They comment that the city has "straight,	Motivation: Surprising

	og by-torget ● Finner lett veien tilbake til hangaren Error → kommer gjennom → prøvde å åpne døra	fine lines" and "pretty tall buildings". At this point, they had gotten quite good at teleporting, yet they said it was still a bit unfamiliar. They seemed very fascinated by the big buildings and city square. They easily found their way back to the hangar, but had an error where they got through the walls when trying to open the door.	Motivation: Interesting
7	● Ser hangaren med det samme ● Prøver å gå på gresset ● Går rund i bysentrum → → syns det er litt for lite grønne fasader → kult om en helt veggene er helt grønn Ser opp og ned himmelen "Lurer på om det går på sykkelen" ● Flink og kjapt til å teleportere ● Prøver "fake døra" først ● Griper dørhåndtaket med det samme og kommer inn ved første forsøk	The participant immediately spotted the hangar. They tried to go onto the grass. When that did not work, they instead went to the city center. They thought there were too little green facades, and it would have been cool to see fully green walls. They look up at the sky and back down. They wondered if they could ride the bicycle. At this point, they were quite good and	Presence: Beginner friendly

		fast at teleporting. At the hangar, they tried to open the fake door first. After, they immediately grabbed the door handle and got inside the hangar at the first try.	Presence: Beginner friendly
8	→ Sier "så tøft" og veldig glad overrasket da deltakeren kommer til byen → ser inni søppelkassen → "utrolig tøft fordi virker så ekte1" (byen) "Føler å være på ferie" → går med samme til bysentrum → veldig kjappt teleporterting → bruker kroppen mest for å snu seg → Lurer på om man kan gå på gresset, → finner hangaren → "fake dør" først → "føltes veldig naturlig å gripe døra"	The participant thought it was cool and seemed pleasantly surprised when they arrived in the city. They started by looking inside the waste bins. They said it was incredibly cool because the city seemed so real. They said it felt like being on vacation as they immediately went towards the city center. They had become very quick when teleporting. They were mostly using their body to turn. They wonderd if they could walk on the grass. When at the hangar, they first tried to open the fake door.	Motivation: Surprising Presence: showing / visualization Presence: Beginner friendly Presence: Presence in VR

		It felt very natural when they tried to open the hangar doors.	Presence: Presence in VR
9	● Virker ikke overrasket for å komme til byen ● "Hører naturlyder" ● Ser hangaren med det samme, og går til sentrum "å her er jo denne byen" ● "Trær i bygninger" ser opp i himmelen ● "Ville gjerne hatt enda lengre teleporteringsmulighet ● Griper døra med en gang	The participant did not seem surprised when they arrived in the city. They mentioned how they were hearing nature sounds. Immediately they spotted the hangar, then they went to the city center. At this point, they noticed that it was the same city they had seen earlier. They looked up in the sky and said "trees in buildings.". They wanted to be able to teleport further. They immediately grabbed the hangar door and opened it.	
10	● Går i sentrum ● Veldig sterilt → liker ikke byen, syns det kaldt, ultra moderne, litt lite, mer planter, altfor høye bygninger. Liker bedre hvis laget av trær (personen er ikke vant med) liker sjøen, alt er blått → "det mest normal og føles naturlig er himmelen"	The participant went into the city center. They said it was very sterile, and did not like the city. They thought it was cold, ultra modern and small. It needed more plants, and the buildings were way too tall. They prefer	Presence: Break in presence

	● Har lært seg å teleportere ● Ser hangaren og år dir ● Greide åkomme inn ved å gripe med første forsøk	buildings to be made from wood. They did like the lake. Everything was blue, which made it feel cold. The most normal and natural feeling part was the sky. At this point, they had learned how to teleport. They spotted the hangar and went there, managing to enter at first attempt by gripping the handle.	

- Utforsk første og andre etasjen av hangaren og lær om de forskjellige konseptene innenfor dyrking som finnes der

Participant no.	Notes/codes	Translation to english & coding	Themes & Subthemes
6	• Legger med det samme at salater stables • Så nøye på salathyllen → • Lrer på hvor sola er og hvordan plantene fokser, der led-lys oppsettet • Blir minnet på at det finnes kuler å trykke på → trykker på hydroponisk-kule og hører nøye på stemmen (rolig i kroppen) virker konsentrert → går videre i hangaren → prøver "fake døra" → trykker på hydropniske kula igjen → trykker lukk → trykker på CEA kulen → hører og ser nøye på kulen → virker som at hodet beveger seg med tekstlinjen → Trykker på vertikalt landbruk "dette har jeg hørt om før" → trykker på LED-lys kulen → hører og følger nøye med → lukker alltid vinduene → trykker på knappen for ledlys → virker litt forvirret så artig at de byttes "ville gjerne hatt grønn" → går inn i heisen uten noe problemer og leser skiltet "Skifterom" → går i des. døra og ler av desinfisering → overrasket at det var "noe av det samme", litt skuffet → overrasket og glad når aeroponisk ses → åpner kulen og ser ikke lenger på kulen men hører på teksten	The participant started by immediately noticing that salads were stacked. They closely looked at the salad shelf. They were wondering where the sun is and how the plants were growing, when looking at the LED-light setup. They were reminded that there were spheres to click on and started by selecting the hydroponics sphere. They were calm in their body and listened closely to the voice. They seemed to be concentrating. They moved on through the hangar and tried to open the fake door. They went back and selected the hydroponics sphere again, before closing it shortly after. They selected the CEA sphere and	Presence: showing / visualization Presence: Presence in VR

	Ser trucken → trykker kjør havner baklengs på trucken → → finner heis 2 → lurer på om det er heis 1 først → ser først på modellen og snakker om hva som ses → virker å reflektere på hva som ses → trykker derteter på kulen og følger nøye med → trykker kryss på bolene	listened closely, looking at the information sign. Their head seemed to be following along with the text as it was spoken. When selecting the vertical farming sphere, they mention they had heard of it before. They selected the LED light sphere and paid close attention. After having listened to a sphere, they were always closing the window again. They tried pushing the button to change the color of the lights. At first they were confused, then they thought it was fun. They would have wanted green light to be added. They went into the elevator without issue and read the sign that says "changing room" when they got down. They went through the disinfection room and laughed at the disinfection process. They were surprised	Presence: Presence in VR Motivation: Fun Motivation: Fun

		that there was more of the same down in the underground area, and seemed to a little disappointed by it. However, they were pleasantly surprised when they saw the aeroponics area. They selected the sphere but were only listening to it, not watching it. They saw the forklift and went to drive it. When they got on, they were placed backwards. After, they found the second elevator, and mistook it for the first one. In the aquaponics area, they looked at the model and seemed to be reflecting on what they were looking at. They selected the aquaponics sphere and listened to it, then closed it.	Motivation: Surprising Presence: Break in presence Presence: showing / visualization
7	• Trykker på CEA-kulen med det samme → leser heller for seg selv i stedet for å lære på teksten • Forslag til endring → istedet for tekst og heller best → går til hydroponi → kulen →	The participant selected the CEA sphere immediately, and preferred to read if themselves rather than listen to it. After, they went and selected the	Presence: Control

	leser hva vertikalt landbruk er → ledlys kulen → leser rolig for seg selv → det virker som at teksten er interessant → "her er vertikalt landbruk"-kulen! → snakker høyt med seg selv og reflekterer → har blitt → drar inn på kontoret → ser quizen, prøver å ta → "fake døra" Kommenterer på at dette er jo → lurt at man ikke kan gjøre altfor mange interaksjoner engentli → blir glad overrasket at ledlys knappen kan forandres. → fant ut av heisen med det samme → leser skiltet → går til aeropo. Og hører på kulen → blir overrasket → prøver å plukke poteter → spør oss om teksten og innholdet på det som blir nært → ser heis 2 → går tilbake → bruker kroppen fysisk til å leke at sitter på gøy å kjører trucken → tar heis 2 → "wow" ser fisk → hører på kulen og stemmen • Hører på teksten og sier "ja så man trenger ikke kaste avføring" • Prøver "fake døra" men det funker jo sikkert ikke • Lurer på om det finnes snarvei	hydroponics sphere, followed by vertical farming and then LED lights. They calmly read the text by themselves, and it seemed like the text was interesting to them. They said it out loud when they spotted the vertical farming sphere, and reflected. They went into the office and tried to solve the quiz. They tried to open the fake door. They were pleasantly surprised that the LED light colors could change. They comment that it is good that there are not too many interactions. They figured out the elevator immediately. When they got down, they read the sign and went through disinfection and straight to aeroponics. They were surprised by aeroponics, and tried to grab a potato.	Motivation: (Guided) exploration path Motivation: Interesting Motivation: Want to perform because of end quiz Motivation: Surprising Presence: Beginner friendly Presence: Beginner friendly Motivation: Surprising

		They asked if what was said in the text and what they saw was close to real life. They saw the second elevator and went back to it. But first, they rode the forklift. When riding, they used their body to act like they were sitting on it for fun. They took the second elevator and said "wow" when they saw the fish in aquaponics. They selected the aquaponics sphere and listened to it before saying "So there's no need to throw out the waste". They tried to open the fake door. They wonderd if there was a shortcut.	Presence: showing / visualization Motivation: Fun Motivation: Surprising Presence: showing / visualization
8	• Trykte på hydroponisk-kulen → går ikke nært teksten → men hører på "dette var noe nytt for meg" • Går deretter rundt i hele arealet på etasje 1 • Går inni kontoret → ser PC-en og prøver å ta qiuzen → Flirer når det nevnes at dette må kanskje ventes med → Ser nøye på objektene på kontroet og prøver å ta de	The participant started by selecting the hydroponics sphere, but did not go close to the text. They were listening, and said it was something new to them. They then explored the whole area in the first floor.	Motivation: (Guided) exploration path

	opp, prøver å starte mikroen og åpne kjøleskapet → Trykker på led-lys kulen → går ikke nært men hører tålmodig på → deretter vertikalt landbruk-kulen → virker rolig og hører på → hører på CEA (brukes aldri egen tekst-lesing options) → Prøver led-lys knappen "overrasket at det ble → ingen problemer med heisen → prøver å ta på skoene og skapet, prøver å ta vaskemaskinen, prøver vasken → går inn i des.rommet flirer av des. → "Så det er vertikalt landbruk når det står sånn i høyde" sier deltakeren når det leses på skiltet → prøver trucken → "nesten begynner å gynge fordi føles at man blir tatt med på ekte" → Trykker aeroponisk kulen → hører på fra avstand → "er det ekte? Er det slik det ser ut i virkeligheten?" blir overrasket da dette bekreftes • Går til leveringsheisen og ser salaten som ble levert • Går til heis 2 → veldig naturlig trykking på heisknappen • Ser kulen og hører på fra avstand	They went into the office and found the PC, then tried to solve the quiz. They laugh when it is mentioned they should wait with the quiz. After, they go through the office and examine the objects therein, trying to pick them up. They also try to start the microwave and open the fridge. They went back out and selected the LED light sphere, again not going close to it but calmly listening, followed by the vertical farming sphere. They selected the CEA sphere and listened to it aswell. They never chose the option to read for themselves. They tried the button next to the LED light sphere and were surprised when it changed the lights' colors. They had no issues when taking the elevator down. In the disinfection area, they tried to	Motivation: Want to perform because of end quiz Motivation: Active Motivation: Surprising Presence: Beginner friendly

		interact with everything in there, including the shoes, lockers, washing machine and sinks. They laugh when going through the disinfection process. When they entered the underground area and saw the vertical farming sign, they understood that it was vertical farming when the salad stood like that in height. When they tried the forklift, they almost started rocking back and forth, because it felt like they were being taken away for real. When they selected the aeroponics sphere, they asked if it was real and if that was how it looked in reality. When told yes, they were surprised. They went to the delivery elevator to see the salad they had delivered on the forklift ride. They went to the second elevator and had no issues going up to aquaponics. There they stood and	Motivation: Fun Presence: Presence in VR Motivation: Interesting Presence: Beginner friendly

		listened to the aquaponics sphere from a distance.	
9	• Teleporteringsavstanden er bedre inn en bysentrum" • Trykker hydroponisk kule først → hører på istedet for å se på teksten • Tok en runding i området, så gikk til vertikalt-kulen • Trykte led lys kulen → leser ikke på teksten, heller hører på, ser ikke på skiltet • Tester kontordøra, men får den ikke opp med det samme og tror at den derfor ikke funker • Trykker på CEA-kulen → trykker første gang på les-mer • Trykker på ledlys knappen uten problemer • Ingen problemer (speselt heisen) stor • "Føler meg liten men gir mening fordi dette er jo industri" • Ser rundt → kommenterer på skoene • Bruker mye hodet for å se på vertikalt farmen • "Se her poteter" → trykker på kulen og ser nøye på beskrivelsen → går rundt den • Går forbi trucken først "det er ikke meg som styrer" • Går til heis 2, liten bug • Trykker på kulen og hører på samtidig som det ses på fiskene	The participant started out by saying the teleportation distance worked better in the hangar than in the city center. They firstly went to the hydroponics sphere and listened to it rather than reading it. They went around the area, then to the vertical farming sphere. After, they went to the LED light sphere, and again did not read the text, instead just listening to it. Not even looking at the window. They tried to open the office door, but could not get it done immediately, and thus thought it did not work. They then selected the CEA sphere, and for the first time selected the option to read the full-text. They pushed the button to change color of the lights with no issues.	Presence: Control Presence: Beginner friendly

	“likte fiskeanimasjon” lol	They managed to take the elevator down with no issues, but they did mention that it was a quite large elevator and they felt small. However, they also noted it made sense because it was an industrial elevator. In the changing room, they looked around and made a comment that there were shoes. They were turning their head when looking at the vertical farm in the underground area. They selected the aeroponics sphere and read it thoroughly, then walked around the aeroponics system. At first, they went past the forklift. Notes that it is not them driving when on it. They experienced a small bug on the second elevator, going through the walls. They selected the aquaponics sphere and listened as they were looking at the fish.	Presence: Beginner friendly Motivation: Active

		They liked the fish animations.	Motivation: Fun
10	• Ser nøye på salatene og grubler på at det ikke har jord • Ser forskjellige kuler → velger ledlys kule → hører nøye på hva som sies → trykker på knappen det blir gul med deltakeren legger ikke merke til det med det første • Vertikalt landbruk kulen → høres interessant ut • Kom seg midt i salaten • Hydroponi-kulen → virker interessert, kommer med noe overraskende i teksten → krysser ut • Bruker kroppen for åkomme seg til • CEA kulen → kom seg inn ik ulen (blir litt forvirra) → trykker deretter CEA-kulen → virker som at høres konsentrert ut på stemmen • Går til heisen → error → teleporterer seg inn deretter går tilbake for å åpne døra for så å deretter • Leser skiltet des. “Nå blir det veldig spennende” • “Heldig hvis merker jeg ikke at jeg blir desinfisert” (ler) • Bruker mye kroppen • Går til aeroponiske systemer → ser på modellen → “Ledlys rør” og mystiske røtter” • Ser dampen på røttene (legger merke til	The participant started by looking closely at the salads and ponder that they did not use soil. They saw different spheres, and chose the LED light sphere at first. They listened closely to what was said. Then they pushed the button to change color of the lights, however they did not notice at first they were changing colors. They thought the vertical farming sphere sounded interesting. They ended up inside the salads at one point. The hydroponics sphere seemed interesting, and came with a surprise in the text. The participant closed it after they were done with it. They were using their body a lot to move. When selecting the CEA sphere, they ended up inside the	Presence: showing / visualization Motivation: Interesting Motivation: Interesting Motivation: Surprising

	detaljer) • beveger seg mye fysisk (garden hjelper mye slik at deltakeren stopper og ikke går inn i ting) • “Ble nesten litt svimmel” → av gaffeltrucken • Finner heis 2 → error kommer seg litt ut av heisen → trenger hjelp å komme seg inn i heisen • “ser fisk, hører vannlyden”, • Trykker på akvaponi-kulen → hører nøye på	sphere and got confused by where it was. They seemed to be concentrating on the voice when listening to it. They went to the elevator and had an error where they teleported into through the door. However, they went back out and did it properly. When down in the underground area, they read the sign there and said “Now it’s getting real exciting.” When getting disinfected, they say that they are lucky not to feel the disinfection process. They use their body a lot. They went to the aeroponics area, look at the model there and mention led lights, pipes, and mystic roots. They notices the mist in the aeroponics system. They paid attention to details. They were moving a	Presence: Attention on VR environment Presence: Break in presence Motivation: Interesting Presence: showing / visualization Presence: showing / visualization

		lot physically, and the guardian helped prevent them from going outside of the zone and bumping into things.. When riding the forklift, they felt a little dizzy. They went to the second elevator, and some issue getting into it. With some help, they managed to do it. They saw the fish and heard the sounds of the water. They selected the aquaponics sphere and listened closely to it.	Motivation: Active Presence: Break in presence

- Finn kontoret i første etasje og svar på sluttquiz for å fullføre

Participant no.	Notes/codes	Translation to english & coding	Themes & Subthemes
6	• Blir forvirret at knappsymbolen på des.rommet er en pil opp, men ellers finner veien greit til kontoret → blir litt redd at døra kom inn på ansiktet → virker veldig immersed → bruker bare høyre hånd på alt → ser på kontoret og drar ett til pc-en → snakker med seg selv når det reflekteres over rette svar → kom bort iet annet all på tastaturet → spør om vil avslutte eller ta alle 10 spm. Og virker at personen er veldig motivert til å ta den → greier uten feil å skrive inn på spm. 4 → blir stille og konsenterer seg på quizen → leser høyt quiz teksten for seg selv → fikk litt hjelp på spm. 6	The participant got confused by the button symbol in the disinfection room, due to it being an upwards arrow, but otherwise found their way fine back to the office. They got a little scared when the door closed on their face. They seem to be very immersed. They are only using their right hand for everything. They looked through the office and go straight to the pc. While doing the quiz, they talk out loud to themselves about what the right answers are.	Presence: Presence in VR Presence: Presence in VR Presence: Control Motivation: Want to perform because of end quiz

		They accidentally pushed the wrong key on the keyboard. When asked if they would rather finish, or answer all 10 questions, they seemed very motivated to answer the quiz. They had no issues typing the answer on question 4. They became quiet and concentrated on the quiz. They were reading the quiz text outloud for themselves. They needed some help on question 6.	Motivation: Want to perform because of end quiz Presence: Beginner friendly Motivation: Want to perform because of end quiz
7	• Finner veien veldig kjapt • Forslag → kunne hatt tall i heisen • Går og tar quizen på pc-en • "Husker ikke alle disse ordene da" (på Pc-en) • Virker som at deltakeren ikke sliter med å komme • Kommenterer på skrivelfeil på quiz spm.4 • Virker ikke at det funker greit å skrive på spm.4 på egen hånd. • Såg at det var samme spm. Om • "Å gå videre betyr at svaret er riktig?"	The participant quickly found their way back tot the office. They suggested having numbers in the elevator. They went to the pc and started the quiz. They mentioned how they did not remember all the words when on the pc, however it did not seem like they were struggling. They mention a	Presence: Beginner friendly

	• Klarte å fullførte med bare en feil	spelling error on question 4. It seemed like it went alright typing the answer to question 4 on their own. They noticed that a question repeated. They were unsure about whether they answered correctly and said "Moving on means that the answer was right?" They succeeded in the quiz with only one failed attempt.	Presence: Beginner friendly
8	• Finner lett itlbake til første etasje • Glemte hvor kontroer var, går til fake dørene • Bruker pekefingeren naturlig "det å huske burde jeg kanskje ha tenkte på…" flirer • Ble feil → måtte gjøre fra starten "å nei ble det jo litt dumt fordi da må gjøre på nytt?" • "Er det en ulempe?" spm. 3 • Blir overrasket over at det skal skrives inn på spm. 4 → virker som at tastaturet er greit • Virker veldig konsenteret og lese spm. → er stille og virker tenkende	The participant easily found their way back to the first floor. They forgot where the office was, and went to the fake doors instead. With the keyboard, using their index finger seemed natural. They mentioned how they should have thought about remembering when they went through, and laughed. When they got a wrong answer, they thought it was a bit dumb that they had to start all over again.	Presence: Beginner friendly Presence: Beginner friendly Presence: Break in presence

		Question 3 was a trick question, using the term "disadvantage". They were surprised that they had to type in the answer at question 4. It seemed like the keyboard worked alright. They seemed very concentrated when reading the questions. They were also quiet and seemed thoughtful.	Motivation: Surprising Presence: Beginner friendly Motivation: Want to perform because of end quiz

9	• Kommer seg lett til første etasje "prøver først fake dører
	• Ser quizen, men går rundt og utforsker kontorrommet først → legger merke til katten
	• "Litt motsatt med tall rekkefølge"
	• vårt
	  | 1 | 3 |
	  | 2 | 4 |
	• Burde være
	  | 1 | 2 |
	  | 3 | 4 |
	• Ser "bæsjen" skrivefeil
	• "Et pineri å ha typewriter inn i der" på spm. 4, bruker store bokstaver
	• Flirer av "spare sparepenger i
		The participant easily got back to the first floor, but went for the fake doors at first.
		
		They saw the quiz, but chose to walk around and explore the office room first.
		
		They made note of the cat.
		
		They thought it was a bit backwards with the order of numbers.
		
		They mentioned the misspelling in question 4.
		
		They thought it was painful to have a typepwriter in there at question 4.
			Motivation: (Guided) exploration path
			
			Presence: Break in presence

	sparegrisen" • "Kanskje istedetfor tastatur kunne ha fire knapper? • Greit, 6 forsøkt	They used large letters when typing. They laughed at the "spare sparepenger i sparegrisen" option. They suggested having four button to select from, rather than having a full keyboard. They succeeded after 6 attempts.	
10	• Error → kom seg først ut av området/"universet" to ganger • Tok litt tid å komme tilbake • Prøvde først å trykke på PC-skjermen • Blir forvirret at ved feil går man tilbake på spm. • Avslutter quizen før fullførelse, fordi deltakeren blir litt svimmel	The participant had some error where they got out stuck outside of the area, the universe, twice. It took some time to get back in. At the quiz, they first attempted to select on the monitor. They got confused by that wrong answers send them back to the beginning of the quiz. They had to quit before finishing the quiz, as they began to feel dizzy.	Presence: Break in presence Presence: Break in presence

SPØRRESKJEMA - SKJER ONLINE PÅ SURVEYXACT

SLUTT-TEST INTERVJU

1. Hvordan var denne opplevelsen for deg? Utdyp?

Participant no.	Notes/codes	Translation to english & coding	Themes & Subthemes
6	• Uvant, litt keitete begynnelsen, men ellers veldig interessant opplevelse	The participant thought it was unfamiliar and awkward, but otherwise a very interesting experience.	Motivation: Interesting
7	• Var gøy → en gøy måte å lære på → gå rundt • En veldig ressurskrevende/dyr måte å lære på da • "Når ting er gøy lærer man mer"	The participant thought it was a fun way to learn, and enjoyed walking around. They did admit it was a very resource heavy and expensive	Motivation: Fun Motivation: (Guided) exploration path

		way to learn. They think that when things are fun, that we learn more.	Motivation: Fun
8	• spennende , lærerikt → skulle fått inn i skolene, eller jobber, f.eks. Kunne hatt i matte → regne • Ser mange bruksområder ut ballonger • Hvis jeg ville vært 15 og skolelei → ville vært motiverende, ville ha vært en kul måte å lære annet på	The participant thought it was exciting, informative. They thought it should be adde to schools or work, and gave an example of having such an experience for math and calculations. They could see many use areas for the balloons. They thought that if they were 15 and tired of school, this would have been motivating, and a cool and different way to learn.	Motivation: Interesting Motivation: Interesting
9	- Var grei, såg ting som kunne forbedret - Litt irriterende med idgital tastatur, fordi du blir liksom "straffet" unødvendig, ville kanskje heller laget noen få knapper - Lite ting å interagere med - Kulen føltes som dekorasjon med det første → skrive noe på de for å indikere - Veldi intro-messig → ekte voiceover?	The participant thought it was alright, but saw areas that could be improved upon. They found it to be kind of irritating with the digital keyboard, because it was like they were being punished unnecessarily for being wrong. They suggest instead having only a few buttons. They thought there	Presence: Break in presence

		was little to interact with. The spheres felt like decoration at first, so there should be something written on them to indicate what they are. It was overall very introductory. They suggested having a real voice over, rather than an AI voice.	
10	• Helt nytt, var noe en del interessant, lærte også noe	The participant thought it was completely new, and that there were parts that were interesting. They also felt like they learned something.	Motivation: Interesting

2. Hvordan var det å kunne utforske omgivelsene i en virtuell verden?

Participant no.	Notes/codes	Translation to english & coding	Themes & Subthemes

6	• Var helt okay og gøy • Forslag → ville gjerne hatt en gjennomgang eller oversikt over alle konsept-ord • "Fin by" → litt artig å bli desinfisert	The participant thought it was okay and fun. They suggested having an overview of all the concept words they could look up. They thought it was nice city, and that it was fun being disinfected.	Motivation: Fun Motivation: Fun
7	• Kunne jo ikke plukket opp alt det ville vært mer gøy men samtidig var hjelpsomt med tekst	The participant thought it would have been more fun if there was more objects to pick up. At the same time, they thought the text was helpful.	
8	• Var lærerikt • Etterhvert forstår hvordan man beveg seg • Ville gjerne at utforske mer enn det var å utforske	The participant thought it was informative. After awhile they understood how to move. They would have liked if there was more to explore.	Motivation: Interesting Motivation: (Guided) exploration path
9	• bra → var litt lite å utforske • Pirke kulene med fingrene istedet • Litt mer å plukke opp osv. • Gjerne å kunne velge å ha kontrollere i tillegg • Tror at andre også syns kontroller er lettere	The participant thought it was good, but somewhat little to explore. They wanted to poke the spheres with their fingers instead. They wanted there to be more to pick up.	Presence: Control Presence: Control

		They would have liked the option to select having controllers as well as hand tracking. They thought that others would also find controllers to be easier than hand tracking.	Presence: Control
10	• var spennende → totalt ukjent Her studert geografi og samfunnsplanlegging så litt	The participant thought it was exciting, and totally unknown.	Motivation: Fun

3. Hvordan opplevde du formidlingen av tema?

Participant no.	Notes/codes	Translation to english & coding	Themes & Subthemes
6	• Litt mer overikt over konseptene • Ville flytte beskrivelsene litt rundt omkring • Kunne hatt at ballongen sa pang	The participant wanted more overview of the concepts. They also wanted to move the descriptions around	Presence: Control

		a bit. The balloon could have said "pop!"	
7	• Var jo into i tekst → var interessant → gikk ikke i dybden, men det gikk bra spesielt hvis du ikke er en fagperson • Forslag → kunne vært en animasjon En person f.eks. Som forklarer	The participant thought it was introductory in the text, and that it was interesting. It did not go in-depth, but it was okay, especially if someone is not a professional. They suggested having animation of someone talking and explaining.	Motivation: Interesting Motivation: Interesting
8	• Var spennedne → begynte kanskje litt på et litt for høyt nivå → mange ord jeg ikke hadde hørt om før - Fikk en forståelse om temaet → ble overrasket over at det visuelle var slik det er i virkeligheten	The participant thought it was exciting, and that it started a too high level. There were many words they had not heard of before. It gave them an understanding of the topic. They were surprised that the visuals matched how it is in reality.	Motivation: Fun Motivation: Surprising
9	• Kan bli litt monotont med kulene • Bruke enda mer lys med kulene • Visuelle var bra, men kanskje litt likt, men mer variasjon	The participant thought it could be a bit monotonous with the spheres, and suggested using more lights with them. The visuals were	

		good, but lacked variation and were too similar.	Presence: showing / visualization
10	• var veldig bra å kunne høre, og se teksten og modellen i tillegg "er en berikelse"	The participant thought it was very good to be able to hear and see the text along with the model. They felt it was an enrichment.	Motivation: (Guided) exploration path

4. Hvordan var dybden på det du lærte om?

Participant no.	Notes/codes	Translation to english & coding	Themes & Subthemes
6	• Fikk ideer på hvordan ting gjøres → f.eks. Effektiv nær → reflektere rundt mer • Husker bedre med slikt • Var veldig bra med stemmen → innholdet var på andre plass, fordi aldri gjort • Kunne tenkt å gjort det igjen	The participant got ideas on how things were done. They could reflect after. They felt it helps them remember better. They thought it was really good with the voice, and that the content was second place, because they	Presence: Beginner friendly Presence: Beginner friendly

		had never done it before. They could have gone through again.	Motivation: Interesting
7	• Ble interessert å lære med • Forslag → ha option for "lær mer" → at folk kan styre dybden	The participant was interested in learning more. They suggested having the option to learn more, so that people could control the depth themselves.	Motivation: Interesting Presence: Control
8	• Var forsåelig → var grei dybde → spennende tema • Fikk et godt startpunkt/introduksjon	The participant thought it was understandable, and alright depth. They thought it was an exciting topic. And that this was a good starting point or introduction.	Presence: Beginner friendly Motivation: Interesting Presence: Beginner friendly
9	• Var på overflaten, var greit • Har blandede følelser om det • Handler om hensikten og målgruppen, blir kanskje litt formelt → kunne vært mer interaksjon f.eks. Planteprossesen f.eks. Plukke potetre, se de vokse osv. • Heller å se prinsippet istedet for teksten (som en tilleggsgreie)	The participant thought it was surface level, and that it was alright. They had mixed feelings about it. They thought it depends on the target group. It could be seen as a bit too formal. There could have been more interactions, such as related to the plant process, pick	Presence: Beginner friendly

		potatoes, watch them grow, or such. They prefer seeing the principle, rather than the text. They would want the text as just an extra thing.	Presence: showing / visualization
10	Passelig, konsist og klart, uten å kjøre en lang lekse, følte ikke behov for mer	The participant said it was suitable, concise and clear, without making it a long homework. They did not feel the need for more.	Presence: Beginner friendly

5. Hvordan var det å lære om temaene i en slik virtuell opplevelse, i motsetning til hvis du skulle lært om det ved å lese i en bok, på nett, eller se en video?

Participant no.	Notes/codes	Translation to english & coding	Themes & Subthemes
6	• Har vært lærer for vgs • Gå gjennom først og deretter å lese boka • Får nysgjerrighet først • Her må du da være aktiv og holde deg våken, bedre enn film	The participant had been a teacher for high school, so they saw the experience as something that could be done first, then read the book. They thought it gave curiosity first.	Presence: Beginner friendly

		Because in the experience, you have to be active and stay awake, which makes it better than film.	Motivation: Interesting Motivation: Active
7	• En ting er jo at i en bok så er det en start og en avslutning aka du har kontroll Mens her så kan det hende du har glipt → forslag → ha en tema oversikt system → to-do list som kan krysses av	The participant mentioned how compared to a book which has start and an end, you have control in the immersive experience. Here, you could miss something when going through. They suggested having an overview system, or a to-do list that keeps up with the progress of the topics.	Presence: Control Motivation: (Guided) exploration path
8	• "Som natt og dag" → bok ikke tvil om det ville ha blitt lagt bort • Mye bedre enn video → fordi kunne utforske og se ting, trykke på ting • Ville også vært interessant med et system på pc- også som kan trykkes	The participant thought it was like night and day. There is no doubt that they would have put the book away. They thought it was better than video, because they could explore and inspect things, as well as push things. It would also have been interesting with a system on pc where things can be pushed.	Presence: showing / visualization Motivation: (Guided) exploration path

9	• Bedre å gjøre dette enn en video • Godt grunnlag, mye man kan gjøre med det • Gjøre det lettere på hvor man skal hen, mer skilting	The participant thought it was better to do this than a video. It was a good foundation, and there is a lot that can be done with it. They made a suggestion of making it easier to know where they are supposed to go, by having more signs.	Motivation: (Guided) exploration path
10	• Ville foretrukket dette → fordi noe helt nytt, fikk det forklart og konsist i en bra mengde	The participant would have preferred this, because it is something completely new. They felt they got the topic explained in a concise and good amount.	Presence: showing / visualization Presence: Beginner friendly

6. Tror du at å lære på denne måten kommer til å hjelpe deg å huske temaene lengre i ettertid? Hvorfor?

Participant no.	Notes/codes	Translation to english & coding	Themes & Subthemes
6	• Ja fordi bildet og fordi vært aktiv, kunne	The participant thought yes,	Presence: showing / visualization

	gjerne gjort flere ganger ● En gang litt for lite	because they have an image to look back on and they had been active. They could have done it multiple times. One time was too little.	Motivation: Want to perform because of end quiz
7	● Ja det tror jeg → fordi spennende tema og hvor mye som er lagt i omgivelsene ● Det å være aktiv gjorde lettere Var på memorering kurs → bruke å visualisere et rom for å huske ting bedre	The participant thought yes, because it was an exciting topic and because of how much was put into the environments. Being active made it easier. They had been on a memorization course, and used a strategy of visualizing a room to make remembering things easier.	Motivation: (Guided) exploration path Motivation: Active Presence: showing / visualization
8	Ja, fordi jeg ble mer involvert i selve tema enn hvis jeg ville lest en bok, fordi knytte visuelt F.eks. Det at det var fisker heter akvaponisk det hadde jeg aldri husket uten slik jeg såg det	The participant thought yes, because they got more involved in the topic itself, rather than if they had read a book, because they can make visual connections. As an example, they mentioned how they would not have remembered that the fish area was called aquaponics without experiencing it like they did.	Presence: showing / visualization Presence: showing / visualization

9	Jo, men tror at det burde være mer interaksjoner	The participant thought yes, but that it needs more interactions.	Motivation: Active
10	● visse deler → fordi jeg kunne se det visuelt "en annen opplevelse, andre/mer synsinntrykk en bok	The participant thought some parts of it, because they could see it visually. It was a different experience and gave other sensory inputs than a book.	Presence: showing / visualization Presence: showing / visualization

7. Tror du VR opplevelser generelt kan gjøre det mer interessant å lære?

Participant no.	Notes/codes	Translation to english & coding	Themes & Subthemes
6	Ja, det engasjerer, litt spillete, "grep meg også som en litt eldre person"	The participant said yes, it engages, it is somewhat game-like, and that it gripped them even as an elder person.	Presence: Beginner friendly
7	Ja, kommer an på hvordan det er gjort ● Skal mye til at VR ikke gøy ● Kommer også an på kvaliteten, og hva som skal læres f.eks. Matte litt vanskelig	The participant thought yes, but it depends on how it is done. It is hard to make VR not fun.	

	● Praktiske ting funker	It depends on the quality, what is to be leaned. As an example, math could be difficult. Practical topics work.	Presence: showing / visualization Motivation: Active
8	Ja veldig, men merker ble litt sliten på slutten fordi f.eks. Bevegelse i trucken	The participant thought yes, very. However, they felt tired at the end because of the movement in the forklift.	
9	● Ja tror det for mange, men skal være ● Spill gjør mange nysgjerrig ● Men man skal være litt forsiktig fordi det kan noe ganger bli dårlig	The participant thought yes, and that it would apply for many others as well. They thought games make people curious. However, one should be careful because it can sometimes be bad.	Motivation: Interesting
10	● i mitt hodet er dette i startfasen, men ser potensialet "Mer effektiv på en korttidsintervall"	The participant thought it was in the start phase, but they see the potential.	

8. Hvordan følte du det var å bevege deg rundt ved å teleportere?

Participant no.	Notes/codes	Translation to english & coding	Themes & Subthemes
6	● Krevde litt ● Prøver åf inne pekeren fordi den forsvant av og til	The participant thought it demanded some effort. They struggled with finding the pointer at times.	
7	● Funker veldig fint	The participant thought it worked quite nicely.	Presence: Beginner friendly
8	● Gikk greit → følte det gikk greit ● Følte det var naturlig å bruke fingrene og ikke beinene så mye	The participant thought it went alright. They felt it was natural to use their fingers and not their legs so much.	Presence: Beginner friendly
9	● Helt greit ● Har p erfaring med det, er ikke den mest naturlig, men andre VR har jo det samme ● Mer komfortable hvis kontrollere brukes	The participant thought it was alright. They did have some experience with it, but it is not the most natural thing, but they note that other VR experiences have the same. They would have preferred using controllers.	Presence: Control
10	● hadde problemer i startenmed klyping, men " ● veldig spennende å være med på dette"	The participant had some issues at the start with pinching and selecting from distance, but they got more control by the end.	Presence: Control

		They thought it was very exciting to be part of this study.	

9. Hvordan føltes det å kunne se det digitale lagt over det virkelige?

Participant no.	Notes/codes	Translation to english & coding	Themes & Subthemes
6	• Merker ikke det engang • Trodde at vi var en en "forsker peride" • Tenkte ikke over det engang, først da vi gikk fra bro til byen og det ble svart → døra var en portal ikke en bro for meg (forvirret med mindre bro)	The participant di not even notice anything. They did not even think about it, it was first when they crossed into the city and it got black that they noticed. The door was a portal, not a bridge to them, which they confused with the smalled bridge.	Presence: Presence in MR Presence: Presence in combination of MR and VR
7	• Var veldig stilig → følte at det kanskje mer pikselert en VR området • Føltes ganske naturlg "nesten som om det var et bord" også "kan	The participant thought it was very cool. They felt it was a bit more pixelated than the VR environment.	Motivation: Interesting

	du ikke gå inn i et bord"	It felt quite natural, almost like there was a table there, and you know you cannot go into the table.	Presence: Presence in MR
8	• La ikke merke til det "tenkte ikke over det" • Såg egentlig bare by-modellen	The participant did not think about it. They only really saw the city model.	Presence: Presence in MR
9	• Bedre passthrough her, føltes naturlig, men haptic mangler jo her da	The participant thought it was better passthrough on the Quest Pro, and that it felt natural. They mentioned that haptics were missing.	Presence: Presence in MR
10	• Føltes naturlig → la ikke merke til det	The participant thought it felt natural, as they did not notice anything.	Presence: Presence in MR

10. Hvordan føltes det å gå gjennom døra mot broen? Merket du noen forskjell? Utdyp?

Participant no.	Notes/codes	Translation to english & coding	Themes & Subthemes
6	Husker ikke		

7	• "Det var jo der det ble fullimmersion" • Føltes naturlig, merket ikke noe	The participant said that was where it became full immersion. It felt natural, as they did not notice anything.	Presence: Presence in combination of MR and VR
8	• Ja reagerte var "først sammen med dere" så dro på ferie" • Føltes ikke naturlig • Ble sjokkert at det gikk ann (overgangen) fra ekte til fully immersed	The participant thought yes, the reaction was at first that they thought they were with us, and then they went on vacation.	Presence: Presence in combination of MR and VR
9	• Var greit, ikke så veldig intuitivt å trykke på kulene • Jeg er vant med slikt så det føltes naturlig	The participant thought it was alright, but not so very intuitive to select the spheres. They are used to it so it felt natural.	Presence: Presence in combination of MR and VR
10	• Føltes naturlig → tenkte ikke over det	The participant thought it felt natural, because they did not think about it.	Presence: Presence in combination of MR and VR

11. Hvordan føltes det da du gikk fra broen til byen? Merket du noen forskjell? Utdyp?

Participant	Notes/codes	Translation to english	Themes &

no.		& coding	Subthemes
6	Alt føltes mye større → følte at jeg var i byen	The participant thought everything felt a lot bigger, and that they were in the city.	Presence: Presence in VR
7	• Føltes naturlig, la ikke så merke til det	The participant thought it felt natural, as they did not notice anything.	Presence: Presence in VR
8	• Wow "føltes å gå inn i ferien" • "Følte at jeg var liten, plutselig, føltes naturlig (fra å se mini-modellen også være inni den)	The paritcpant said "wow", and that it felt like going into vacation. They felt small suddenly, and that it was natural going from seeing the miniature model to being in it.	Motivation: Surprising Presence: Presence in VR
9	• Forbauset først da, ville finne ut reglene • Antok at jeg var ib yen, jeg såg i MR(mini modellen)	The participant were baffled at first, and wanted to figure out the rules. They assumed they were in the city they had seen in the miniature model.	Motivation: Surprising Presence: Presence in VR
10	• Urealistisk → minnet om science fiction, livløs, øde Følte meg tilstede der, men med sterk ønske om at det skulle se annderledes ut	The participant thought it was unrealistic, reminded them of science fiction, lifeless, deserted. They felt they were there, but they had a strong desire that it had looked different.	Presence: Connections between immersive tendencies and presence Presence: Presence is subjective

12. Hvordan føltes det da du satt på gaffeltrucken?Merket du noen forskjell? Utdyp?

Participant no.	Notes/codes	Translation to english & coding	Themes & Subthemes
6	"Følte den kjørte bakover" → følte ikke jeg hadde kontroll	The participant felt it drove backwards, and that they did not have control.	Presence: Control
7	• var veldig skuffet at jeg ikke kunne kjøre det • "Man kan jo ikke sitte heller" → prøvde jo å sitte litt" • Forslag → istedet for å trykke på skilt → heller kunne åpne døra	The participant was very dissapointed that they could not steer it. They also note how they could not sit either, as they had attempted. They made a suggestion of instead having to click buttons, that they could open the doors and control it manually.	Presence: Control Presence: Control
8	• Veldig lyst å kunne styre det • Var ikke forberedt på det • Gav mening at det jobbes slik	The participant wanted very much to steer it. They were not prepared for it. They thought it made sense how the work	Presence: Control

		was done.	
9	• Var ikke skuffet at jeg ikke kunne kjøre det	The participant was not dissapointed that they could not steer.	
10	• Følte meg uvel, ble litt forvirett hva som skjedde	The participant felt unwell, and got confused by what was happening.	Presence: Break in presence

13. Hva ville du ønsket å fått ut mer av denne VR opplevelsen? For eksempel har du noen forslag til endring? Er det noe som stakk ut for deg som du likte eller ikke likte?

Participant no.	Notes/codes	Translation to english & coding	Themes & Subthemes
6	• Noe annet enn bare salat → litt andre planter • Bassenget med fisk, noe krabber	The participant wanted there to be more plants than just salads, that there was more diversity. There could be some crabs in the fish tank.	Motivation: (Guided) exploration path
7	• Jo mer ting som puttes inn destå mer mer gøy" → så lenge det passer med hensikten at man lærer	The participant thought that the more stuff is put in, the more fun it will get. As long as it fits with the purpose of what they are supposed to learn.	Motivation: (Guided) exploration path

8	• Vet så lite om det kan ikke komme på noe • Ville vært gøy å hatt om andre temaer innenfor bærekraft • Plukke opp mer ting	The participant knew so little of that they could not think of anything. It would have been fun to hear about other topics within sustainability. They would also like to be able to pick up more in the environment.	Motivation: (Guided) exploration path Motivation: Active
9	• Likte ideen, veldig mye bra, godt base • Litt mer utviklet eks. Meningsfulle interaksjoner	The participant liked the idea, and said there was much good in there and that it was a good base to develop further on. They would have liked if it was more developed with meaningful interactions.	Motivation: Active
10	• Byen burde se litt annderledes ut, mer livlig → vil ha mennesker • Syns det var artig å å se jordbruks på denne måten, → ville kunne hjelpe norsk landbruk, og globalt • Syns temaet med plantedyrking var veldig interessant	The participant thought the city should look different, more lively, and have people. They thought it was fun to see agriculture in this way. They thought it could help norwegian agriculture, as well as globally. They thought the topic of plantgrowing was very interesting.	Presence: Presence in subjective Motivation: Fun Motivation: Interesting

14. Har du noe annet som du føler burde bli nevnt?

Participant no.	Notes/codes	Translation to english & coding	Themes & Subthemes
6	-	-	
7	• Ja hensikten med undersøkelse å • Ville gjerne hat mer guide slik at en bruker kan gjøre ting selv, • Forute mer farger og at ting lyser • Gjerne hatt en rekkefølge på kulene	The participant would have wanted more guide so that they could have done more on their own. They would also have like more colors and lights, and that the spheres were in order.	Motivation: (Guided) exploration path
8	nei	No.	
9	-	-	
10	-	-	

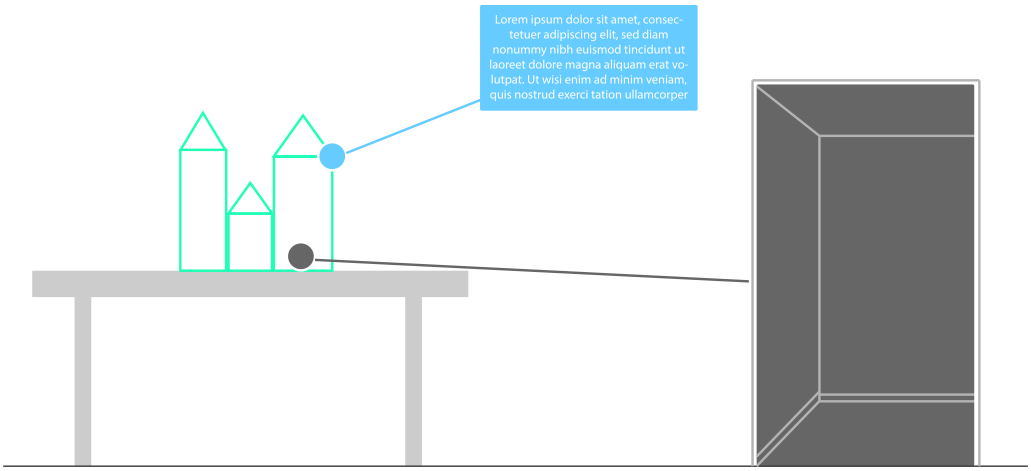
Appendix D

Link to video demo of sustainable future city use case prototype

Link: https://vimeo.com/828936205

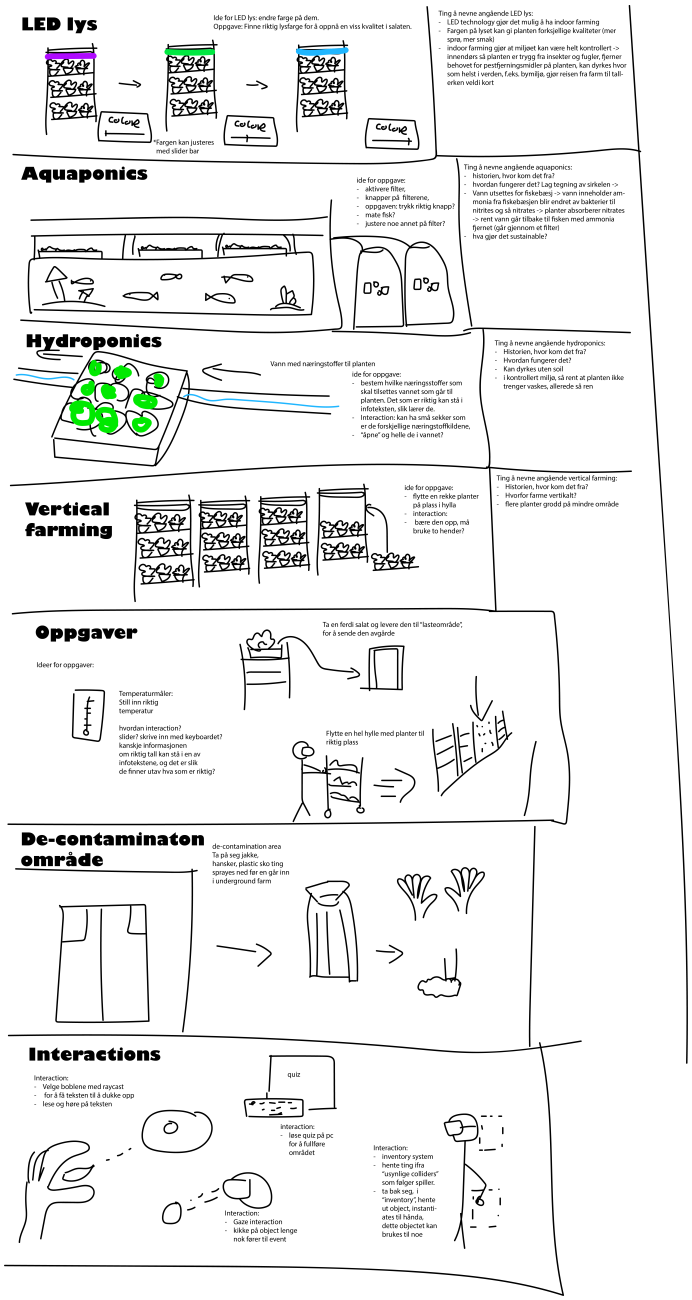
Appendix E

Storyboard - MR and VR environment & concept spheres for learning of concepts overview plan



Appendix F

Storyboard - visualization & interactions



Appendix G

Text script & assets

Text Script

Iteration 1

Explanation of Concepts

Hva er Bærekraft?
Begrepet 'bærekraft' blir mye brukt den dag i dag. Når vi hører politikere i mediene snakke om at vi må jobbe mot et bærekraftig samfunn. Hva betyr det egentlig? I følge FN sine norske hjemmesider fra 2021 er definisjonen på 'bærekraftig utvikling' slik, sitat; "En utvikling som imøtekommer dagens behov uten å ødelegge mulighetene for at kommende generasjoner skal få dekket sine behov [107]".

Med andre ord, det handler altså om å ta vare på mennesker og miljøet. Vi må passe på at vi ikke bruker opp ressurser på den måten at det skapes en ubalanse, og jobbe mot at dagens og fremtidige generasjoner har en klode å leve på. I tillegg til at alle kan leve et godt nok liv der behovene deres er møtt istedet for å leve et liv i fattigdom [107].

Hva er CEA?
CEA er en forkortelse for det engelske begrepet 'Controlled Environment Agriculture'. Konseptet går ut på å bruke teknologi for å kontrollere miljøet der plantene dyrkes slik at det så kan kontrolleres hvordan plantene vokser på den beste og mest effektive måten [108], [109]. Dette gjøres ved å ha et avgrenset og isolert område, som for eksempel et innendørs eller undergrunns anlegg, for å kunne kontrollere alt fra lys, næringsstoffer, temperatur, luftfuktighet og andre avgjørende sider ved produksjonsprosessen [109].

En fordel med CEA er at man kan dyrke planter som er av god kvalitet, flere ganger i året, fordi bonden verken er avhengig av været, sopp, dyr eller andre uforudsigbare hendelser som kan skade avlingen [109].

LED lys teknologi
Spranget i utviklingen av billigere, mer miljøvennlig og effektivt LED-lys teknologi i de siste årene har gjort det mulig å se på CEA konseptet som en mer seriøs løsning innenfor plantedyrking og landbruk enn før. Forskning viser også at forskjellige typer lysinnstillinger kan gi forskjellige typer utfall for plantene. For eksempel kan styrken på lyset avgjøre at planten vokser fortere, konsistensen er fastere, eller til og med at fargen på lyset gjør noe med smaken til planten.
End Quiz - 3 questions

1. **Hva handler 'bærekraft' og 'bærekraftig utvikling' seg om?**
   (a) Ta vare på trærne
   (b) **Ta vare på mennesker og miljø**

(c) Ta vare på matproduksjonsindustrien

(d) Ta vare på alle menneskene

2. **Hva er CEA en forkorteles for?**

   (a) **Controlled Environment Agriculture**

   (b) Controlled Eating Agriculture

   (c) Constructed Environment Agriculture

   (d) Controlled Environment Agression

3. **Er dette utsagnet korrekt eller falsk?**

   (a) Korrekt

   (b) **Falsk**

Iteration 2 - last version/final version for scope

Explanation of Concepts

Hva er Bærekraft?
Begrepet 'bærekraft' blir mye brukt den dag i dag. Når vi hører politikere i mediene snakke om at vi må jobbe mot et bærekraftig samfunn. Hva betyr det egentlig? I følge FN sine norske hjemmesider fra 2021 er definisjonen på 'bærekraftig utvikling' slik, sitat; "En utvikling som imøtekommer dagens behov uten å ødelegge mulighetene for at kommende generasjoner skal få dekket sine behov [107]".

Med andre ord, det handler altså om å ta vare på mennesker og miljøet. Vi må passe på at vi ikke bruker opp ressurser på den måten at det skapes en ubalanse, og jobbe mot at dagens og fremtidige generasjoner har en klode å leve på. I tillegg til at alle kan leve et godt nok liv der behovene deres er møtt istedet for å leve et liv i fattigdom [107].

Hva er CEA?
CEA er en forkortelse for det engelske begrepet 'Controlled Environment Agriculture'. Konseptet går ut på å bruke teknologi for å kontrollere miljøet der plantene dyrkes slik at det så kan kontrolleres hvordan plantene vokser på den beste og mest effektive måten [108], [109]. Dette gjøres ved å ha et avgrenset og isolert område, som for eksempel et innendørs eller undergrunns anlegg, for å kunne kontrollere alt fra lys, næringsstoffer, temperatur, luftfuktighet og andre avgjørende sider ved produksjonsprosessen [109].

En fordel med CEA er at man kan dyrke planter som er av god kvalitet, flere ganger i året, fordi bonden verken er avhengig av været, sopp, dyr eller andre uforudsigbare hendelser som kan skade avlingen [109].

LED lys teknologi
Spranget i utviklingen av billigere, mer miljøvennlig og effektivt LED-lys teknologi i de siste årene [110] har gjort det mulig å se på CEA konseptet som en mer seriøs løsning innenfor plantedyrking og landbruk enn før.

Forskning viser også at forskjellige typer lysinnstillinger kan gi forskjellige typer utfall for plantene. For eksempel kan styrken på lyset avgjøre at planten vokser fortere, konsistensen er fastere, eller til og med at fargen på lyset gjør noe med smaken til planten [111], [112].

Hva er et hydroponiske systemer?
Hydroponiske systemer er når planter blir dyrket uten jord. De vanligste er å brukes vannbaserte næringsrike løsninger, eller til og med kokosnøttskall blandinger i stedet [113]. Ofte blir hydroponi kombinert med andre dyrkingsmetoder som for eksempel vertikalt landbruk. Det finnes også flere

undergrupper som har blitt til noe eget. Noen av de største undergruppene er aeroponiske og akvaponiske systemer [114].

Hva er vertikalt landbruk?
Vertikalt landbruk er akkurat som navnet tilsier, nemlig å dyrke plantene vertikalt og i flere lag oppå hverandre [115]. En fordel med dette er at det sparer plass. Et slikt oppsett finnes ofte i innendørs eller undergrunns dyrking i kombinasjon med CEA metoden [114].

Hva er akvaponiske systemer?
Akvaponiske systemer, også kalt akvaponi, er når planteproduksjon, akvariske dyr som for eksempel fisk, og bakterier kombineres for å skape et resirkulerende økomiljø. Her, i likhet med helt hydroponiske systemer, brukes det ikke jord, i stedet absorberer plantene vannet fiskene svømmer i. Vannet inneholder fiskenes avfall som bakteriene i vannet omvandler til en næringsrik løsning [116], [117].

Hva er aeroponiske systemer?
Aeroponiske systemer er når planten dyrkes ved at vann eller vannbaserte næringsrike løsninger sprutes som 'damp' på røttene til planten, mens selve planten blir plassert uten jord ovenpå en platform. Fordelen med slike systemer er at røttene får mer oksygen som hjelper dem å vokse fortere [118].

Aeroponiske systemer kan se forskjellige ut. Noen ganger kan dampprossessen ikke ses, fordi selve planten ligger i lukkede beholdere [118].

End Quiz - 10 questions

1. **Hva handler 'bærekraft' og 'bærekraftig utvikling' seg om?**
   (a) Ta vare på trærne
   (b) **Ta vare på mennesker og miljø**
   (c) Ta vare på matproduksjonsindustrien
   (d) Ta vare på alle menneskene
2. **Hva er CEA en forkorteles for?**
   (a) **Controlled Environment Agriculture**
   (b) Controlled Eating Agriculture
   (c) Constructed Environment Agriculture
   (d) Controlled Environment Agression
3. **Er dette utsagnet korrekt eller falsk?**
   (a) Korrekt
   (b) **Falsk**
4. **Det at planter dyrkes uten jord kalles hydroponiske systemer. Skriv enten Falsk eller Korrekt nede i feltet.**
   (a) **Korrekt**
5. **Hva er en fordel med vertikalt landbruk**
   (a) Sparer olje
   (b) Sparer planter
   (c) **Sparer plass**

(d) Sparer sparepenger fra sparegrisen

6. **Hva kalles systemer der planten dyrkes ved at vann eller vannbaserte næringsrike løsninger sprutes som 'damp' på røttene til planten, mens selve planten blir plassert uten jord ovenpå en platform.**

   (a) Dampmaskin systemer

   (b) **Aeroponiske systemer**

   (c) Airponiske systemer

   (d) Heng i lufta systemer

7. **En ulempe med aeroponiske systemer er at planten ikke får nok oksygen og dermed vokser saktere.**

   (a) Korrekt

   (b) **Falsk**

8. **Innenfor akvaponiske systemer blir basjen til fisken eller andre akvariske dyr brukt som dyrkemiddel for plantene ved at bakterier i vannet omvandler det til noe næringsrikt.**

   (a) **Korrekt**

   (b) Falsk

9. **Akvaponi, er et annet ord for akvaponiske systemer**

   (a) Falsk

   (b) **Korrekt**

10. **Det er bare lov å bruke fisker i akvaponiske systemer**

    (a) Korrekt

    (b) **Falsk**

Sound Effects

Iteration 1

From package - Oculus Integration SDK

Name of sound effect	Where it was used	Source
Interaction BasicRay Back	Used whenever the user teleports	[66]
Interaction BasicRay Hover	Used whenever the user hovers over a an information sphere or a menu element	[66]
Interaction BasicRay Press	Used whenever the user selects an information sphere or a menu elements	[66]
Interaction BasicRay Release	Used whenever the user releases an information sphere or a menu element after having selected it	[66]
Interaction Object Reappear 01	Used for the door to the bridge whenever the red sphere is selected	[66]
Interaction BasicGrab Grab 01	Used for when the elevator, disinfection room, and LED light buttons are pressed in	[66]
Interaction BasicGrab Grab 03	Used for when the elevator, disinfection room, and LED light buttons are released	[66]
Interaction BasicGrab Grab 02	Used for when a key on the keyboard in the office is pressed down	[66]
Interaction BasicGrab Grab 04	Used for when a key on the keyboard in the office is released	[66]
Interaction BasicPoke ToyButton Press 01	Used for when grabbing the hangar and office doors	[66]
Interaction BasicPoke ToyButton Release 01	Used for when releasing the hangar and office doors	[66]

From other sources

Name of sound effect	Where it was used	Source
Norwegian voice, Finn	Used for creating voice over that is played when an information sphere is selected	[89]

Iteration 2

From package - Oculus Integration SDK

– all sounds from interaction 1 are still used

From other sources

Name of sound effect	Where it was used	Source
Fridge motor hum	Used for sound of water circulation in the aquaponics area	[119]
Industrial machine hum	Used for sound of elevators' engine when going up or down	[119]
Industrial hum loop	Used as a humming sound from LED lights	[119]
Heavy sliding door	Used for sound of elevator doors and disinfection room doors sliding when opened or closed	[120]
Motorcycle engine working	Used for sound of forklift driving	[121]
Noise of spinning rattle	Used for the sound of the disinfection process	[122]
Doorbell tone	Used for the elevator reaching either its top or bottom destination	[123]
Ocean game movement water air tank bubbles huge long	Used for the fish tank in the aquaponics area	[124]
Deep water bubbles	Used for the fish tank in the aquaponics area	[124]
Small waves harbor rocks	Used for the water around the bridge, ocean around the city, and the fountain inside the city	[125]
Desert ambience	Used as wind while crossing the bridge and also in the city	[126]
European forest ambience	Used as chirping birds while crossing the bridge and also in the city	[127]

Code Script

Iteration 1 and 2 (there were no changes to the following scripts between iterations)

Name of script and where it can be found in the Unity project	What it does	Inspirat -ion?
AnimationVariantSelector.cs *Where is it used?* UndergroundFarm.scene → Objects → Greenhouse → Aquarium → Fish → Fishmover The script is placed on all the "fishmover" gameobjects, invisible gameobjects that the fish models are attached to.	Fish in the aquaponics area can have 3 different animations of how they swim. This script randomly assigns one of these animations to each fish as well as randomizing where in the timeline the animation starts. This is done to make the fishes' movement unique and not seem like they all have the same animation and movement.	
BillBoard.cs *Where is it used?* In the bridge.scene and undergroundfarm.scene, on the information spheres' glow. Find a sphere gameobject and see under Sphere → circular	Makes a gameobject always face the player. The information spheres have a slight glow to them. This is done by having a transparent circular gradient image that has a higher intensity in the middle and fades off near the edges. This image is symmetrical, which makes it hard to notice that it is actively rotating to face towards the user.	
ColorChanger.cs *Where is it used?* UndergroundFarm.scene → Objects → Top Floor → Button LED	Changes the color of the LED lights in the scene. This is done by accessing the LED lamps' fake volumetric light material and changing its color value, as well as toggling on or off groups of point lights that are different colors in the scene.	
Decontaminate.cs *Where is it used?* UndergroundFarm.scene → Objects → Basement → Structure → Decontaminate → First door, and Second door	Handles the disinfection process by opening and closing the doors, as well as toggling the disinfection spray's particle and sound effects.	
Dooranimations.cs *Where is it used?* Bridge.scene → Objects → Table → Information Spheres → Sphere - DoorToBridge	Handles the door to the bridge sphere in the mixed reality scene. It plays the animation to make it come up from the ground or go back under, as well as toggling the gameobject from active to inactive, or vice versa.	
DoorGrabbable.cs *Where is it used?* City.scene → Big city → Structures → Buildings → Handar → gate door (L and R) → Handler → GrabbableHandler UndergroundFarm.scene → Objects → Top Floor → Structure → Office → Structure → Openable door → Door → Handler → GrabbableHandler	The hangar and office doors can be opened by grabbing the handle and pushing or pulling. The user does not actually grab the door object, instead they grab an invisible "grabbable handler" gameobject. The DoorGrabbable.cs script makes the "grabbable handler" gameobject reset its position and rotation back to where it should be. Without it, the "grabbable handler" would no longer be positioned on the door handle, because the user had moved it somewhere else. The function was inspired by a video tutorial by user Valem on Youtube.	[128]

Name of script and where it can be found in the Unity project	**What it does**	**Inspirat -ion?**
ElevatorMove.cs *Where is it used?* UndergroundFarm.scene → Objects → Elevator 1 & Elevator 2	Handles elevator behavior. The user can press buttons to open the elevator doors, walk in and take the elevator down to the basement, up to the first floor again, as well as up or down from the greenhouse. The elevator works by changing the Y value of the user's position to move them up or down, as there are two elevator models on top of each other.	
FollowForklift.cs *Where is it used?* UndergroundFarm.scene→ Objects → Basement → Forklift → Viewpoint	Makes the user gameobject follow the forklift by updating its position and rotation to match that of the forklift. It does this whenever the "viewpoint" gameobject is active	
FollowPhysics.cs *Where is it used?* City.scene → Big city → Structures → Buildings → Handar → gate door (L and R) → Handler UndergroundFarm.scene → Objects → Top Floor → Structure → Office → Structure → Openable door → Door → Handler	This script is attached to an invisible gameobject, "Handler", that is attached to a "GrabbableHandler" gameobject. The script makes it so that the "Handler" gameobject follows the "GrabbableHandler" gameobject when it is grabbed by the user. The "Handler" is also attached to the door's hinge joint as a fixed joint, so when the "Handler" gameobject is moved, the door moves with it. The function was inspired by a video tutorial by user Valem on Youtube.	[128]
ForkliftRide.cs *Where is it used?* UndergroundFarm.scene → Objects → Basement → Forklift → Forklift	Handles the forklift ride. When selecting to ride the forklift, the screen fades to black and the user is moved to be positioned at the wheel of the forklift before fading back in. An animation then plays of the forklift picking up a shelf of lettuce and delivering it to the large elevator. At the end an exit button appears, and the user is placed back on the ground.	
Keyboard.cs *Where is it used?* UndergroundFarm.scene → Objects → Basement → Forklift → Forklift	Handles the keyboard input events when pressing keyboard buttons. The function was inspired by a video tutorial by user RealaryVR on Youtube.	[129]

Name of script and where it can be found in the Unity project	What it does	Inspirat -ion?
KeyboardButton.cs *Where is it used?* Can be found on the buttons. Example: UndergroundFarm.scene → Objects → Top Floor → Structure → Office → Keyboard → Buttons → Normal → Letters → q	This script handles what characters are assigned to each key of the keyboard. It takes the name of the gameobject and makes it the string value of the child as well, which can then be grabbed as a string. The function was inspired by a video tutorial by user RealaryVR on Youtube.	[129]
QuizChecker.cs *Where is it used?* UndergroundFarm.scene → QuizChecker	Handles quiz functionality and checks if user answers are correct. If correct, it moves onward. If wrong, it resets the quiz. It also counts how many attempts the user takes to complete the quiz. On completion, the user can return to the mixed reality scene.	
RaisePlayer.cs *Where is it used?* City.scene → OculusInteractionSampleRig → OVRCameraRig → TrackingSpace → CenterEyeAnchor → Playercollider	If the user is detected in the area in front of the hangar, there is a teleport area there that will be activated. The teleport area that is normally beneath the player will be disabled. This is because the area in front of the hangar is sloped, so the user needs to be raised or lowered when going up or down the ramp.	
Scenes.cs *Where is it used?* Bridge.scene → OculusInteractionSampleRig → OVRCameraRig → TrackingSpace → CenterEyeAnchor → Playercollider and City.scene → SceneManager and UndergroundFarm.scene → SceneManager	Handles loading of other scenes. It also fades to black before loading a scene.	
Teleport.cs *Where is it used?* In mixed reality scene, teleportation area. Also in city and underground farm scene → OculusInteractionSampleRig → Teleportation area → Teleportation Plane (all)	Handles teleportation. Under the user there are hundreds of small invisible square planes that can be selected to move to that position.	
IllusionShader.shader *Where is it used?* It is applied as a material in: Bridge.scene → Objects → InvisPlane and Bridge.scene → Objects → Door To Bridge → Structure → ExteriorWall (all 3)	This is a shader that hides everything behind it. It is used to have invisible surfaces in the mixed reality scene around the door to make it seem like a portal to the VR world. This shader was inspired by and found as a reply in a forum on gamedev.stackexchange.com, by user DMGregory, who helped someone solve a similar issue.	[83]

Downloaded assets and models

3D models and object used in Iteration 1 and 2

Name of model	Where it was used	Source
Wooden Crate Storage Box	Used to place salads in on the salad shelves in the underground farm	[130]
Bench	Placed in various locations in the city as decoration	[131]
Commuter bike 3D	Placed in the city as decoration	[132]
Modern Street Bin #05	Placed in the city as decoration	[133]
Concrete column	Placed in the city as decoration and to indicate where the player cannot go	[134]
Madeka Fish	Used in the aquaponics area and animated to swim in the fish tank	[135]
Forklift truck	Used in the underground area of the hangar as an interactable vehicle the user can ride	[136]
Greenhouse 3d Model	Used in the city as exterior for a greenhouse and as an interior for the aquaponics area	[137]
Arched Hangar	Used in the city as exterior for the hangar and as interior for the underground farm area	[138]
Fluorescent Lamp	Used as LED lights in the underground farm area	[139]
Animated water	Used as guiding material to make animated water in and around the city	[140]
Shelf	Used as a shelf to display vertical farming	[141]
Metal fly	Used as a statue piece in the city	[142]
Gaia 2021 - Terrain & Scene Generator	Gaia is a add-on tool to Unity that was used to create the terrain in the city	[86]
Pack Natureza Arvores e pedras model	Trees placed in the city on the terrain	[143]
Bridge	Used as a bridge in the mixed reality scene and the city	[144]
Miami 2525	Part of the model is used for the city buildings	[85]
3D Commercial Steel Doors model	Used for the sliding doors in the disinfection area of the underground farm	[145]
Modern Luxury Arch	Used as the doorway into the fully virtual space in the mixed reality scene	[146]

Name of model	Where it was used	Source
Street Lights Pack	Used as decoration around the city	[147]
3D Doors	Used door2 as the door to the office	[148]
Yughues Free Bushes	Used on the top of tall buildings in the city	[149]
Translucent Crystals	Used in the fishtank in the aquaponics area	[150]
Elevator - Low Poly Animated	Used as the elevators in the underground farm area	[151]
Grass Flowers Pack Free	Used for tall grass on the terrain near the city	[152]
Garden Vegetables 2. Update	Used for the salads and herbs in the underground farm	[153]
Potatoes 2	Used as potatoes in the aeroponics area	[154]
Conference Table	Used as decoration in the office area in the hangar	[155]
Wooden Armchair	Used as decoration in the office area in the hangar	[156]
Chair	Used as decoration in the office area in the hangar	[157]
Cupboard 900 450 1800 Mm	Used as decoration in the office area in the hangar	[158]
Credenza 1200 450 Mm	Used as decoration in the office area in the hanga	[159]
Office Desk 1200 600mm	Used as decoration in the office area in the hangar	[160]
Dark Narrow Bookshelf	Used as decoration in the office area in the hangar	[161]
Books	Used as decoration in the office area in the hangar	[162]
Porcelain Vase	Used as decoration in the office area in the hangar	[163]
Carton Box	Used as decoration in the office area in the hangar	[164]
Peaking Birds	Used as decoration in the office area in the hangar	[165]
Wireless Mouse	Used as decoration in the office area in the hangar	[166]
Monitor Samsung U28d590d	Used as decoration in the office area in the hangar	[167]
A4 Paper Pile	Used as decoration in the office area in the hangar	[168]
Books	Used as decoration in the office area in the hangar	[169]

Name of model	Where it was used	Source
Pencil	Used as decoration in the office area in the hangar	[170]
Vivacious Arabesque Rug	Used as decoration in the office area in the hangar	[171]
White Porcelain Mug	Used as decoration in the office area in the hangar	[172]
Noodle Cup	Used as decoration in the office area in the hangar	[173]
Cup Of Coffee	Used as decoration in the office area in the hangar	[174]
Bowl	Used as decoration in the office area in the hangar	[175]
Cocacola Can	Used as decoration in the office area in the hangar	[176]
Cup & Saucer Set White 2	Used as decoration in the office area in the hangar	[177]
Moka Coffee Maker	Used as decoration in the office area in the hangar	[178]
Paper Stack	Used as decoration in the office area in the hangar	[179]
Cupboard Var 2.3	Used as decoration in the office area in the hangar	[180]
Cupboard Var 2.2	Used as decoration in the office area in the hangar	[181]
Cupboard Var 2.6	Used as decoration in the office area in the hangar	[182]
Microwave	Used as decoration in the office area in the hangar	[183]
Fridge	Used as decoration in the office area in the hangar	[184]
Trash Bin	Used as decoration in the office area in the hangar	[185]
Whiteboard	Used as decoration in the office area in the hangar	[186]
Sticky Notes (Written On)	Used as decoration in the office area in the hangar	[187]
Alcohol Marker Box	Used as decoration in the office area in the hangar	[188]
Cat Figurine	Used as decoration in the office area in the hangar	[189]

Name of model	Where it was used	Source
Lg Dryer	Used as decoration in the changing area in the hangar	[190]
Plastic Landry Basket	Used as decoration in the changing area in the hangar	[191]
Corner Table-01	Used as decoration in the changing area in the hangar	[192]
Dish Washer Sink	Used as decoration in the changing area in the hangar	[193]
Folded Towel	Used as decoration in the changing area in the hangar	[194]
Paper Towel Stand	Used as decoration in the changing area in the hangar	[195]
Towel Crumpled	Used as decoration in the changing area in the hangar	[196]
Skateboard Shoes	Used as decoration in the changing area in the hangar	[197]
School Locker	Used as decoration in the changing area in the hangar	[198]
Shufan Chair	Used as decoration in the changing area in the hangar	[199]
Shufan Bench	Used as decoration in the changing area in the hangar	[200]
3D Free Classic Mini Temple model	Used as decoration in the fish tank in the aquaponics area	[201]
Branch rotten wood 25	Used as decoration in the fish tank in the aquaponics area	[202]
Plastic water tanks model	Used as decoration for the water filtration system in the aquaponics area	[203]
Herbs and Plants	Used for the herbs in the aquaponics area	[204]

Textures used in Iteration 1 and 2

Name of model	Where it was used	Source
Outdoor Ground Textures	Used as grass texture	[205]
Hexagonal Concrete Paving	Used as pavement texture in the city	[206]
Metal 046 A	Used for various metal surfaces	[207]
Plastic 010	Used for some floor surfaces in the underground farm scene	[208]
Gravel Concrete	Used for floor surface in lower level of the underground farm scene, and the displacement map has been on other materials, such as the greenhouse glass material	[209]
Painted Plaster 017	Used for wall surfaces in the underground farm scene	[210]
Clean Pebbles	Used as ground texture in the fish tank in the aquaponics area	[211]
Wooden Planks	Used for wood roofing above office and elevator inside the hangar	[212]
Wood 018	Used for the wood parts of the bins and benches in the city	[213]
Concrete 016	Used in the city for the small concrete columns on the pathway	[214]

Appendix H

PACT analysis

People

People can be very different, and this is why it is important for the solution to consider differences in regards to physical ability, cognitive ability, technological knowledge, and preferences. Some may have difficulties with reading text in virtual reality, so the information text should have an accompanying narrator voice. Others may prefer it without the voice, so it should be able to toggle between them both.

Virtual reality (VR) has certainly become more popular in recent years, but that does not mean people using the solution are already familiar with VR. Chances are they have heard about it, but never tried it themselves. The solution should therefore be easy to get into by someone doing their first dive in VR, as well as be easy and enjoyable to control by everyone, including those experienced with the technology. Time should be spent on exploring the virtual environment, rather than on figuring out the controls.

Users will primarily interact with the world by hand tracking. Interactions will be done by grabbing objects or selecting them from a distance by pointing and pinching the air. It should be easier for users to recognise this way of interacting rather than remembering a more complex method.

Activities

The solution is a learning experience where the user can select which concepts of a sustainable future city they want to explore. This puts them in control of the order of things. Users select a concept they want to learn more about, then are able to visit a related area in the city. In this area, there are various interaction options, one of which are information bubbles that are floating next to a sub-concept of the overarching concept of that area. There are multiple of these all around, which tell the user information about the particular topic by voice-over. The user can also choose to read the full text themselves without the voice. Along with these information bubbles are related tasks to the sub-topic that the user can do to learn more about it. These tasks are different kinds of interactions, where the user is expected to do something to accomplish the task. The interactions should not be physically demanding, nor should they be too complex to avoid frustration from the user. This could mean that there are few steps to the interaction or that things like buttons to be pushed are a good size or not difficult to reach. User interface (UI) elements such as colors, text, and shapes should also be easy to perceive and understand.

The solution is expected to be used as a learning tool by students in related courses, which means it can be used as part of the curriculum of a semester, and also be available to be used outside of class if requested. It is expected to be used by one person at a time, with the possibility of casting to a nearby screen so that others can see. The solution is technically continuous in that it does not store where the user is when they close the application. However, because the user selects which order they want to go through in, this means they can continue where they left off last time by going straight there the next time they use it.

Context

The solution will be able to be used anywhere due to the Quest Pro being a portable device that does not have to be connected to a PC or another device to work. This means that the solution has to be optimized for performance when not connected to a PC. Ideally, it will be indoors with enough light for the sensors and cameras on the HMD. This could be in class where the display of the HMD is broadcasted to a bigger screen in the room so that others can see what the user sees. If it is possible to acquire multiple Quest Pro HMDs, they could also be divided into smaller groups.

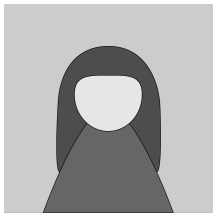
Technology

The solution will be made for the Meta Quest Pro HMD, which is the successor to the Quest 2. The Quest Pro has significant improvements in tracking, display, and functions such as improved passthrough quality and capabilities.

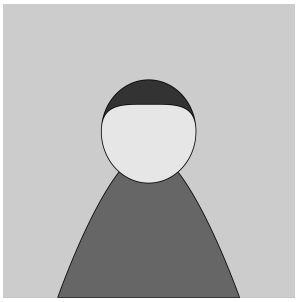
User input comes from the HMD which updates the position of the user's head, as well as hand tracking which will be used instead of controllers. Hand tracked movements such as grabbing and pinching will be the main manner of input from the user. Outputs include the displays of the lenses inside the HMDs, which update according to what is going on within the system, as well as auditory feedback.

Appendix I

Personas

Persona 1 - Leah Moen  **General information & Background** **Name:** Leah Moen **Age:** 19 **Role:** New student **Residence:** Grimstad **Occupation:** student at University of Agder, studies multimedia **Income:** 0 kr/year, but gets help from Lånekassen and her parents **Skills and knowledge:** Grew up with technology, but as most people, has not tried mixed or virtual reality before, but is very open to it if an opportunity would arrise. She also loves going fishing with her grandpa since she was little. Can speak norwegian and english.	**User stories/user goals:** “As a new student I’m open to trying out new ways of learning. I think I’m a visual and practical learner so I can see the potential in being able to ‘visit’ or experience a ‘sustainable future city’. Especially as such concepts are difficult to imagine when you are just reading a text about it, because no-one can ‘visit’ the future, so it would be cool to ‘visit’ it in that way, digitally.”

Persona 2 - Simon Solheim

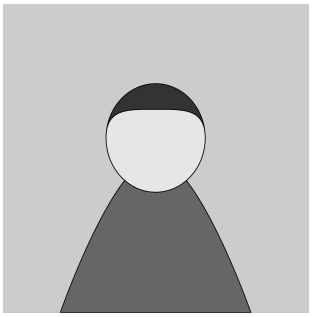


General information & Background

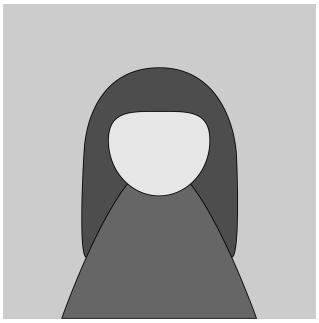
Name: Simon Solheim
Age: 51
Role: Teacher/Lecturer
Residence: Grimstad
Occupation:
Income: 608 000 kr./year
Skills and knowledge:.

Has some familiarity with VR technology because the school owns some devices. He has not yet understood the full potential of VR, but finds it interesting enough.

User stories/user goals:
“As a teacher, I want to provide my students with new fun ways for them to learn, and I always advocate that learners learn best when they are active. Therefore I like to go on field trips with my students, however sometimes it can become difficult or expensive to travel with the whole class.”

Persona 3 - Nils Petter Gundersen  **General information & Background** **Name:** Nils Petter Gundersen **Age:** 34 **Role:** Electrician **Residence:** Grimstad **Occupation:** **Income:** 427 000 kr./year **Skills and knowledge:**. Is somewhat familiar with VR technology, however he is not particularly interested in it. He only knows what he has seen in the media, and has not tried it himself.	**User stories/user goals:** “As an electrician, I enjoy problem solving and being active when I learn. However, I feel I have learned what I need to know, and do not feel the need to spend a lot of time learning outside of work. If I do, I prefer it to be simple and not take up too much time of my day. I would not bother to read a whole book on a topic, instead I would Google it and find a concise description. “

Persona 4 - Joanne Lisbeth Ruud



General information & Background

Name: Joanne Lisbeth Ruud
Age: 49
Role: Museum Director
Residence: Grimstad
Occupation:
Income: 1,2 mill. kr./year
Skills and knowledge:.

Has VR because of the technological museum, and would like to use it for virtual displays.

User stories/user goals:
"As a museum director, I want visitors to have an experience they won't forget. And as a lifelong learner, I am always interested to learn, and help others learn too. In particular, I enjoy waking people's interest in a topic that they maybe would not have been so interested in if not nudged towards it, and I think VR is an exciting technology and has a lot of potential to provide unforgettable experiences."

Appendix J

Volere snow cards for requirements

Requirement #: 1 **Requirement Type**: 1 **Event/use case #**: All

Description: The project is part of a master thesis to explore how active learning can be supported with mixed and virtual reality immersive technologies, therefore an immersive application must be developed to perform user testing with

Rationale: Findings from user testing can help answer the research questions

Source: The project group

Fit Criterion: The findings of user testing answer the research questions

Customer Satisfaction: 5 **Customer Dissatisfaction**: 5

Priority: 1

Supporting Materials: Proposal, requirements material

History: Created 25.02.2023

Requirement #: 2 **Requirement Type**: 1 **Event/use case #**: All

Description: The solution should support active learning by use of immersive technologies such as mixed and virtual reality. It should be effective for learning about the topic “Sustainable Future Cities” through immersive interactions and exploration of environments

Rationale: The goal of the project is to explore how such a solution should be designed and measure what level of immersion is experienced when using it

Source: The project group

Fit Criterion: The solution can be used to learn about concepts of a sustainable future city by exploring it virtually and interacting with the environment

Customer Satisfaction: 3 **Customer Dissatisfaction**: 3

Priority: 1

Supporting Materials: Proposal, requirements material

History: Created 26.02.2023

Requirement #: 3 **Requirement Type**: 3 **Event/use case #**: All

Description: The solution should be targeted towards users who are at least 19 years old, and not require prerequisite knowledge of VR or the topic

Rationale: The solution is aimed at the general population

Source: The project group

Fit Criterion:

Customer Satisfaction: 3 **Customer Dissatisfaction**: 4

Priority: 1

Supporting Materials: -

History: Created 19.03.2023

Requirement #: 4 **Requirement Type**: 4 **Event/use case #**: All

Description: The solution shall be targeted to run on the Meta Quest Pro headset

Rationale: The Quest Pro is at the time of writing the newest VR headset in the Quest line, and has significant improvements to functionalities that enhance immersion, such as the passthrough possibility and sensors

Source: The project group

Fit Criterion: The final build of the solution can be installed and run on the Meta Quest Pro

Customer Satisfaction: 4 **Customer Dissatisfaction**: 3

Priority: 1

Supporting Materials: Meta Quest documentation

History: Created 26.02.2023

Requirement #: 5 **Requirement Type**: 9 **Event/use case #**: X

Description: The user should be able to interact with the environment by grab, ray and poke interactions

Rationale: Interaction with the environment gives the user agency and makes the experience more immersive
Source: The project group

Fit Criterion: The user can interact with objects through grab, ray and poke interactions
Customer Satisfaction: 5 **Customer Dissatisfaction**: 3

Priority: 1

Supporting Materials: Oculus Integration SDK documentation

History: Created 26.02.2023

Requirement #: 6 **Requirement Type**: 9 **Event/use case #**: X

Description: The user should be able to teleport around to maneuver

Rationale: Teleportation is a way to move around the environment that is less likely to cause motion sickness, rather than continuous movement
Source: The project group

Fit Criterion: The user can teleport to another location

Customer Satisfaction: 4 **Customer Dissatisfaction**: 3

Priority: 1

Supporting Materials: -

History: Created 26.02.2023

Requirement #: 7 **Requirement Type**: 9 **Event/use case #**: X

Description: The environment should include realistic visualizations of concepts and have selectable spheres nearby to find that explain the concepts further

Rationale: This gives the user agency and can make it more fun for users to explore

Source: The project group

Fit Criterion: The user can explore the environment freely and chooses which concept they want to learn about in the order they want

Customer Satisfaction: 4 **Customer Dissatisfaction**: 5

Priority: 1

Supporting Materials: -

History: Created 26.02.2023

Requirement #: 8 **Requirement Type**: 10 **Event/use case #**: X

Description: The solution should look and feel appropriate to the near future and clean, sustainable solutions

Rationale: The solution is supposed to showcase what a sustainable future city could look like as well as teach about concepts that relate to it, therefore the look and feel of the solution should support that

Source: The project group

Fit Criterion: Users' feedback confirm that the look and feel is appropriate

Customer Satisfaction: 5 **Customer Dissatisfaction**: 3

Priority: 2

Supporting Materials: -

History: Created 26.02.2023

Requirement #: 9 **Requirement Type**: 11 **Event/use case #**:

Description: The solution should be effective to use, easy to learn, and easy to remember how to use

Rationale: It should be effective in being able to learn about concepts of a sustainable future city through use of the solution, it should be easy to learn by being intuitive to control, and also easy to remember how to use by having few and simple steps to perform these actions

Source: The project group

Fit Criterion: Feedback from user testing show that the usability goals are reached

Customer Satisfaction: 3 **Customer Dissatisfaction**: 5

Priority: 1

Supporting Materials: -

History: Created 26.02.2023

Requirement #: 10 **Requirement Type**: 12 **Event/use case #**:

Description: The solution should be efficient and safe to use

Rationale: It should be efficient to reduce frustration and increase enjoyment, with few steps required to complete individual tasks. It should be safe by being accounting for user error and support of various user actions

Source: The project group

Fit Criterion: Feedback from user shows that the usability goals are reached

Customer Satisfaction: 3 **Customer Dissatisfaction**: 4

Priority: 1

Supporting Materials:

History: Created 26.02.2023

Requirement #: 11 **Requirement Type**: 13 **Event/use case #**:

Description: The solution is expected to be used indoors with enough room so that there is no danger of bumping into things in their physical environment

Rationale: The user needs to be able to turn around and move their arms without fear of knocking things over or bumping into real world objects
Source: The project group

Fit Criterion: The application includes instructions on the recommended amount of space for use
Customer Satisfaction: 3 **Customer Dissatisfaction**: 2

Priority: 3

Supporting Materials: -

History: Created 26.02.2023

Requirement #: 13 **Requirement Type**: 10 **Event/use case #**:

Description: The visualization should be as realistic as possible for the concepts users are to learn about.
Rationale: It is important because these are real world concepts that need to be visualized accurately to convey the learning material.
Source: The project group

Fit Criterion: The visualizations of concepts are accurately portrayed as they are in real life.
Customer Satisfaction: 3 **Customer Dissatisfaction**: 6

Priority: 3

Supporting Materials:

History: Created 19.03.2023

Requirement #: 14 **Requirement Type**: 10 **Event/use case #**:

Description: The text script and learning material has to be fact-based, concise, and easy to understand for anyone.
Rationale: The experience should be educational about real world topics so people will get an overview, without the need to go in-depth, as to spark interest.
Source: The project group

Fit Criterion: The user learns about topics that are based on accurate sources.

Customer Satisfaction: **Customer Dissatisfaction**:

Priority:

Supporting Materials:

History: Created 19.03.2023

Requirement #: 14 **Requirement Type**: 10 **Event/use case #**:

Description: The text script and learning material has to be fact-based, concise, and easy to understand for anyone.
Rationale: The experience should be educational about real world topics so people will get an overview, without the need to go in-depth, as to spark interest.
Source: The project group

Fit Criterion: The user learns about topics that are based on accurate sources.

Customer Satisfaction: **Customer Dissatisfaction**:

Priority:

Supporting Materials:

History: Created 19.03.2023

Requirement #: 15 **Requirement Type**: 10 **Event/use case #**:

Description: There should be audio feedback when performing interactions

Rationale: So users feel that the environment is responsive to their actions

Source: The project group

Fit Criterion: Users can hear audio that matches up to what they experience.

Customer Satisfaction: **Customer Dissatisfaction**:

Priority:

Supporting Materials:

History: Created 19.03.2023

Requirement #: 16 **Requirement Type**: 9 **Event/use case #**:

Description: Interactions should be controlled by hand tracking

Rationale: Hand tracking can feel more natural and easier to understand for beginners

Source: The project group

Fit Criterion: Users can interact with the environment with their hands

Customer Satisfaction: **Customer Dissatisfaction**:

Priority:

Supporting Materials:

History: Created 19.03.2023

Requirement #: 17 **Requirement Type**: 9 **Event/use case #**:

Description: There should be a functional quiz that can be interacted with inside the virtual environment
Rationale: The quiz tests users' knowledge of the topics they have learned about
Source: The project group

Fit Criterion: The user can interact with a virtual interface to answer a quiz and complete the experience
Customer Satisfaction: **Customer Dissatisfaction**:

Priority:

Supporting Materials:

History: Created 19.03.2023

Requirement #: 18 **Requirement Type**: 9 **Event/use case #**:

Description: There should be a mixed reality scene with a miniature model of the city
Rationale: So users can begin in mixed reality and get an overview of the city before they transition into full virtual reality
Source: The project group

Fit Criterion: The users can get an overview from the miniature model in mixed reality before transitioning into the full virtual reality world
Customer Satisfaction: **Customer Dissatisfaction**:

Priority:

Supporting Materials:

History: Created 19.03.2023

Appendix K

Summary and translation to english in full sentences of street interview with five participants

Validate requirements, design decisions, user needs, and find out if there is an interest in the topics and use of technology, knowledge gaps. Data collection for the street interviews was done on 03.03.2023 and 04.03.2023, in Grimstad. Notes were written with pen and paper, then digitalized, converted to full sentences, and translated. The following are the digitialized translated summaries of the participant's answers.

Street interview with 5 participants: Validate requirements, design decisions, user needs, and find out if there is an interest in the topics and use of technology, knowledge gaps SIDE 1/16

SKJEMA: 15 + (1 valgfritt) SPØRSMÅL

BÆREKRAFT

1. Tenker du på fremtiden og muligheten for å spare naturressurser?

Are you thinking about the future and the possibility of saving natural resources?

Participant no.	Notes	Translation to english
1	Ikke så mye	Not so much
2	• klart gjør det • er gårdsbruker tenker på naturressurser → passe på blanding av kunstgjødsel	The participant said they 'of course' think about the future and different methods to save natural resources . As a farmer they think about natural resources such as to watch out for mixed synthetic fertilizers.
3	Tenker på det, spennene, i media Prøver gjøre det de kan, plukke søppel, matsvinn. Begrense der de kan, ikke kjøre bil, heller buss. Var på utveksling, tenkte hva de kan gjøre for mindre utslipp. Ikke kjøpe alt man har lyst på for å spare, kjøper brukt, prøver vegetar	They are thinking about it. They think it is an exciting topic. It comes up a lot in the media. They try to do what they can, such as pick up trash, try not to waste food. Limit where it is possible such as not driving a car. Instead they take the bus. They been on an exchange program, and it made them think about emission on travels. They also think that one should not buy everything one wants, buy used instead, and try to become a vegetarian.
4	• ja vi er heldige i Norge, andre land har mer vanskeligheter • man gjør det man kan • litt og litt	They think we are lucky to live in Norway, because they think in other countries it is much more difficult. They say that they do what they can do.
5	Ja → Alt mulig	Yes. They think about a lot of things in regards to this topic.

Street interview with 5 participants: Validate requirements, design decisions, user needs, and find out if there is an interest in the topics and use of technology, knowledge gaps SIDE 2/16

2. Bryr du deg om miljøet? Hvordan da?

Do you care about the environment? How?

Participant no.	Notes	Translation to english
1	Ja men vet ikke helt å sette ord på det, bevisst men ikke noe plan	Yes, but don't quite know how to put it into words. They are conscious about it but without any plan.
2	• ja selvfølgelig, som sagt hobbybonde og jobber i oljebransjen, gjenbruk • resurkelerings sirkulering → man gjør det man kan • har elbil	yes of course, as I said hobby farmer and works in the oil industry, recycling recirculation circulation → you do what you can, have an electric car
3	Føler de gjør det, trist å se søppel rundt forbi. Tror hvis alle hadde gjort litt, ville hjulpet. Trist at u-land tar konsekvensene	Feel they do, sad to see trash around. I think if everyone did a little, it would help. Sad that developing countries take the consequences
4	• gjør det, spesielt nærmiljøet → gå på tur	do it, especially the local environment → go for a walk
5	• Ja kaste ikke søppel i naturen • Vise hensyn	Yes, don't throw rubbish in nature Show consideration

3. Hva tenker du hvis du hører ordet “bærekraft”?

Topic: Sustainability - What do you think of when you hear the word "sustainability"?

Participant no.	Notes	Translation to english
1	positivt ladet, klinger positivt, noe personen tror på	positively charged, sounds positive, something the person believes in
2	• er viktig, men • tenker litt at det blir brukt litt for mye som en innskyldning • har venner i annleggskraft og hvis du ikke er bærekraftig da velger de ikke deg?	is important, but I think that it is used a little too much as an excuse. Have friends in construction power, and if you are not sustainable then they will not choose you?
3	Skal være ressurse for de neste som kommer, ikke bruke opp alt. Viktig med neste generasjon	Should be resources for the next ones to come, not use up everything. Important with the next generation
4	akkurat ferdig med utdanning → jobber i barnehage → passe på hva slags mat de skal ha → ikke bare kjøtt	just finished education → works in a kindergarten → watch what kind of food they should have → not just meat
5	Tenke på klær industrien “Lager nytt unødvendig hele tiden”	Think about the clothing industry “Creating new things unnecessarily all the time”

4. Kan du gi noen eksempler på bærekraftige løsninger?
Can you give some examples of sustainable solutions?

Participant no.	Notes	Translation to english
1	Når det gjelder energi → syns det høres bærekraftig ut	When it comes to energy → I think it sounds sustainable
2	• kunstgjøtsel • på 80-tallet var de ikke klar over det, og “kun tilføre det når det trengs” • nå bevissgjøring i dag	artificial fertilizer in the 80s they were not aware of it, and "only added it when needed" raising awareness today
3	Fornybar energi, el-bil, gjenbruk, ikke kjøpe nytt av alt. Kan ikke stoppe at itng produseres, men kan begrense oss selv ved å kjøpe brukt. Livsstisvalg. Trenger kanskje ikke reise med fly, alternativ transport	Renewable energy, electric car, reuse, don't buy everything new. Can't stop things from being produced, but can limit ourselves by buying used. Life path choice. May not need to travel by plane, alternative transport
4	• fornybar energi → elbil • fikse kultur → kjøpe ting som kan fikses • unngå store flyreiser	renewable energy → electric car fix culture → buy things that can be fixed avoid long flights
5	Hvor går alt hen, søppel, klær, matavfall?	Where does everything go, rubbish, clothes, food waste?

5. Hvordan kan man lære bort eller opplyse andre om “bærekraft”?

How can one teach or inform others about "sustainability"?

Participant no.	Notes	Translation to english
1	Personlig, har ikke så mye å bidra, men ser at det er forskning, kjøper solceller, moderne forskning, har undersøkt muligheter med solceller men funket ikke der personen bor, vurderte flere ting. Økonomien styrer det desverre, kan være upraktisk	Personally, do not have much to contribute, but see that there is research, buy solar cells, modern research, have investigated possibilities with solar cells but did not work where the person lives, considered several things. The economy controls it unfortunately, can be impractical
2	• mer informasjon og mer faktabasert, og ikke bruke mange fine ord, men forklarer mer • og opplyser med konkrete info. og ikke bruke skremselsmetode	more information and more fact-based, and not using a lot of fancy words, but explains more and provides specific information. and not use intimidation
3	Merker folk lever i sitt mønster, faller fort inn i vaner. Tror det er viktig at folk får se konsekvensene av hva de gjør. Vise istedenfor fortelle. Barn/unge trenger å lære det	People live in their pattern, they quickly fall into habits. I think it is important that people see the consequences of what they do. Show instead of tell. Children/young people need to learn it
4	• matlaging → barnehagen • kan være vanskelig • bruke janteloven • generasjonen før oss har mye å si • vise at man kan reparere ting → være den som er først → praktisk	cooking → the kindergarten can be difficult use the Jante law the generation before us has a lot to say show that you can repair things → be the first → practical
5	• Diskutert med de unge • Face-to-face	Discussed with the young people Face-to-face

LÆRING

6. Har du lært noe nylig? Hva da?
Have you learned anything recently? What?

Participant no.	Notes	Translation to english
1	Nei kan ikke si direkte, litt vanskelig å def. men man lærer jo hele tiden	No can't say directly, a bit hard to def. but you learn all the time
2	*ler lærte litt om • måne og månefase, spesielt denne jupiter-greier som var på himmelen nylig	*laughs learned a bit about moon and moon phase, especially this jupiter stuff that was in the sky recently
3	Vært i praksis og lært ting der, på sykehus	Been in practice and learned things there, in a hospital
4	• lærer sikkert noe nytt hver dag, men vanskelig å spesifisere • kanskje være mer strukturert/planlegging	certainly learns something new every day, but hard to specify maybe be more structured/planning
5	Lære noe nytt hver dag	Learn something new every day

7. Hvordan går du vanligvis frem for å lære om noe nytt?

How do you usually go about learning about something new?

Participant no.	Notes	Translation to english
1	• google på mobilen • gå til biblioteket å finne bøker	google on mobile go to the library to find books
2	• i dette tilfelle snakker med venner, • google • liker mest face-to-face • observerer • diskuterer	in this case talking to friends, google prefers face-to-face observation discussing
3	Lese seg opp, spørre folk som har erfaring. Gå inn for å forstå ting, ikke gå videre uten å forstå. Selv-disiplin	Read up, ask people who have experience. Go in to understand things, don't move on without understanding. Self-discipline
4	• lytte til folk • observere hva andre har å si før man lager sin egen mening • “aldri slutte å lære”	listen to people observe what others have to say before forming your own opinion "never stop learning"
5	• Leser meg opp • Avis, bøker, reklame	Reading up Newspapers, books, advertising

8. Når du skal lære noe, går du mer i dybden på det du skal lære om eller holder det å gjøre det enkelt? Hva gjør vanligvis at du ønsker å lære dypt eller overflatisk om noe? Kan du gi noen eksempler?

When you are going to learn something, do you go more in-depth on what you are going to learn about or do you keep it simple? What usually makes you want to learn deeply or superficially about something? Can you give some examples?

Participant no.	Notes	Translation to english
1	stort sett blir det enkelt, har med interessen å gjøre, er det som driver. Eks. lære om seiling, snøball effekt, vil ha tillegskunnskap	mostly it will be simple, has to do with the interest, it is what drives you. Ex. learn about sailing, snowball effect, wants to have additional knowledge
2	• i utgangspunktet litt enkelt, men kommer an på interesse	basically a bit simple, but depends on interest
3	Går litt i dybden hvis det er interessant, ellers går ikke så i dybden. Går i dybden på studie. Har med interesse å gjøre.	Goes a little in depth if it is interesting, otherwise does not go so in depth. Goes in depth on studies. Has to do with interest.
4	• spørs hva det er → interessebasert	ask what it is → interest-based
5	Komme ann på hva det er. Automatisk i dybden hvis interesse eller nødvendig (f.eks. tett i vasken, daglidagse)	Figure out what it is. Automatic in depth if interest or necessary (e.g. clogged in the sink, daily)

TEKNOLOGI

9. Hvilke digitale teknologier bruker du i en vanlig uke?

What digital technologies do you use in a typical week?

Participant no.	Notes	Translation to english
1	• Mobilen → dekker største behov • tv	The mobile phone → covers the greatest needs tv
2	• mobil • (traktor) • Pc • TV • radio • bil	mobile (tractor) Pc Television radio car
3	Mobil, kaffemaskin, bil, TV, smartklokke, kjøkkenting, dørlås, tørketrommel, vaskemaskin	Mobile phone, coffee machine, car, TV, smart watch, kitchen items, door lock, tumble dryer, washing machine
4	• mobil • PC • bil • smartklokke • dørlås	mobile PC car smart watch door lock
5	• Mobil • Nettbrett	Mobile Tablet

10. Bruker du digitale teknologier for å hjelpe deg å lære? Hvilken?

Do you use digital technologies to help you learn? Which?

Participant no.	Notes	Translation to english
1	Ja mobil, internett, det er der man henter først	Yes, mobile, internet, that's where you pick up first
2	• Ja jobben som gjøres er jo alt digitalt kurs osv. • interaktive kurs etter korona	Yes, the work that is done is all digital courses etc. interactive courses after corona
3	PC, mobil, svar på alt på de, lite bøker, er ofte digitalt de og	PC, mobile, answers to everything on them, little books, are often digital also
4	• PC • mobil → google, internett	PC mobil → google, internett
5	Ja og nei → Se på nettet, google ting	Yes and no → Look online, google things

11. Følger du med eller holder du deg oppdatert på ny utvikling innenfor digital teknologi?

Do you follow or keep up to date with new developments in digital technology?

Participant no.	Notes	Translation to english
1	nei, men elsker når det fungerer, f.eks. pc-en, liker ike hvis det ikke funker	no, but love when it works, e.g. the pc, does not like if it doesn't work
2	• halvveis • liker best å observere mer • er ikke sånn at "jeg vil ha det nyeste" • leser mye om det, men ikke går i dybden	half way prefer to observe more is not like "I want the latest" reads a lot about it, but don't go into depth
3	Ikke så interessert, følger litt med, helst hvis det er noe som er praktisk. Tror man trenger ting så kjøper man det	Not so interested, following along a bit, preferably if it's something practical. If you think you need something, you buy it
4	• smartdør • følger ikke helt med, "trenger ofte ikke noe"	smart door doesn't follow completely, "often doesn't need anything"
5	• Prøver så godt jeg kan • Kommer for fort nye løsninger som kan være unødvendig • "Norge vil være veldig flinke på det enn andre land"	Trying my best New solutions that may be unnecessary come too quickly "Norway will be very good at it than other countries"

TEKNOLOGI

12. Hva tenker du når du hører begrepene: 'Extended Reality', 'Virtual Reality', 'Augmented Reality' og 'Mixed Reality'?

What do you think of when you hear the terms: 'Extended Reality', 'Virtual Reality', 'Augmented Reality' and 'Mixed Reality'?

Participant no.	Notes	Translation to english
1	har hørt før, men som vinden, ikke interesse for det	have heard before, but like the wind, not interested in it
2	• har hørt om VR briller • "Mixed" er sikkert en blanding? • kjenner ikke alle begreper men kan se for meg • kjem gjennom oljebransjen	have heard of VR glasses "Mixed" is surely a mixture? don't know all the terms but can imagine comes through the oil industry
3	Har hørt vitual reality, ser en virkelighet som ikke er virkelig	Have heard vitual reality, seeing a reality that is not real
4	• har hørt om VR og AR	have heard of VR and AR
5	• Tenke på film, science fiction • Er dette virkelig noe som finnes?	Think of movies, science fiction Does this really exist?

13. Har du prøvd VR før? Hvodan var det?

Have you tried VR before? What was it like?

Participant no.	Notes	Translation to english
1	har prøvd for droneflyging, ble sjøsyk. Er en gøy opplevelse, såg ikke gevinst personlig, men kan se det i jobbsammenheng. Klarte ikke å venne til det, ble desorientert	have tried for drone flying, got seasick. It's a fun experience, I didn't see any benefits personally, but I can see it in a work context. Couldn't get used to it, got disoriented
2	• Har prøvd briller, og ha vært på oljemesse → du kunne gå inni en VR experience med skjermer (brønner) • var gøy å prøve. • gøy at det blir mer og mer tilgjengelig	Have tried glasses, and been to an oil fair → you could go inside a VR experience with screens (wells) was fun to try. fun that it is becoming more and more available
3	Vært i 5D, men ikke prøvd briller	Been to 5D, but haven't tried glasses
4	• prøvde på en messe → veldig kult → såg perspektivet på en måke, ble svimmel	tried at a fair → very cool → saw the perspective of a seagull, got dizzy
5	Nei har ikke prøvd, har hørt barnebarn har brukt → Var spennende for de først men så ble det kjedelig	No, I haven't tried it, I've heard my grandchildren have used it → It was exciting for them at first, but then it got boring

14. Hadde du vært villig til å lære om noe nytt ved hjelp av VR?
Would you be willing to learn about something new using VR?

Participant no.	Notes	Translation to english
1	Ja hvis det var gevinst med et formål	Yes, if it was profit with a purpose
2	• ja, liker håndsånd. • syns det er kult å være med på ting, ta på ting, experience det	yes, like hands-on. I think it's cool to take part in things, touch things, experience it
3	Som sykepleire, en ting å lese om prosedyre, anna åse det. Hvertfall i studie. Når ting er så teoretisk, vanskelig å lese om, bedre å se det. Er student, går bachelor.	As a nurse, it's one thing to read about procedure, another to see it. At least in studies. When things are so theoretical, hard to read about, better to see it. Is a student, doing a bachelor's degree.
4	• spill med matlaging • spørs hva det er	cooking games wonder what it is
5	Kjenner ikke noe umiddelbar trang til det	I don't feel any immediate urge to do so

Street interview with 5 participants: Validate requirements, design decisions, user needs, and find out if there is an interest in the topics and use of technology, knowledge gaps SIDE 15/16

15. Hvor virkelig tror du en VR verden kan føles? Hva gjør at du tror det?

How real do you think a VR world can feel? What makes you think so?

Participant no.	Notes	Translation to english
1	av det man har sett kan man bli litt skremt hvor virkelig det kan være. F.eks drone da er det jo video, men hvordan man har sett på tv kan det bli veldig virkelig	from what you have seen, you can be a little frightened at how real it can be. For example, with a drone, then it is a video. But from what you have seen on TV, it can be very real
2	• veldig virkelig, spesielt hvis de får inn flere sanser	very real, especially if they bring in more senses
3	Kan føles virkelig hvis man kjenner flere sanser. Kommer ann på hvordan VR verden er laget, hvis det ser virkelig ut. Tror ikke de hadde glemt at de lever, at det er et spill.	Can feel real if you feel several senses. Depends on how the VR world is made, if it looks real. Don't think they had forgotten that they are alive, that it is a game.
4	• føles veldig ekte → såg alt rundt (måke-spill)	feels very real → saw everything around (seagull game)
5	Kan bli veldig virkelig “Der og da”	Can get very real "There and then"

Street interview with 5 participants: Validate requirements, design decisions, user needs, and find out if there is an interest in the topics and use of technology, knowledge gaps SIDE 16/16

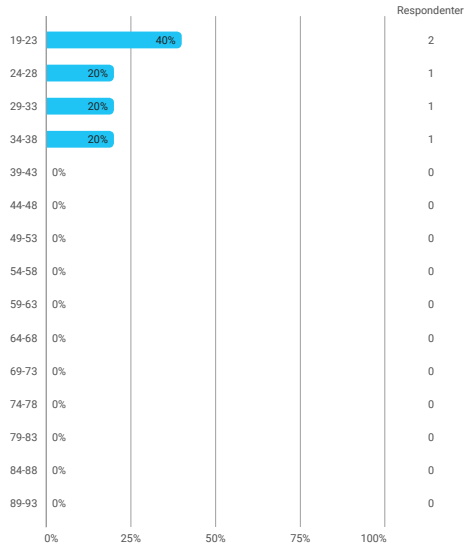
16. Valgrfritt spørsmål → Hva ville du ha ønsket å få ut av VR?
Optional question → What would you have liked to get out of VR?

Participant no.	Notes	Translation to english
1	• Operasjoner • Lære verktøy i helse • Ville ha syns det ville vært genialt • Ikke foreløpig noe innen seiling • Ikke likesilt som virkeligheten idag ennå, men kan se at det kan bli noe	Operations Learning tools in health Would have thought it would have been brilliant Not yet anything in sailing Not the same as reality today yet, but can see that it can become something
2	• vet ikke helt, men kanskje lære slik som youtube f.eks. bilmodeller instrukser, flytte ting i VR	don't know completely, but maybe learn things like youtube e.g. car models instructions, move things in VR
3	Føler det er nyttig i læring, i skolesammenheng	Feel it is useful in learning, in a school context
4	• praktiske eller fysiske ting den ikke kunne ha gjort → være med på en operasjon (kan jo ikke bare gå til sykehuset og spør hvordan en operasjon ville ha blitt.)	practical or physical things it could not have done → take part in an operation (can't just go to the hospital and ask how an operation would have turned out.)
5	Nei ikke noe, “Min tanke er at folk burde være i den virkelige verden”	No, nothing, “My thought is that people should be in the real world”

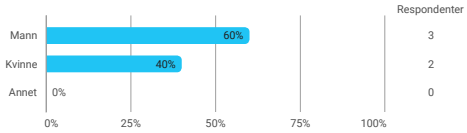
Appendix L

Questionnaire findings original norwegian version iteration one

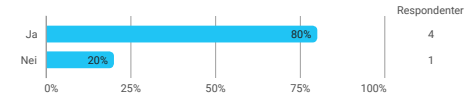
Alder?



Kjønn?



Er du student?



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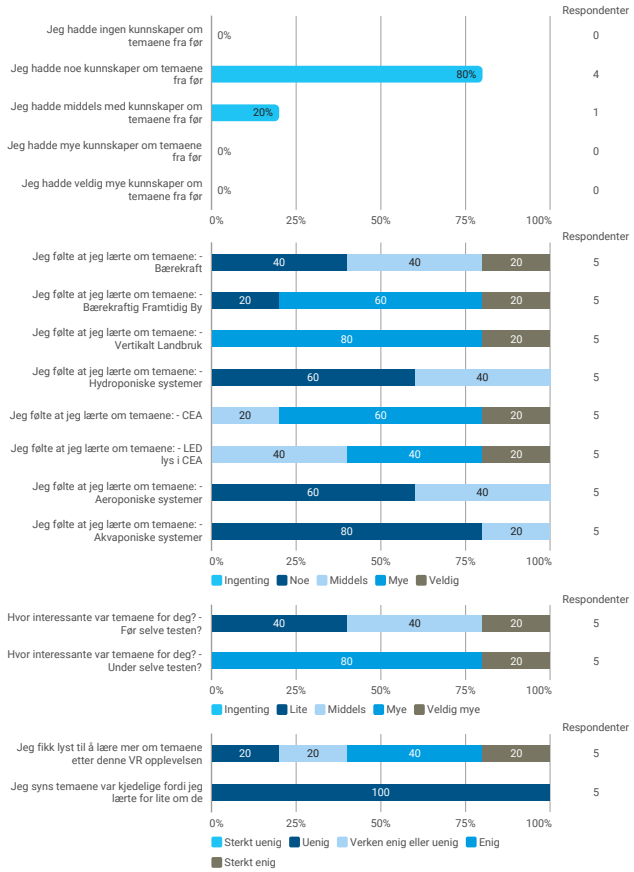
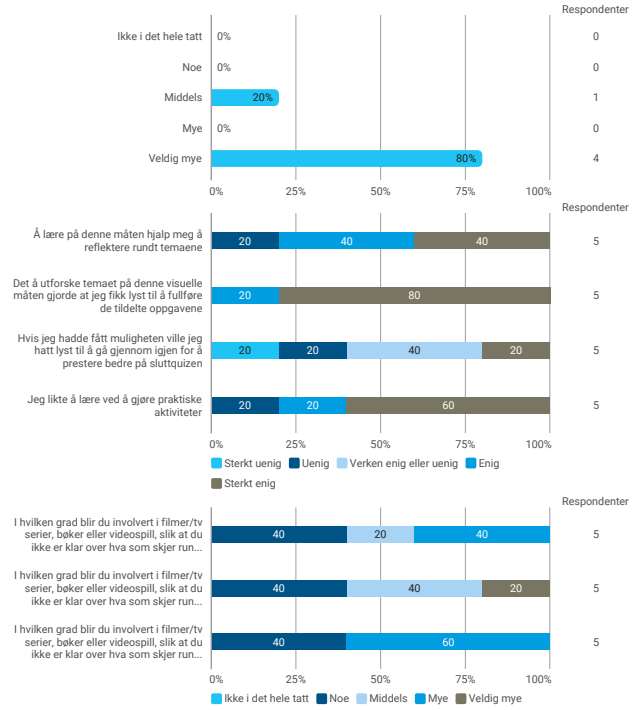
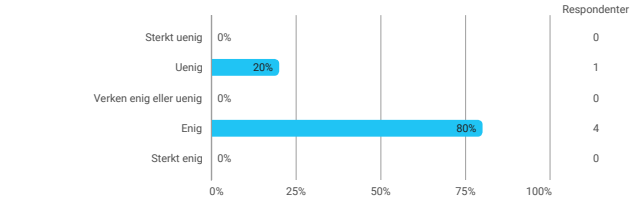


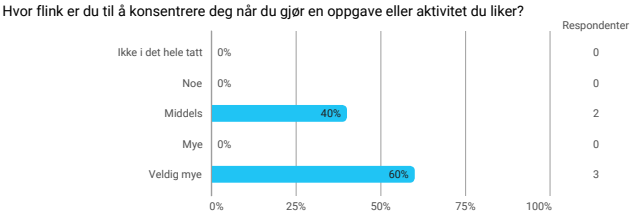
Gjorde det å være aktiv i den virtuelle opplevelsen at du hadde lyst til å fullføre de tildelte oppgavene?



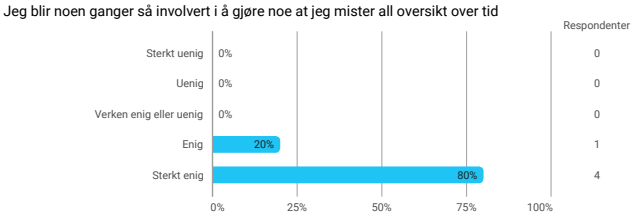
Jeg er flink til å blokkere eksterne distraksjoner når jeg må gjøre ferdig en oppgave eller aktivitet



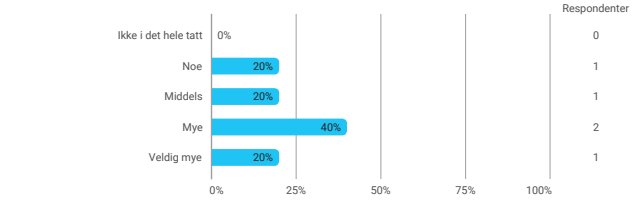
Hvor flink er du til å konsentrere deg når du gjør en oppgave eller aktivitet du liker?



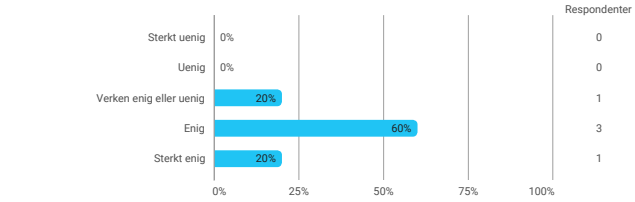
Jeg blir noen ganger så involvert i å gjøre noe at jeg mister all oversikt over tid



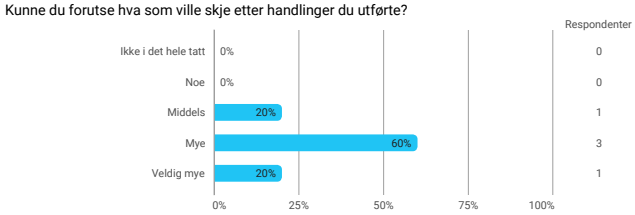
Kunne du kontrollere hendelser i den virtuelle verden?

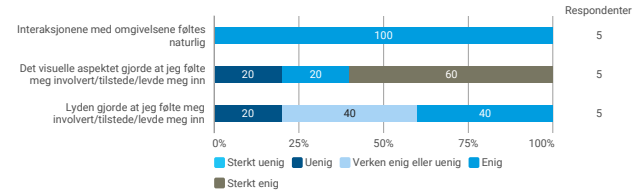


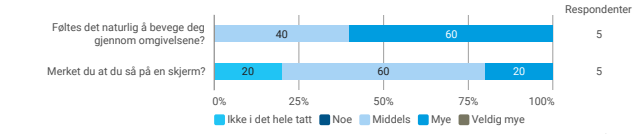
Omgivelsene var responsive for handlingene jeg utførte

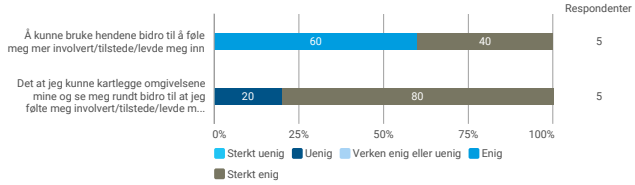


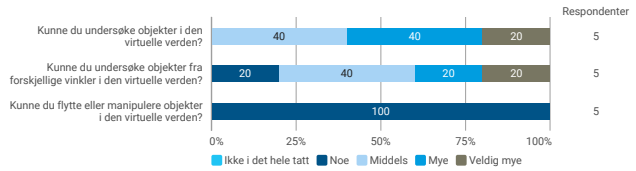
Kunne du forutse hva som ville skje etter handlinger du utførte?

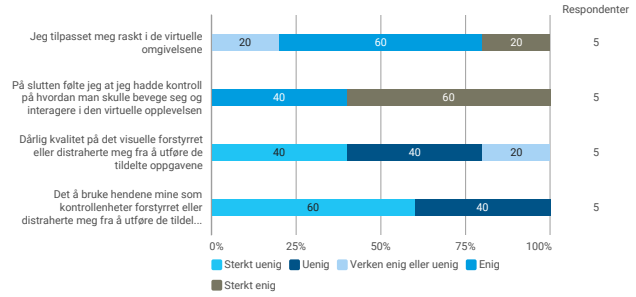


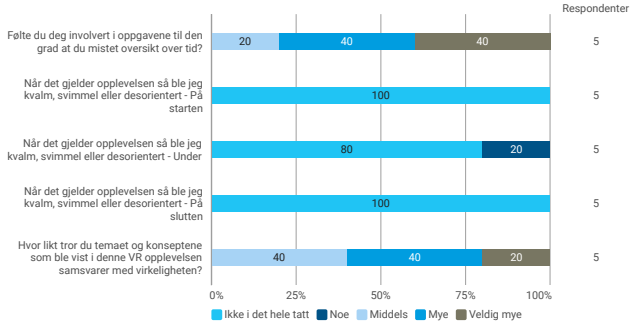












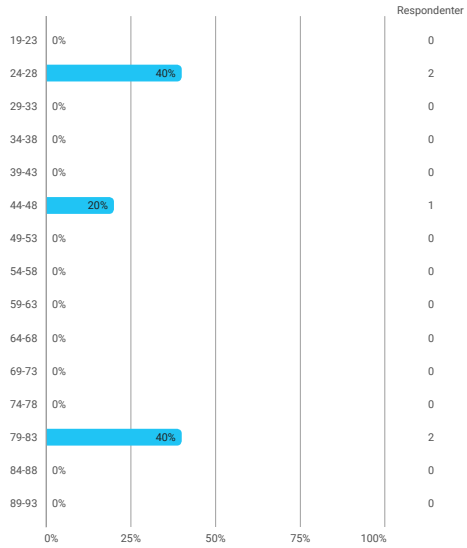
E-post

Samlet status

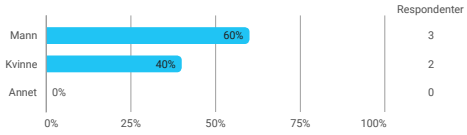
Appendix M

Questionnaire findings original norwegian version iteration two

Alder?



Kjønn?



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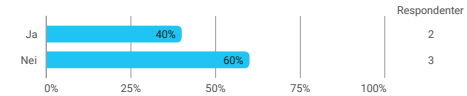

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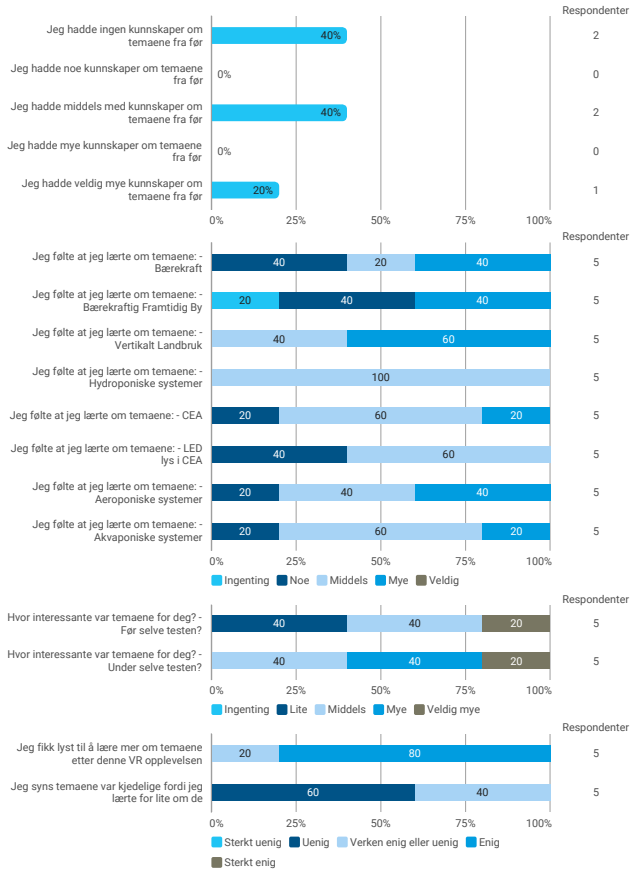

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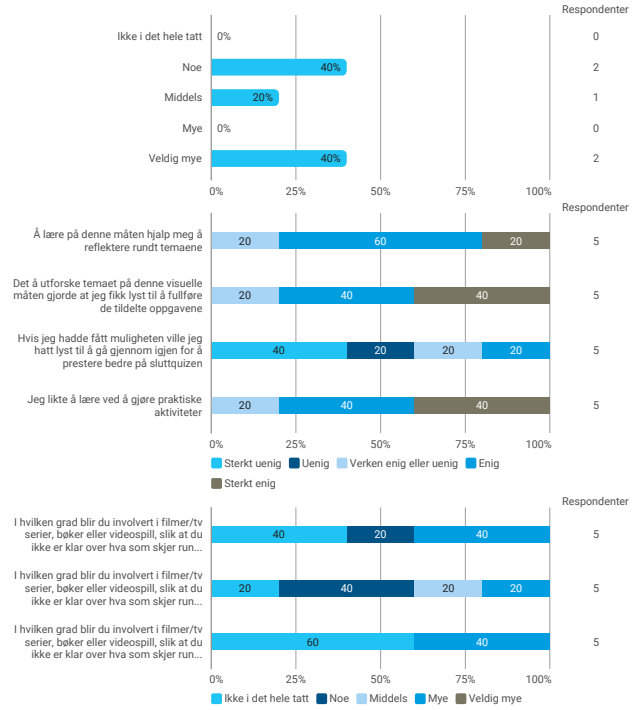

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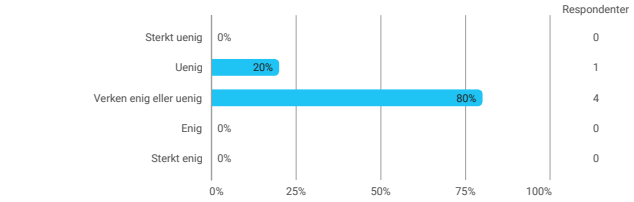

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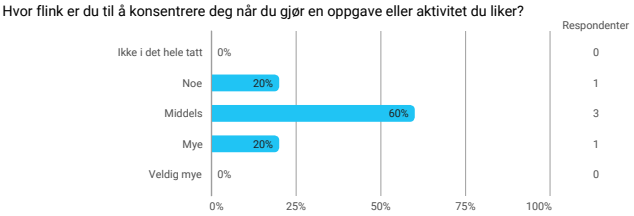

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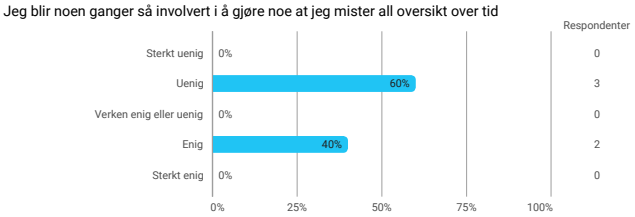

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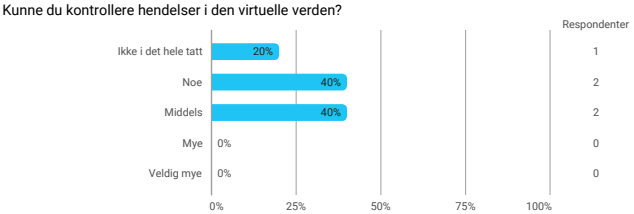

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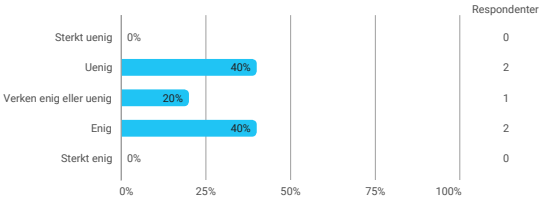

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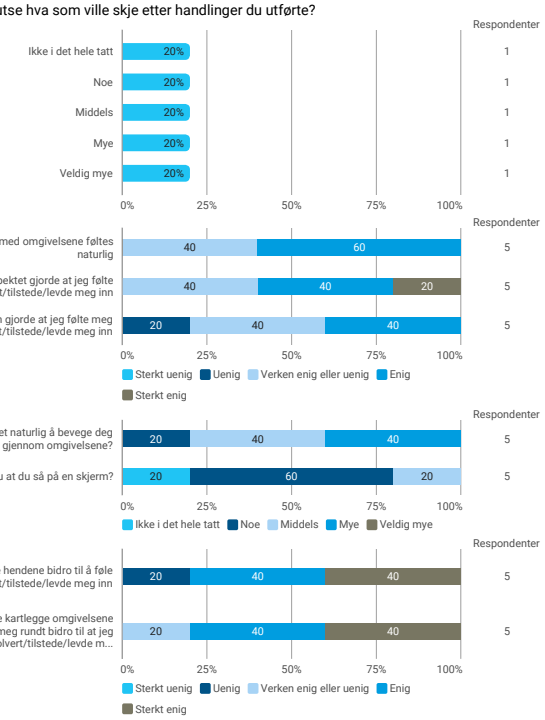

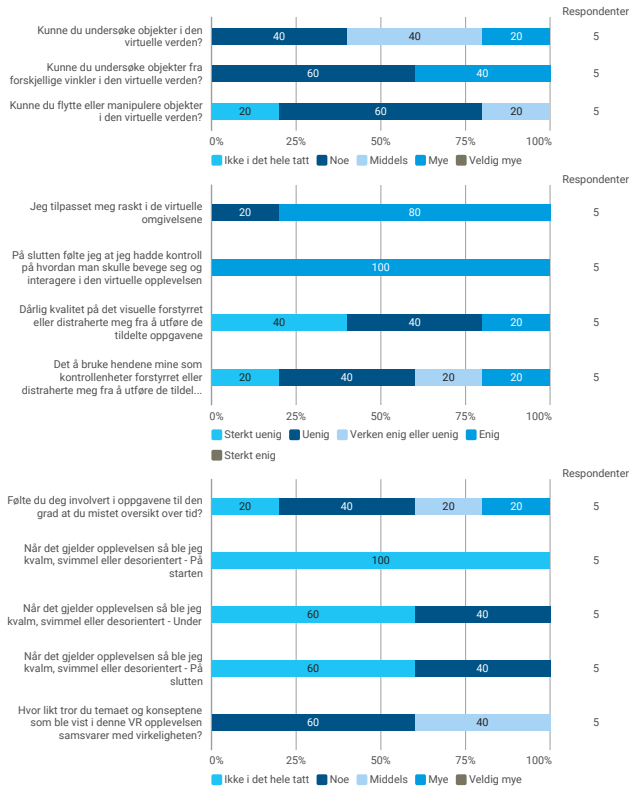

E-post

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