

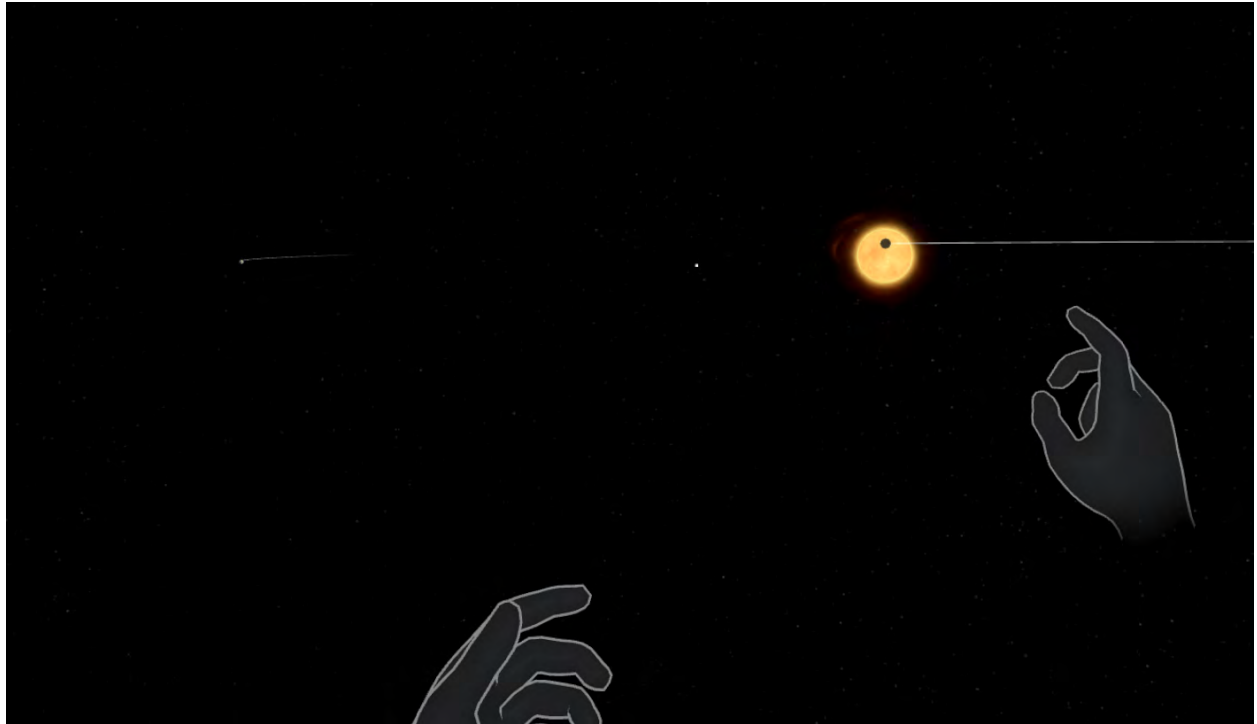


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# Exploring Astronomy in VR

Examining the effects on adolescents' engagement in astronomy through an interactive VR learning environment

Master's thesis in Computer science and engineering

AUGUSTAS EIDIKIS  
MARCUS SVENSSON



MASTER'S THESIS 2022

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CHALMERS UNIVERSITY OF TECHNOLOGY  
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Gothenburg, Sweden 2022

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Cover: A view of our sun and Venus using the Virtual Reality application.

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## Abstract

Research has demonstrated that adolescents find it challenging to understand astronomy. It is evident that traditional methods of learning the subject simply do not provide the adequate tools for students to grasp the sheer magnitude of celestial objects, the unimaginable distances between them, and the building blocks that comprise them. This thesis investigates the potential of using Virtual Reality (VR) as an educational tool for teaching astronomy in a science centre setting. More specifically, it aims to design an interactive and engaging learning experience with a constructivist approach, where students can freely explore the subject in a VR environment.

The exploration of the research question and hypotheses was influenced by a Research through Design approach with the intention to generate new knowledge in the field of Interaction Design. A prototype was designed and iterated on continuously through the Design Thinking process, and software development was conducted in Unity to build the VR environment. Efforts were put into conducting rigorous user tests to gain a deep understanding of the target audience's needs and thus form requirements. Insights and considerations for designing for experiential learning, VR, and science centres are highlighted and discussed. The results strongly indicate that VR can be used successfully as a learning environment for astronomy, and further suggests that prioritising continuous user evaluation, a coherent design, and intuitive interactions are of utmost importance.

Keywords: Interaction Design, Research through Design, Virtual Reality, Astronomy, Experiential Learning, Constructivist Theory, Science Centre.



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Augustas Eidikis, Gothenburg, May 2022  
Marcus Svensson, Gothenburg, May 2022





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# 1

## Introduction

Studies have shown that children and adolescents have difficulties grasping the subject of astronomy. 79.3% of senior secondary students (ages 17-18) understand the size order of sun > earth > moon, and only 11.38% of pre-school children manage to grasp it (Bryce & Blown, 2013). This is mostly a consequence of younger children not being able to "decentre" themselves from the earth and imagine celestial objects from other points of view. However, it is understandable that their knowledge is lacking, partly due to young age, but also inexperience with the subject and the fact that it is something learnt from textbooks and documentation rather than individual experience. After all, one cannot simply travel to space and learn about celestial objects since technology does not allow for this yet. Virtual Reality (VR) allows the user to experience things that are otherwise out of reach or unimaginable for the general populace. This type of device can benefit children and adolescents concerning the subject of astronomy through experiential learning.

Through Interaction Design (IxD) principles, this project proposes an interactive VR experience aimed at children, adolescents, and anyone interested in the subject of astronomy with the purpose of teaching about our vast universe. More specifically, we will design and implement an interactive VR experience in the form of a stationary optical telescope. A Head-Mounted Display (HMD) will be attached to the telescope in which users can view the firmament and freely explore and learn about planets and stars in relation to our own place in the universe.

### 1.1 Our Place in the Universe

The possibility for us humans to explore outer space firsthand is extremely slim and only a handful of people have done so. Therefore, we are left with our imagination as to how the universe looks, and how our little planet fits into the bigger picture. The sun is merely a blinding small dot in the blue sky. The moon, to our appearance, is also glowing in the night. Above us, the sky is speckled with bright stars. We can only imagine their size, age, and distance from the Earth. We are at the mercy of scientists' observations and logical conclusions, rather than experiencing it for ourselves. Kahane (2013) argues that the data and numbers that scientists have given us regarding size and distance are something we simply cannot comprehend due to the magnitude of these numbers. Outer space is immense and empty, and we are tiny in comparison. Kahane concludes that it is no wonder human life can appear insignificant.

### 1.2 Onsala Space Observatory

Onsala Space Observatory (OSO) is located outside of Gothenburg and is a national infrastructure for radio astronomy. The observatory gives scientists the tools and equipment needed to study the earth and space. One of the central areas of research at OSO is the research of the origins and life cycle of stars and galaxies, which is done by using radio telescopes. In contrast to optical telescopes, these telescopes operate on a different wavelength than that of visible light. Therefore, this technology gives astronomers the ability to observe the radio emission of objects that are otherwise not visible through using optical telescopes due to e.g. dark dust clouds cluttering the sky. The observatory is also tasked with conducting geodesy activities, such as estimating the Earth's orientation in space, the movement of tectonic plates, and measuring changes in the earth's gravity.



**Figure 1.1:** Onsala Space Observatory, showcasing the large radio telescopes.  
**Source:** *Onsala Space Observatory* (n.d.)

Onsala Space Observatory also hosts guided tours of the facility, mainly aimed at classes of students on study visits. Currently, a new visitor centre is being built with the purpose of, through an exhibition format, showcase what kind of research is conducted at OSO, and why it is relevant to learn about space and Earth. One of the goals of the centre is to increase students' engagement and spur an interest in learning more about our place in the universe and the planet that we live on.

### 1.3 Target Group

A centric part of our study is our target group, which is children and adolescents in the ages 10-19. It is therefore essential to take this age group into consideration,

and how we best tailor the experience with them in mind. (Ott & Tavella, 2009) conducted a study with younger students to find what genuinely increased their engagement regarding computer-based learning. It was found that the students' keenness for trying out "mini" games (games that take less than an hour to complete) was high during the evaluation period. These games were mind games with a focus on cognitive challenges and development. It was also found that there was a correlation between eagerness to continue playing and success within a game. Additionally, those that failed in previous game sessions were also less enthused about upcoming game sessions. Generally, it was understood that perceived genuine engagement was highly related to the student's performance. If they did well in the mind games, they showed more interest and wished to learn more. Surprisingly, Ott & Tavella found that the degree of attractiveness and ease of use of the mind games had no differentiating impact on the engagement of the students. Therefore, it is reasonable to consider it important that tasks and experiences need to be tailored to specific users in order to induce genuine engagement in learning. The authors concluded that the activity and content at hand concerning the learning session highly impacts the students' engagement.

Studies made on children regarding our solar system brings benefit to this project in terms of understanding our target group. A study made on children aged 3-18 and their understanding of the size and shape of the earth, moon, and sun showed that current-day media has a huge impact on a child's understanding of the size and shape of the earth, moon, and sun (Bryce & Blown, 2013). Movies, social media, newspapers, etc. play a big part in forming a perception of these celestial objects. Bryce & Blown argue that this helps children to decentralise themselves and view celestial objects from other perspectives rather than from standing on the earth. Younger participants had a harder time correctly estimating the sizes and shapes of the earth, moon, and sun due to not being able to decentralise themselves. For example, some believed that the sun and the moon are only as big as they appear in the sky and that the earth is flat. The culture the child is raised in also plays a part in the understanding of celestial objects. Chinese participants were more inclined to believe that the earth is egg-shaped due to cultural upbringing, even in their teens. The study also showed that most children understood that the moon and sun are far away, and this was due to the appreciation of distance arising from the daily commute between their home and school. Generally, most children possessed the knowledge that Sun > Earth > Moon size-wise, but pinpointing the exact size differences were quite a challenge for most. Lastly, younger participants were more inaccurate regarding the sun's composition as well as the comparative size. Thus, it is important to consider all these aspects when the participants of a study are teens and younger. Cultural background is important, as well as exposure to media. The lack of comprehension of more precise distances and sizes is something that can be improved in the education of celestial objects by means of more "hands-on" learning through VR.

### 1.4 Design Challenge

The purpose of this project is to design an experience that sparks an interest in astronomy for users who aren't interested in the first place as well as encourage already interested users to delve deeper into the subject. Therefore, our design problem is how to encourage people to learn about hard-to-grasp subjects such as astronomy. We aim to achieve this by providing the user with an immersive tool in which they have the freedom to explore the subject as they please, facilitating a fun and interactive experiential learning environment. Designing for an exhibition poses challenges, such as attracting visitors to the installation as well as making it easy to understand and robust so that it can be left unsupervised. We plan to achieve this by creating a robust and intriguing prototype implementing VR technology that can be used in the exhibition at Onsala Space Observatory. The prototype will be in the form of an optical telescope, which fits the users' mental model of a telescope in contrast to radio telescopes. Additionally, we want to explore how research through design coupled with an agile work methodology can impact this kind of project, and examine the efficacy of such an approach.

### 1.5 Research Question

This section will present our research question and any connected hypotheses, which will during the course of the project either be verified or rejected.

*RQ: What considerations are essential when designing an interactive and inviting learning experience using Virtual Reality with the purpose of engaging adolescents in the advanced and hard-to-grasp subject of astronomy?*

Our research question aims to discern key factors that play a part when designing an educational VR experience for a younger audience. We wish to find factors that determine the quality and efficacy of a VR experience tailored toward adolescents so that future work in this field can take part of our findings and thereby optimise the outcome.

Below we present three different hypotheses that relate to our research question, whose purpose is to examine the outcome of the project and whether we succeeded in what we aimed for.

1. Virtual Reality makes learning more appealing in comparison to traditional educational methods
2. Virtual Reality can be used successfully as a tool for learning
3. Virtual Reality technology sparks an interest for an otherwise hard-to-grasp subject

## 1.6 Project Limitations

There are several limitations to this project that have to be considered. VR as an experience has certain limitations such as battery life and robustness. Additionally, the visitor centre (where the exhibition will be held) will have constraints in regard to the premises. Lastly, the sensitive instruments at OSO can be disturbed by cellular network signals as well as Wi-Fi signals and is therefore not allowed at the premises, which can pose an issue to us.

### **Virtual Reality**

The limitations of Virtual Reality systems is an aspect that has to be taken into consideration. First and foremost, there are limitations regarding battery - the proposed HMD has a battery life of roughly 2-3 hours before needing to be connected to a power source. If a power cable is connected the user may be restricted by the length of the cable, thus affecting the immersion of the experience which is something that we want to avoid. Moreover, using a stand-alone HMD raises the question of robustness. Even though a modern HMD is quite sturdy, frequently passing the headset back and forth between users will result in it wearing down quicker. There is also a risk of accidentally dropping the headset, potentially damaging it.

Additionally, the use of a single HMD restricts the participation of the experience to one person at a time. Since the experience that we plan to create is going to be held at an exhibition, the potential drawback is that there will not be enough time for everyone to use it. This could be solved by introducing more HMD's, although this would drastically raise costs, as well as having several HMD's in the exhibition may not be viable.

### **Exhibition Space**

The outcome of this project will be displayed at the exhibition at Onsala Space Observatory. This fact introduces several limitations to the project as a whole. Firstly, available physical space has to be considered. Since there will be several exhibition items present, we have to take into account the designated space for our project and not exceed it. As of writing this report, we have been designated an area in the main hall of the exhibition (see figure 1.2). It will take place in the visitors centre at OSO, which is currently under construction, thus making it hard to plan in detail and know how constricted we will be.



Initially, we considered developing the VR environment in Unreal Engine and coupling it to Open Space<sup>2</sup>, an interactive data visualisation tool of outer space funded by NASA. This would have given us an abundance of material to kick-start our project and develop it further for our purpose. However, this has been replaced with development in Unity due to several reasons. Firstly, we have previous experience in Unity which we believe will favour the project. Additionally, it will reduce the time needed to learn to use the Unity engine as well as learn the specifics of c++. Lastly, we have to learn how to use and incorporate Open Space into our environment, which we believe can be a steep learning curve. Therefore, we found it reasonable to focus solely on Unity and create an environment from scratch with the knowledge we possess.

## 1.8 Ethical Considerations

In regards to accessibility, there are several concerns that need to be addressed. Firstly, visitors with visual impairments will not have the intended experience, since it is primarily visual. This challenge lies beyond the scope of the project, and although we will strive to produce the best possible experience, it is not feasible to optimise the experience for every type of minor visual impairment. Additionally, wheelchair-bound visitors need to be considered. The physical accessibility of the prototype should not pose a challenge to movement-impaired individuals. Although we believe this will not be an issue with the current idea in mind, it is beneficial to acknowledge all things accessibility when designing.

Privacy will have to be considered when researching and evaluating with our target group. Measures will be taken in regard to study participants' anonymity, and it will be made clear that participation is not mandatory and anyone can opt-out at any given time during e.g. interviews or user tests. Furthermore, since the target group is adolescents, we may need a teacher's or adult's permission to conduct studies. Privacy issues regarding the installation are few if none at all since the experience do not require any data to be gathered or used.

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<sup>2</sup><https://www.openspaceproject.com/>





# 2

## Theory

This section will provide insight into the theories, fields and approaches that will act as a foundation for the project work. Theories that are relevant to the subjects of designing for exhibitions, Virtual Reality, and experiential learning are discussed. Furthermore, the fields of IxD and User Experience (UX), as well as the theory of information visualisation are explained in relation to the context of the project.

### 2.1 Interaction Design

Interaction design can be seen as the practice of designing the interaction between (often digital) products and their users. In contrast to traditional design disciplines, interaction design therefore focuses to a greater extent on the design of *behaviour* (Cooper, Reimann, Cronin, & Noessel, 2014). It is the focus and specialisation of how people interact with technology (Norman, 2013). As an interaction designer, one's mission is to augment the user's perception of what is happening, what has happened and what is possible to manipulate. Norman notes that it is a field based on principles of many different disciplines: design, art and psychology. Additionally, emotion plays a crucial part in interaction design, as taking it into consideration can result in a pleasant, memorable experience.

IxD has similarities to other design fields, such as industrial design and experience design (Norman, 2013). Industrial designers focus on the value, appearance and function of products/services/systems through the development of concepts and specifications, and experience designers focus on the general experience of the user with a product or system and how to optimise enjoyment through design. In these disciplines (IxD included), Norman presents fundamental principles of interaction. These exist to enhance the experience to be memorable and pleasant, and to reduce the risk of negative emotions. Norman establishes several terms: **affordances**, **signifiers**, **mappings** and **feedback**.

**Affordance** is what a product or system allows by appearance. Norman (2013) comments that one can use the terminology "is for" when speaking of affordance. It is tied to human perception and the possible actions we identify with objects with help of our senses. The object's properties and the user's capabilities form a relationship that dictates how the object in question may or may not be used. Norman states that affordances and their opposites (anti-affordances) have to be identifiable so that interaction mistakes, followed by a negative experience, are avoided.

A **signifier** is a property that tells the user where an action is possible (Norman, 2013). Norman argues that the role of the signifier is to communicate the purpose and structure of a device. Without them, the user is left clueless about how to operate a device and has to learn through trial and error.

**Mapping** is the relationship between action and outcome (Norman, 2013). A well-designed mapping is the outcome of a clear user understanding of how the layout of the controls affects control over the device. Norman states that it should feel natural, but that it is also culture-dependent and might not be cross-cultural, meaning that a certain mapping will not result in a good experience across many cultures.

**Feedback** is the concept of communicating that a system received a user action or request (Norman, 2013). It can present itself in many forms: visually, auditory, etc. Choosing the form of feedback is a challenge in itself and can result in a negative experience for the user if implemented poorly. Norman claims that feedback has to be instant. A delay of even a tenth of a second can irritate the user, which ultimately leads to the abandonment of the device. Other issues, such as too many sources of feedback, or non-informative feedback that lacks a description of the result of an action, are also of importance.

## 2.2 User Experience Design

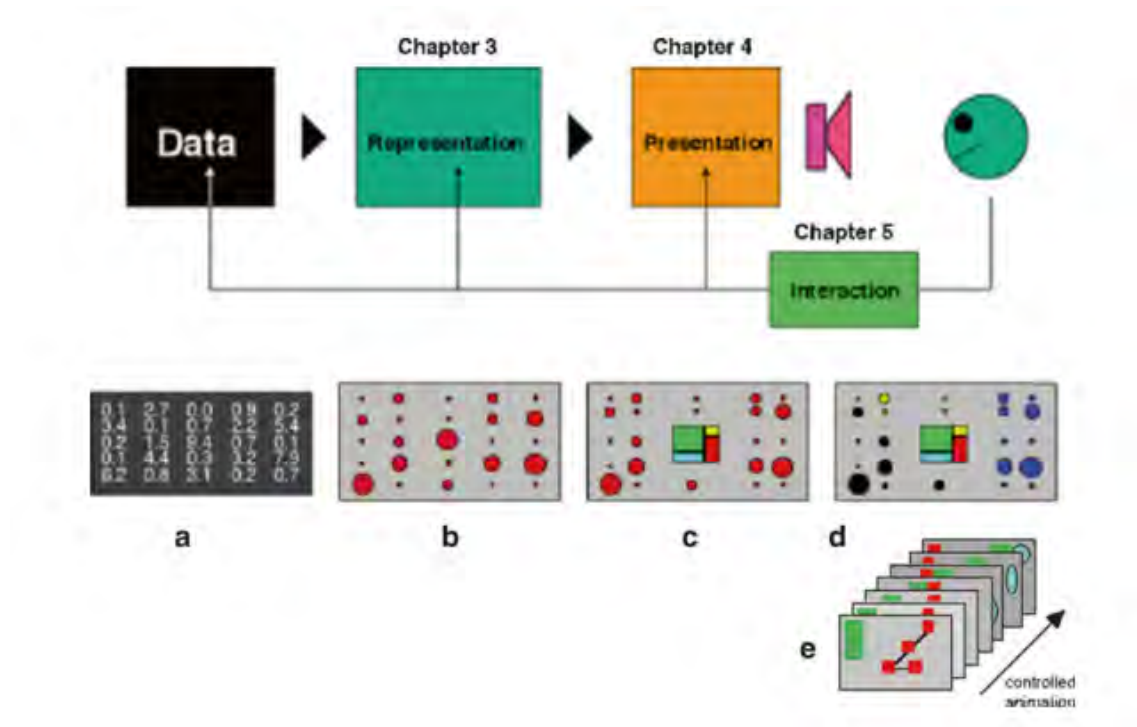
In contrast to Interaction Design which focuses on designing meaningful interactions between the user and a product, UX design is the process of designing the *whole* experience of using a product or service. This means that, while the essence of a user experience will be during usage, a user experience is an encounter with a system during a period of time that stretches from before usage to after usage (Roto, Law, Vermeeren, & Hoonhout, 2011). For example, before using a product or service a user may have already formed anticipations based on previous experiences of e.g. similar technologies. Furthermore, the experience also extends indirectly after usage by e.g. reflection and change of opinion.

Roto et al. (2011) argues that the experience itself is dynamic and highly individual, which means that users may experience a system in completely different ways depending on for example their motivation, expectations, and current emotions. Furthermore, the UX may change if the context changes, even though the system itself has not changed. The context can for instance refer to a change in the social context, for example, if the person using a system works with other people. The authors state that the features of a system itself naturally influences the experience in regard to e.g. aesthetics, functionality, interactivity and responsiveness.

## 2.3 Information Visualisation

Information visualisation theory presents unique methods to designers that ultimately helps the user understand complex data through purposeful, visual representation and presentation of said data (Interaction Design Foundation, n.d). It is useful when one has hard-to-grasp data or huge amounts of data and there is a need to make that information digestible. Furthermore, there might be an incentive to make the data interactive; to compare and filter it, thus providing the user with differing perspectives and angles.

Spence (2014) proposes a model, the *Reference Model*, for the process of information visualisation (see figure 2.1). Firstly, one's data has to be **represented** in an understandable manner. Spence states that three things have to be taken into consideration when trying to represent something: the **type** of data (numerical, categorical, etc.), the dimension of the data (number of attributes that need to be considered) and the **user** (their capabilities and limitations). Some representation techniques that Spence mentions are star plots, point representation and dials. Once the representation is produced, a **presentation** of it follows. Here, it is vital to understand the capacity of the human mind and eyes; how they receive and process information. For example, the eye's ability to distinguish details in the periphery view is extremely poor. Additionally, the preattentive processing of the human mind is a powerful tool and it has been shown that "outlying" data can be identified within 50ms. Spence mentions a variety of techniques to present the representation of data in space: documents (scrollable, flippable presentations) and zoomable environments (geometric and semantic). The final step of the process is to design the **interaction** with the information. The goal of this last step is to create intuitive, pleasant steps of interaction.



**Figure 2.1:** Information Visualisation Reference Model.  
**Source:** *Information Visualization: An Introduction* (n.d.)

## 2.4 Virtual Reality

A way to help people explore and thereby understand space is through Virtual Reality (VR). VR is a simulated experience that, in contrast to traditional interfaces, places the user inside of the experience. Modern commercial VR devices such as the Oculus Quest 2 (see figure 2.2) make use of a Head-Mounted Display (HMD) to portray the virtual environment to the user, along with handheld controls to interact with the virtual world. While HMD's are by far the most widely used and recognized implementation, VR can also be achieved by Cave Automatic Virtual Environments (CAVE) (Creagh, 2003). The CAVE2 project is an immersive system that projects virtual worlds onto large screens surrounding the user, which supports a mixture between 2D and 3D applications to be running in parallel (Febretti et al., 2013). This particular implementation makes use of 72 LCD panels which roughly creates a 360 degrees panoramic environment. The drawbacks of this implementation of VR is that it is much less cost-efficient than HMD's and that it requires a lot of space - which for commercial use favours HMD by a large margin.



**Figure 2.2:** "Oculus Quest 2" by Meta Platforms.

**Source:** *Meta Oculus Quest 2* (n.d.)

### 2.4.1 Immersion vs. Presence

The compelling aspect of VR, and especially through the use of HMD's, is that it can provide the user with a great sense of presence. The level of presence that a user feel relies heavily on immersion - which can be described as the technical aspects that makes a virtual reality experience possible (Slater, 2018). VR can, in other words, let the user *feel* like they are present in a different place through e.g. the use of visual elements, a realistic field of view, sounds, haptic feedback, and different ways of interacting with the virtual environment.

However, even if a virtual environment provide deep immersion which in turn produces great presence as an outcome, user will never truly *believe* in this perceived reality. Slater (2018) argue that virtual reality provides a perceptual illusion of presence rather than a cognitive illusion, which means that perceptive system immediately reacts to the perceived reality but as the cognitive system catches up, one will remember that the illusion isn't real. At this point, however, the reactions to whatever happened in the experience would already have taken place. This implies that even though the user *knows* that it is all an illusion, there is no difference in the response to events in the perceived reality. Wideström (2020b) argue that this is the case even though the virtual environment is not realistic - which favours coherent design and thought-out interactions over high-fidelity visual and auditory elements.

This is the beauty of Virtual Reality - if the user accepts the premise that it isn't real, and all the implicit rules that come with it, they can immerse themselves in a virtual world that has the potential to be 'more than real' (Wideström, 2020b). They can lift a car, levitate above the ground, or even travel through space. A

VR experience can also be almost real, or 'as-if', that is when the actions a user can perform mimics reality as closely as possible. Virtual Reality is inherently a compromise between reality and the virtual; a user may be allowed to experience walking around in New York City, while not being able to e.g. open doors, talk to people, or hear cars travelling by. This is what we imagine our experience to be like - a 'more than real' immersive astronomy experience that facilitates learning through exploring, but makes the rules that confine the experience clear to the user.

### 2.4.2 Degrees of Freedom

Degrees of Freedom (DoF) is used for classifying the number of possible ways for an object to move on the X, Y and Z-axis (Google, 2018). There are in total 6 DoFs, and VR HMDs are often either 3DoF or 6DoF. Input devices with 3DoF track rotational movement in 3D space, while 6DoF extends on that with transitional tracking. Basically, with 6DoF we can keep track of movement on the x, y and z axes. DoF is a huge part of immersion and therefore the presence a user feels when using a VR headset. A higher degree of freedom promotes a deeper immersion.

### 2.4.3 Tethered vs. Untethered

A VR headset can be tethered or untethered. A tethered VR headset is powered through another device through a cable, usually a PC. The benefits of tethering are increased power, no battery time, and utilisation of the PC's graphics power. The one flaw is that the cable reduces mobility and comfort. An untethered VR headset has the benefits of lower cost and increased mobility and comfort. However, without a cable, it has a limited battery lifetime (Lucas, 2022).

### 2.4.4 VR Development tools

As the technology's availability has been increased, so has the support for building applications for it. Tools like Unreal Engine<sup>1</sup> and Unity<sup>2</sup> offers extensive frameworks and tools that support building VR and AR applications. Unreal Engine and Unity are free-to-use game engines used by professionals and amateurs alike that offer a range of tools and functionalities, whether it is for creating simple 2D games or immersive VR experiences.

## 2.5 Designing for exhibitions and science centres

Designing an installation for an exhibition in a science centre can be a challenging task since it requires the designer to have an understanding of the subject and the target audience. Lake-Hammond and Waite (2010) argue that the role of the designer is to collaborate with the curator and understand and interpret the contents of the exhibition in order to transform it to an engaging and interesting experience.

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<sup>1</sup><https://www.unrealengine.com/en-US/>

<sup>2</sup><https://unity.com/>

With an understanding of the subject, the designer of the exhibition can act as a communicator that bridges the gap between the sometimes hard-to-grasp content coming from experts in the subject and its audience. In recent times, designers have begun to explore more sophisticated mediums to communicate the contents of exhibitions (Dernie, 2006). Many museums and science centres use modern technologies to complement physical objects in an effort to enhance the learning experience. This does however require the museums, galleries and science centres to invest in more sophisticated equipment, such as VR equipment.

### **2.5.1 VR in social settings**

Rehnberg et al. (2020) illustrate two VR designs in a museum exhibition environment, whereas one is an unsupervised long-term installation and the other is a facilitated experience. Both of the installations were a set of VR headsets lying on a table in the exhibition space. The authors bring forth potential challenges that were discovered during the deployment of these two experiences. Firstly, there is the issue of robustness. Installations in a science exhibition often invite people to explore by interacting with them - which requires the equipment to be sturdy in order to withstand forceful interaction. Rehnberg et al. (2020) bring up several factors that can affect the interaction in this regard. One factor is the age of the visitors; younger audiences tend to be less careful when interacting with objects in an installation, and this is especially the case if an installation is left unsupervised. Using new and exciting technology such as VR can also have an effect on this, since the excitement may result in a more careless interaction. Having tethered stand-alone headsets proved to somewhat constrict the movements of users, hindering them from moving out of the virtual bounds of the experience. However, over time this causes strain on the tether and cables wearing them out, which is sub-optimal.

The authors also discovered challenges in regard to attracting an audience to use the headsets. One issue is that people have fear of embarrassing themselves using the equipment, however, this was mostly the case for older participants. Another issue is the fear of the headset affecting make-up and hair. Another challenge is designing the experience to have a gentle learning curve, thus making it easy to understand and use. If the installation requires prior knowledge on how to use VR equipment, or if it takes too long to understand, the users will be discouraged to use it. Rehnberg et al. (2020) conclude that designing a simple and somewhat restricted experience proves to be a successful method to achieve an easy to understand and inviting experience.

### **2.5.2 Interactive installations**

Installations in exhibitions that are of scientific nature tend to rely on high levels of interactivity (Wideström, 2020a). Furthermore, installations in this specific context often intend to be educational, which puts an even greater emphasis on shaping the interactions. Wideström (2020a) therefore proposes a framework for analysing types of interactions and media in a science centre setting, as well as classifying

these interactions. The author argues that there are three types of interaction to take into consideration: level of participation (*Static vs. participatory*), the level of virtuality (*Physical vs. virtual space*), and the level of collaboration (*Individual vs. collaborative interaction*).

### **Level of participation**

The first classification of interaction discusses the level of participation between the content and the visitors exploring the installation. Most commonly, contents remain static. This means that the content is arranged in a certain way beforehand and that the visitors are free to explore it, but that the visitors can not *change* the content. In a more participatory installation, visitors add value to the content by contributing with their own knowledge and creativity. While high levels of participation can engage and spark interest in a subject it can come with challenges, such as ensuring the scientific validity of the content. The author argues that it is important to note that high levels of participation do not necessarily equal a more entertaining experience in comparison to a static one.

### **Level of virtuality**

The second classification reasons about the physical and virtual space of the installation, and where the interaction with the content happens. An exhibition of physical nature can have tangible objects that the visitors are encouraged to interact with, such as buttons and levers. In contrast, a purely virtual space is not as tangible and can be in the shape of e.g. visualisation of data. An interactive space can however embody both virtual and physical aspects, such that the visitor can experience both spaces as one.

### **Level of collaboration**

The third and last classification presented involves the interaction between participants of an exhibition. Wideström (2020a) discusses individual interaction with content and how it differs from a collaborative interaction, as well as the middle ground of "users *can* collaborate but don't *need* to". An installation can be specifically designed to promote collaboration between visitors. This can be done by either encouraging visitors to work together or by requiring more than one participant for the installation to function. In contrast, purely individual interaction can benefit people who prefer to learn and interact in solitude. The choice between encouraging social interaction and individual interaction depends on the content of the installation. Wideström argues that an exhibition needs to have a combination of both types of interactivity, since some content may benefit from having social interaction while other content may benefit from having individual interaction.

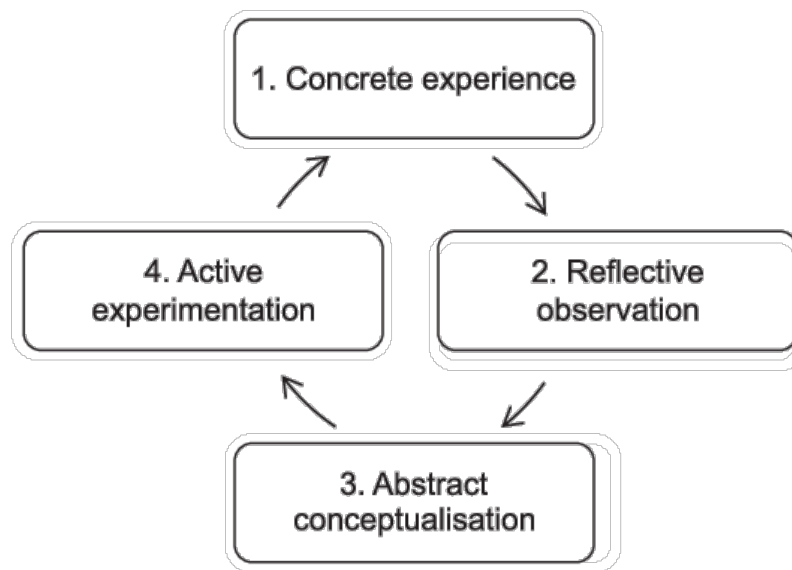
## **2.6 Experiential learning**

The potential for VR to act as a tool for experiential learning is monumental. Bricken (1991) brings forth several arguments for the usage of VR as a learning environment. Firstly, VR promotes experiencing things as though they were in real-life conditions. The user is placed inside a virtual environment with access to physical capabilities



such as touching, moving, hearing and seeing. Bricken argues that learning by experience is the best type of education, and VR provides this in the best possible way. In the aviation and military industry, pilots have been educated through VR simulations in the last two decades. Furthermore, with VR, you adhere to the capabilities of the real world. To pick up objects, you use your hands, to walk you use your legs and to turn around you use your body. These are capabilities we are born with and one can utilise these in VR. This is in stark contrast to computers, where the interaction is unfamiliar to beginners. Additionally, the control that the user/developer can have in VR matches that of a god. Time can be controlled, gravity can be denied, flight can be accessed. Things can be seen from various distances and from different perspectives, which is not something we can do in the real world. Bricken states that a virtual reality experience can be tailored for individuals, meaning that students can be given different tasks and challenges based on requirements and accessibility. However, Bricken highlights that there are challenges with introducing VR to educational settings. Cost, usability and fear are the three biggest hurdles for this introduction. Commercially available VR systems of high quality are in general costly. The systems need to be complex enough to create a suitable learning environment. Furthermore, Bricken states that educational institutions have other financial issues that plague them, such as low wages for employees and the shortage of teachers. Thus this investment has challenges. VR is a relatively new form of interactivity and therefore, as a tool, it is quite unfamiliar to the public. Usability-wise, it will take time to transition away from traditional educational means. Finally, Bricken believes that the greatest obstacle to the rise of VR in education is fear. Fear of hackers accessing control of your VR experience. Fear of distortion of information in a VR environment. Fear of accessibility; only the privileged have access to the prestigious worlds. These fears have to be addressed properly for VR to appear plausible in the domain of public education.

Bricken (1991) claims that VR can aid us in discovering how to best teach children and interest them by comparing objectivist learning to constructivist learning. In objectivism, it is believed that learning should be done through memorisation and replication of the real world, while in constructivism (see figure 2.3), students are given adequate tools to actively interpret the world and create their own meaning and understanding (Jonassen, 1991).



**Figure 2.3:** A model for a constructivist approach in education.

**Source:** *Constructivist Approach in Teaching in Higher Education* (n.d.)

# 3

## Methodology

This section aims to describe how the thesis work is structured based on proven and reputable approaches, processes and methods in the area of IxD and Software Engineering.

### 3.1 Research through Design

The terms *research* and *design* are quite vague - what does it mean to do research, what does it mean to do design, and how do they relate to each other? Generally, research and design can differ in regard to e.g. purpose, result, and outcome. The purpose of research is often to gain or produce knowledge in a specific field, whereas design is more aimed to produce a specific solution to a design problem. The result and outcome of research are theoretical and often quite abstract. Design is on the other hand more than often contextualised and tangible in nature. Even though research and design differ in what is expected of them to produce, they are similar in the sense that they both aspire to produce something new based on what is already known. When scrutinising the two terms it also becomes evident that they share certain elements, such as evaluation and development activities.

The general approach that will permeate this project is Research through Design (RtD). This is nowadays a widely recognised approach within the Human-Computer Interaction (HCI) and IxD community, although its definition can vary. This is because RtD is still a fairly new approach in the field of interaction design, and its theory is yet in its formative stage. Generally, using RtD implies that we conduct research by employing design activities such as methods and processes in order to generate new knowledge (Stappers & Giaccardi, 2017). In other words, we are in this project *exploring* a design challenge in the context of exhibitions through conducting various design activities, with the intent of generating new knowledge in the domain of IxD.

### 3.2 Design Thinking

Design thinking is a process of seeing and consequently thinking (Razzouk & Shute, 2012). The tasks of a design thinker are as follows: identify ideas and concepts for solving a specific problem; compare and relate the different ideas to form a solution, and finally inspect the outcome in order to enable further design efforts. This is an iterative, non-linear process. Razzouk and Shute describe several characteristics

(see Figure 3.1) that of a design thinker; characteristics that appear through constant exposure to the process. These characteristics are beneficial to adopt and will improve the quality of this project through a careful, non-linear process of design.

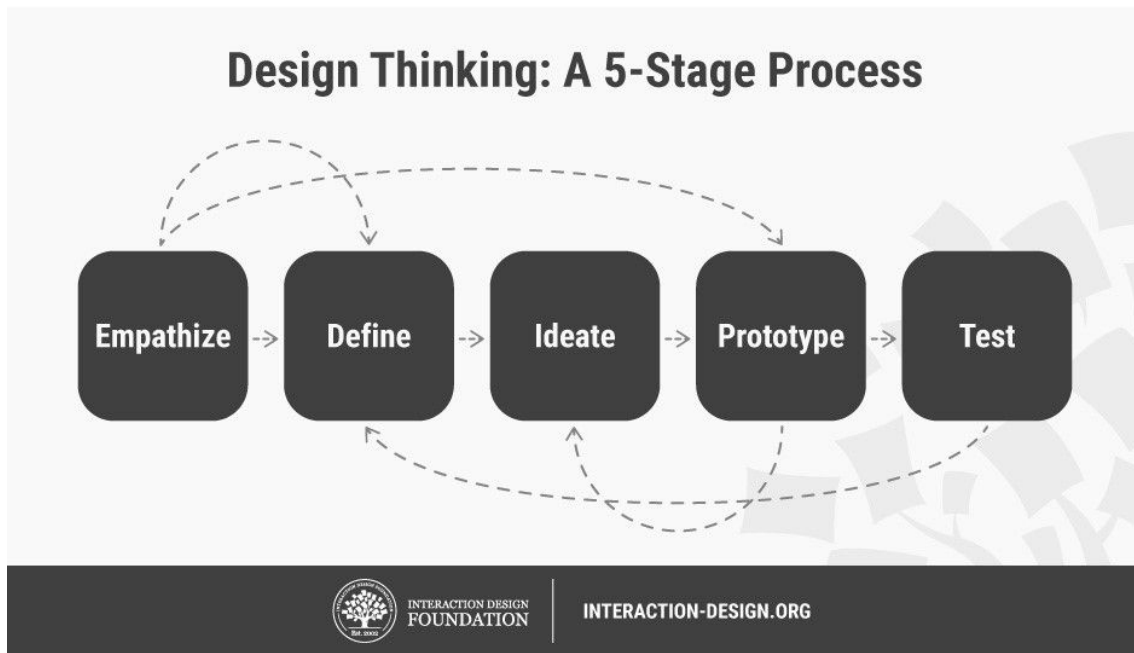
**TABLE 2**  
*Design-thinker characteristics*

Characteristics	Description
Human- and environment-centered concern	Designers must continually consider how what is being created will respond to human needs. They should also consider environmental interests at a level with human interests as primary constraints for the design process.
Ability to visualize	Designers work visually (i.e., depiction of ideas).
Predisposition toward multifunctionality	Designers should look at different/multiple solutions to a problem and keep the big picture of the problem in mind while focusing on its specifics.
Systemic vision	Designers should treat problems as system problems with opportunities for systemic solutions involving different procedures and concepts to create a holistic solution.
Ability to use language as a tool	Designers should be able to verbally explain their creative process forcing invention where detail is lacking and expressing relationships not obvious visually (i.e., explanation should go hand in hand with the creative process).
Affinity for teamwork	Designers need to develop interpersonal skills that allow them to communicate across disciplines and work with other people.
Avoiding the necessity of choice	Designers search competing alternatives before moving to choice making or decision making. They try to find ways to come up with new configurations. This process leads to a solution that avoids decision and combines best possible choices.

**Figure 3.1:** Characteristics of Design Thinkers

**Source:** *What Is Design Thinking and Why Is It Important* (n.d.)

The following definition adequately describes how we intend to structure our design work in accordance to the Design Thinking process: *"Design thinking is a non-linear, iterative process that teams use to understand users, challenge assumptions, redefine problems and create innovative solutions to prototype and test"* (Interaction Design Foundation, 2016).



**Figure 3.2:** Interaction Design Foundation's process for Design Thinking  
**Source:** *Design Thinking* (n.d.)

### 3.3 Agile Development & Software Engineering

The development of the VR system should be approached with an agile mindset. Agile methods exist to help software development companies in their process of creating products and services, making this process dynamic and open for quick and smooth changes based on stakeholder and customer requirements (Cao, Mohan, Xu, & Ramesh, 2009). Rather than massive patches and updates, the focus is to release small-scale and adaptive releases. Additionally, Cao et al. claim that with growing interest within organisations to adopt agile practices, there are several challenges with this practice; overemphasis on early results, insufficient architectural planning and minimal test coverage.

The *Agile Manifesto* was written in the late 90's and serves as a guide for agile practitioners (Shore, 2021). It presents four foundational values (see Figure 3.3) and 12 principles that support it. These principles are (Shore, 2021):

- "Our highest priority is to satisfy the customer through early and continuous delivery of valuable software."
- "Welcome changing requirements, even late in development. Agile processes harness change for the customer's competitive advantage."
- "Deliver working software frequently, from a couple of weeks to a couple of months, with a preference to the shorter timescale."
- "Business people and developers must work together daily throughout the project."
- "Build projects around motivated individuals. Give them the environment and support they need, and trust them to get the job done."

- "The most efficient and effective method of conveying information to and within a development team is face-to-face conversation."
- "Working software is the primary measure of progress."
- "Agile processes promote sustainable development. The sponsors, developers, and users should be able to maintain a constant pace indefinitely."
- "Continuous attention to technical excellence and good design enhances agility."
- "Simplicity, the art of maximizing the amount of work not done, is essential."
- "The best architectures, requirements, and designs emerge from self-organizing teams."
- "At regular intervals, the team reflects on how to become more effective, then tunes and adjusts its behavior accordingly."

Throughout the process of developing the VR experience, we will adhere to these principles and values of agile software development. This will allow the project to not funnel resources and time into functionality that later on when change is costly, is proven to be undesired. There are many Agile methodologies that have been tried and tested over the years; each one is unique in its own way. We will not be using any specific method for this project since these methods, for example, scrum, imply additional work that does not add value to a project of this scale.



**Figure 3.3:** The four agile values of the Agile Manifesto  
**Source:** *The Art of Agile Development* (n.d.)

### 3.3.1 Pair Programming

When pair programming, two developers share a single PC or laptop to program. One is responsible for programming on the computer (the "driver"), while the other one is more of a commentator (the "navigator") (Agile Alliance, 2016). The benefit of this approach to programming is that code is actively discussed between the pair, which results in better solutions. Furthermore, knowledge and experience can easily be shared between the pairs, especially if there is a notable difference.

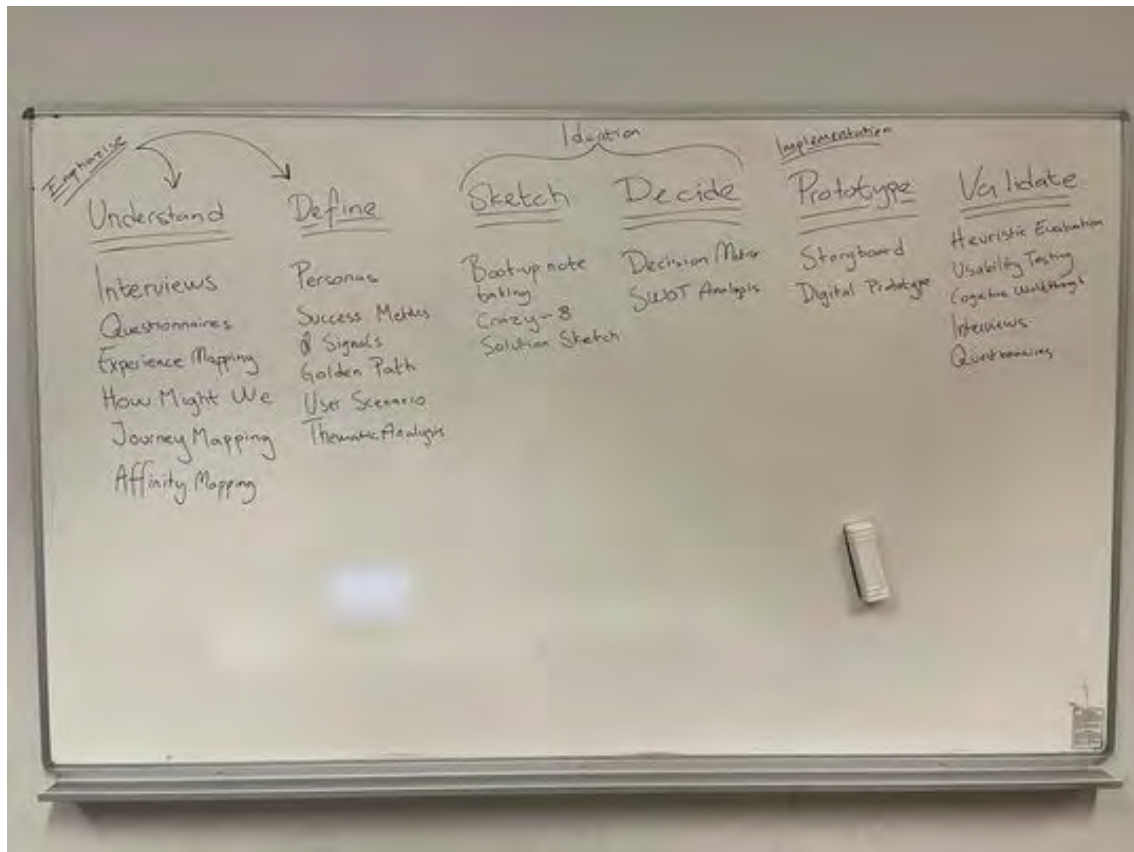
We believe this can be used in the initial phase of our programming journey, where it will unite us in code quality, structure and hierarchy. It might also be utilised during troubleshooting and bug fixes.

### 3.3.2 Code Review

Code Review is a process of inspecting and commenting source code written by someone else (Sadowski, Söderberg, Church, Sipko, & Bacchelli, 2018), and is seen as a means to increase the quality of the software system. Current day developers expect 3 outcomes of modern code review: education (learning about "good" code through guidance), maintaining norms (adhering to industry standards and therefore increasing readability) and accident prevention (fixing code that could potentially be harmful to system performance) (Sadowski et al., 2018). We believe this will increase the quality of the code, but more importantly, reduce the number of bugs which could save us time.

## 3.4 Design Methods

This section will describe the interaction design methods that we intend to use to achieve our aim for the project. The methods are split up into 5 different phases in accordance with the Design Thinking process as described in section 3.2. The activity of choosing appropriate methods for this project can be seen in figure 3.4. During this activity, we discussed a plethora of methods, which were then narrowed down to a number of methods that we deemed reasonable regarding time constraints and the value that they would bring to the project.



**Figure 3.4:** The process of choosing appropriate methods for the project.

#### 3.4.1 Empathize

The first step of the process is to understand the issue that is at hand, which is done through extensive research of the users. The goal in this step is to study the target user and learn about their requirements and needs (Interaction Design Foundation, 2016).

##### Interviews

Interviews will be used in the initial phase of the project to gain insight into the target group and to assess their needs. Preece, Rogers, and Sharp (2015) state that there are three different types of interviews: unstructured, semi-structured, and structured. choosing the appropriate approach to an interview depends on the purpose and expected outcome of the interview. If there is a need for specific questions to be answered, a structured interview should be used where deviation from these questions is rare. An unstructured interview encourages questions and discussion that were not necessarily planned but that popped up as a result of the previous discussion. The semi-structured interview is a mix of the two other interview types. In our case, we most likely will conduct semi-structured interviews due to our need of learning about the target group and their requirements through conversations as well as having specific questions in mind regarding this project.



### How Might We

This method is suitable to use after identifying possible issues and problems through contact with the target group. These problems should then be re-written as opportunities, commonly on post-its (Odell Keller, 2019). They should be stated in such a way that it is not too broad and thus making it difficult to address, but not too narrow as it can limit solution options. For example, an identified problem phrased "users have limited experience with VR systems" should be re-phrased as "How might we increase the learnability and ease of use for inexperienced users?".

### 3.4.2 Define

Followed by the *Empathize* phase (section 3.4.1), we assemble the gathered information in the Define phase. Here, we use different methods to analyze the data in order to define problem statements (Interaction Design Foundation, 2016).

#### Personas & Extreme Characters

A Persona is a fictional character that is based on observations of the users of a target group (Dam & Siang, 2021). Creating personas from the data gathered in the previous phase can therefore be of great value in the project since it helps us as designers to stay in context and keep us from designing for "ourselves". We can also go a step further with personas, creating Extreme Characters (Djajadiningrat, Gaver, & Fres, 2000). Instead of designing for a typical user in the target group, this method focuses on designing for characters with highly exaggerated emotions. Keeping an Extreme Character in mind when ideating can aid us in designing an experience that fits even the edge-cases of the target group.

#### Thematic Analysis

Thematic Analysis is a method of analyzing data collected from e.g. interviews through extracting common themes found in the data set and structuring them in a comprehensible manner (Nowell, Norris, White, & Moules, 2017). This method can aid us in examining different perspectives from a qualitative study to gather insightful knowledge, which in turn can guide our ideation.

### 3.4.3 Ideate

In this phase, it is time to generate ideas and explore possible solutions based on the problem statements developed in the *Define* phase (section 3.4.2) (Interaction Design Foundation, 2016).

#### Crazy 8's

This sketching method encourages the user to generate several ideas for a highlighted problem. Each design team member is to sketch 8 unique ideas in 8 minutes (Google, 2018a). These are supposed to be rough sketches and are meant to promote inspire the team to find the right solution. It is common to present one's ideas afterward and to discuss the strengths and weaknesses with the team.

#### **Decision Matrix**

A Decision Matrix is used to evaluate and grade ideas/prototypes based on criteria (Google, 2018b). The specific criteria are determined by the team based on what is most important. Usually, the Y-axis and X-axis are labeled with two criteria, and the ideas are then mapped on the matrix. It is a method used for filtering ideas based on criteria, and would be useful for us since we have several important criteria when evaluating possible solutions, such as "interest versus implementability" and "immersion versus cost".

#### **3.4.4 Prototype**

The ideas generated in the *Ideate* phase (section 3.4.2) will be realised in this phase through prototyping (Interaction Design Foundation, 2016). It can be beneficial to produce a low-cost prototype so that drastic changes are easier to implement.

##### **Digital Prototyping**

Digital prototyping can be done through various prototyping tools, such as Adobe Xd (see section 3.5.1). It produces high fidelity prototypes where the detail can be quite complex, while still being quick to produce (Tan, 2021). It is beneficial due to its low cost and high evaluation potential.

##### **Physical Prototyping**

Since the project aims to have both digital and physical aspects, physical prototyping is as important as digital prototyping. It is crucial to consider the installation should be presented in the context of a science centre, as well as the theme of astronomy. We intend to use both low-fi and hi-fi prototyping methods to achieve a visually pleasing and functional physical prototype. At early stages of the process, paper prototyping is a quick way to shape to bring an idea to life (Foundation, n.d.), and it also easy to reproduce and to make changes. It does however lack authenticity and may be too basic to get proper feedback on.

##### **Wizard of Oz**

The Wizard of Oz is a prototyping method that evaluates a system that does not yet exist (Hardwood, 2018). This is done by providing system responses to user actions originating from humans, typically concealed from the user. This then appears as genuine system response. It is a method used for accessing the effectiveness of potentially time-consuming implementations, and to decide whether or not they are received well by the target group.

#### **3.4.5 Test**

Once a prototype is established, it should be exposed to testing and evaluation. This is a phase that results in suggestions for improvement in further iterations. (Interaction Design Foundation, 2016).

##### **Heuristic Evaluation**

A heuristic evaluation is done by experts based on several heuristics that evaluate a programs usability (Interaction Design Foundation, 2022b). The most well-known and used heuristics are the 10 Nielsen’s heuristics. These heuristics are (Nielsen, 2020a):

- **visibility of system status**
- **match between the system and the real world**
- **user control and freedom**
- **consistency and standards**
- **error prevention**
- **recognition rather than recall**
- **flexibility and efficiency of use**
- **aesthetic and minimalist design**
- **help users recognise, diagnose, and recover from errors**
- **help and documentation**

In our case, not all heuristics are relevant, and one can decide what heuristics matter in the evaluation. Furthermore, one can introduce other heuristics if it is deemed that they bring value and are of importance. Nielsen argues that between 3-5 evaluators will identify 65%-75% usability issues, which is also the optimal range due to the discovery of new issues falling off rather significantly with additional evaluators (Wong, 2021).

It can be conducted early in the design phase and help prevent issues from the transition from design to actual implementation. Specific issues can be explored and the overall UX can be rated with consideration of UI elements (Wong, 2021).

### **Cognitive Walkthrough**

In a cognitive walkthrough, the evaluators of the product perform tasks and ask questions regarding the UI, with the aim to understand the usability of the product and how new or inexperienced users would react to it (Interaction Design Foundation, 2022a). It is a task-specific approach that is extremely cost-effective and can be used early in the design process to eliminate issues that could make a product ultimately unusable. The chosen tasks are context- and product-dependent. During the walkthrough, these four questions should be answered (Interaction Design Foundation, 2022a):

- Will the user try and achieve the right outcome?
- Will the user notice that the correct action is available to them?
- Will the user associate the correct action with the outcome they expect to achieve?
- If the correct action is performed; will the user see that progress is being made towards their intended outcome?

### **Concurrent Think Aloud**

Concurrent Think Aloud (CTA) is a usability test method that focuses on gaining insight into the thoughts of the user while they interact with the system that is being evaluated (Usability.gov, 2013). Throughout the testing session, users are encouraged to express their feelings, emotions, and thoughts as they explore the system

and encounter issues. Usually, Several task scenarios are created for the CTA. The benefits of this type of usability test are the real-time feedback from the user, and being able to understand how they think when encountering issues (Usability.gov, 2013).

A typical CTA session could look something like this (Usability.gov, 2013):

- Welcome the participant to the CTA and ask any pre-test questions if necessary.
- Explain the CTA to the participant and allow them to ask any questions.
- The participant is given the task scenarios and reads them. once they are ready, they can begin testing while thinking aloud.
- An assigned note-taker documents what the participant says, their behaviour and whether they manage to complete a task or not, and how they do so.
- The sessions ends when all tasks are completed.
- The participant is asked any post-testing questions and thanked.

## 3.5 Tools

A plethora of tools will be utilised for this project. This concerns both the design and programming aspects, as well as the organisational aspect.

### 3.5.1 Design Tools

**Adobe Xd**<sup>1</sup> is a digital prototyping tool developed by Adobe. It allows collaborative prototyping and is test-friendly thanks to functionality that allows interaction with elements. Prototypes can be shared with a simple link, thus allowing for quick and easy evaluation.

**Miro**<sup>2</sup> is a collaborative mind-mapping tool that offers a variety of tools for idea generation, comparison and note-taking. It will be used for structuring, and idea and concept comparisons, analysing evaluation results and general note-taking.

### 3.5.2 Software Development Tools

For developing the actual application, **Unity** will be used. This means that the programming language will be `c#`, which is something we have a familiarity with. It features a variety of tools that makes environment development easier. It supports relevant platforms, such as desktop and mobile. It also fits this project in particular since it supports VR and is free to use.

**Visual Studio Code**<sup>3</sup> is a source-code editor where the application will be written. It is lightweight and allows the programmer to tailor its functionality, such as language, frameworks and libraries to the requirements and purpose of the project.

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<sup>1</sup><https://www.adobe.com/se/products/xd.html>

<sup>2</sup>[miro.com](https://miro.com)

<sup>3</sup>[code.visualstudio.com](https://code.visualstudio.com)

### 3.5.3 Project Management Tools

**Trello**<sup>4</sup>, which is a web-based list-making application, will primarily be used for structuring tasks for implementing features for the VR application. This will help us in prioritising features and updating the status of the implementation, and generally have an overview of the progress for the implementation of the software system.

**Google Drive**<sup>5</sup> is a cloud-based file storage service developed by Google. It will be used for storing and organising meeting documentations, diaries, images, presentations and various research notes.

**Version control** is common in programming and will be used in this project to keep track of versions and updates for the application. To achieve this, we will use Git<sup>6</sup>. Git enables developers to program in parallel through working on separate branches. Branches are created from either the main codebase or from an existing branch. Once work is completed on a specific branch, it can then be merged into the main codebase where potential merge conflicts can safely be resolved.

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<sup>4</sup><https://trello.com/>

<sup>5</sup><https://www.google.com/drive/>

<sup>6</sup><https://github.com/>



# 4

## Planning

This section aims to elucidate our planned work process and how we have decided to conduct research, implementation and evaluation within the given time frame. The process is split into three different phases (see figure 4.1), where the first phase is dedicated to planning and making appropriate preparations for the following phases. The second phase represents the majority of the project, that is the actual ideation, prototyping, implementation, and evaluation of the intended experience. The third and last phase is dedicated to the writing of the final report, along with preparations for presentations and the opposition of another project.

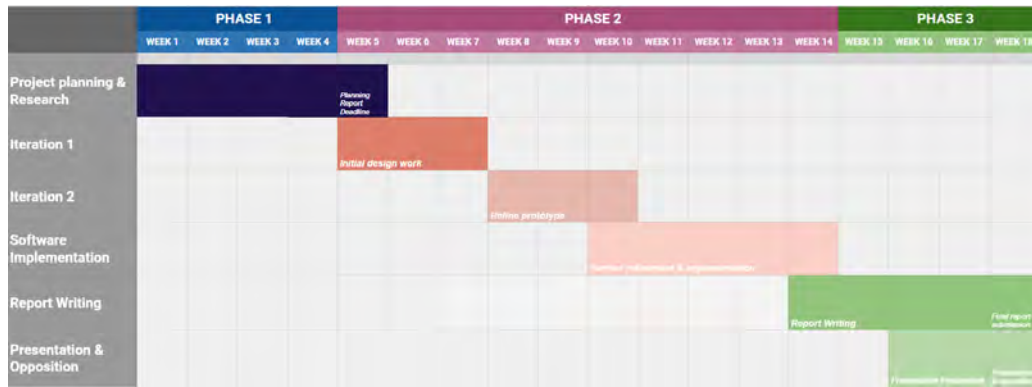


Figure 4.1: GANNT chart of the project.

### 4.1 Phase 1: Structuring and Planning

The first phase of this project is dedicated to researching the subject areas, organising and structuring the project, choosing an appropriate problem statement to tackle, and writing the planning report. Furthermore, a study visit at OSO during the early stage of this phase gave us valuable insights into the context as well as it inspired us to ideate concepts.

#### 4.1.1 Literature search & Relevant Theory

There are several **subject areas** that need to be taken into consideration before starting the design and implementation phases of the project. Education within VR was studied, and how it compares to other forms of education, such as traditional education existing in modern schools. The advantages and disadvantages of VR applied to education were underlined. VR as an interactive system was researched,

and its capabilities and limitations were understood. Astronomy was equally vital to understand due to its importance in this project since we aim to teach about it in a unique manner. The relationship of these three subjects, how they affect each other today, and what the possibilities are when utilising all of them at once is of great concern.

We have decided to structure the literature search in order to gain as much valuable knowledge as possible. First off, we search different databases (Google Scholar, Chalmers Library) with a combination of keywords corresponding to our subjects such as *VR+Education*, *VR+Astronomy*, *Education+Astronomy*, etc. We then save the papers that have relevant titles and proceed to read their abstracts. After reading the abstracts, we decide which papers are still relevant. The papers that remain after this process are read through from start to finish. Lastly, we review the citations of the remaining papers to find other papers that may be useful, which we then repeat the process for.

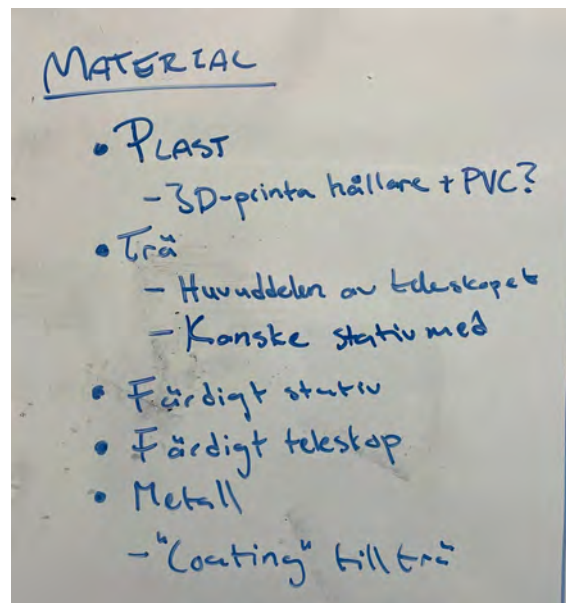
### 4.1.2 Understanding the approach

The approach to this task is characterised by an understanding of various methods, approaches, principles, processes, etc. that will be implemented during the design and programming of our prototype. Therefore, it was useful to read about these topics to make sure that we utilise them correctly. Furthermore, a plan had to be mapped how and when these theories will be implemented into the second phase of the project.

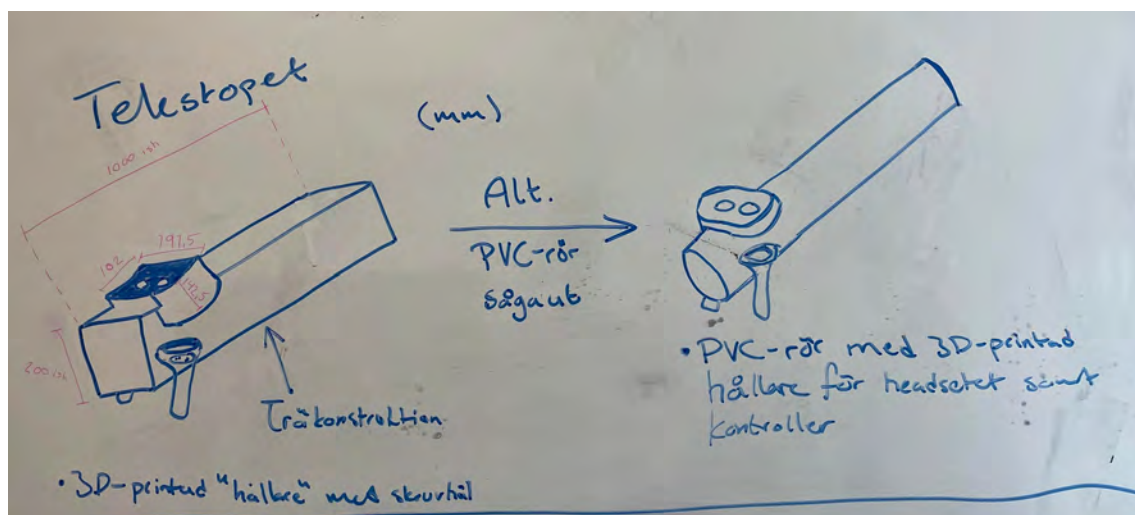
### 4.1.3 Materials & Assets

For the final physical prototype, we are going to need several different components. First and foremost we will need a VR headset, preferably an Oculus Quest 2 with its corresponding controllers and connection cable. This will then need to be attached to the prototype of the telescope. We have discussed the materials needed for the actual telescope, and both wood, metal, and plastic have been considered (see figure 4.2 & 4.3). Since wood and metal can be hard to work with, using a plastic PVC pipe for the main frame of the telescope would be optimal. This pipe could then be coated with a thin metallic film for aesthetic purposes. It would need to be roughly the same diameter as the HMD's length since we plan to fit the HMD in the pipe. Additionally, we propose to create a 3D-printer "holder" for the headset, so that we do not need to attach the headset itself to the telescope but rather the holder. The headset would then be locked in place by the holder by clips.



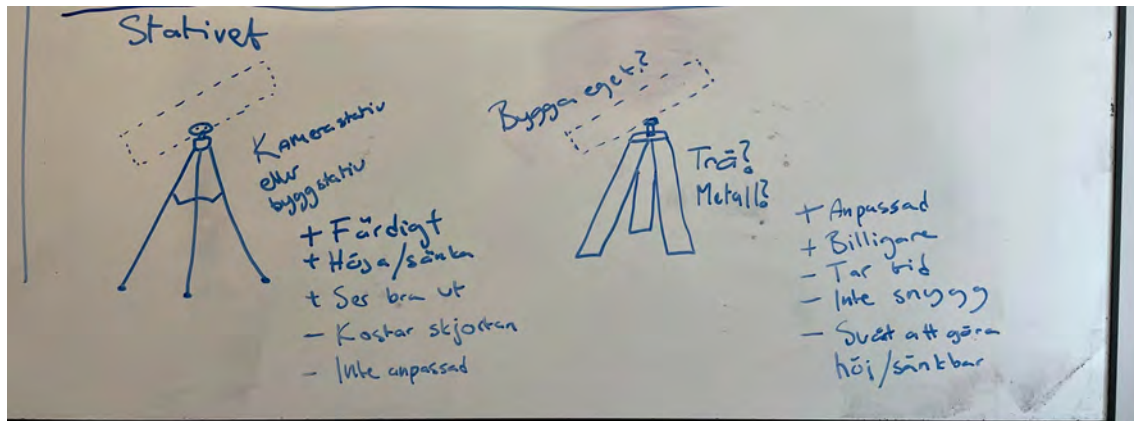


**Figure 4.2:** The materials discussed for the physical prototype.



**Figure 4.3:** Proposed wood vs. PVC pipe as the body for the physical prototype.

Furthermore, we will need to either buy a stand/tripod for the telescope or construct one ourselves. There are pros and cons with these alternatives which have been taken into consideration (see figure 4.4).



**Figure 4.4:** Pros and cons of buying or building a stand for the telescope.

3D modelling can take an enormous amount of time and is not the focus of the project. In order to save time, we may need to buy assets online to use in our virtual world.

### 4.1.4 Planning report

The planning report is a major part of the first phase as it summarises the research and planning that have been done during the first weeks of the project. It also states the scope of the project, what the problem statement is and how we plan to solve the problem. After the research and planning were done, the remaining time of the first phase was dedicated to transferring all information into the final report.

## 4.2 Phase 2: Design and Implementation

Phase two shifts the focus toward the design and implementation of a prototype that will act as a solution to the problem statement. The first iteration will be allotted to ideating and designing the problem solution. Specifically, we will visualise our idea and detail the specifics of physical appearance (look & feel), accessibility and UI. In the second iteration, we will refine the prototype. Here, we will focus on interaction with the system, what the user should see and how they should navigate in virtual reality. Week 10-14 will be used for constructing the VR system through Unity. User evaluation will be conducted continuously at the end of each iteration in order to validate that it fits users' requirements and needs. Appropriate methods to gather data and insight from our target group, as well as experts within the field, will be utilised, which can be found in 3.4.5.

## 4.3 Phase 3: Finishing up the thesis

As we reach the end of the second phase, we will start to write our final report in parallel with finishing up our final prototype. Hopefully, the prototype will be more or less finished by this point, but we want to be prepared to invest more time if needed. Furthermore, we will start to prepare for our final presentation and

opposition. This will include reading another thesis report and giving constructive criticism, as well as adjusting our report in accordance with the critique we receive.

## 4.4 Challenges

Apart from the limitations and challenges that we have highlighted regarding the project work itself, there may also be external factors that have an impact on the project. Firstly, since we are going to develop software, we may bump into unforeseen technical issues. It can be difficult to prepare for these types of issues and we will most likely have to solve them as they appear. Furthermore, when working with an external stakeholder there is always the risk of them changing their mind or suddenly wanting to take the project in a different direction than was previously agreed on. This could jeopardise the entire project, and no real precautions can be taken to prevent this other than having a continuous open dialogue with the stakeholder. We also need to be prepared that the end result of the project might not be what we planned for it to be. Evaluation of the final prototype may yield negative feedback, implementation of the software may not end up as intended, and we need to be prepared for an outcome that differs from our initial expectations.



# 5

## Execution and Process

This Chapter will elucidate the work process regarding the design and implementation of our concept in the project and how specific decisions, implementations and tests were executed. Furthermore, it will highlight how progress was documented so that it can be easily retrieved.

### 5.1 Design and Development Process

The design and development process of this project as a whole was characterised by methods and practices discussed in Chapter 3. They provided us with a solid foundation and guidance throughout the process. This section aims to give a brief overview of how aforementioned methods and practices influenced the execution, both in regard to the design work as well as the software development process.

#### 5.1.1 Design Process

This project relied heavily on Research through Design (section 3.1), which in our case meant that we intended to use the knowledge gained through using design processes and methods to contribute to the research field of interaction design. We view the process of going from a concept to designing a functional prototype as a knowledge generator, and that the insights that we gain from design actions should not only contribute to our own project but also to the field of interaction design.

The design work was structured around the 5-stage process of Design Thinking (section 3.2). This particular process was chosen as the foundation for the project since it excels in tackling ill-defined problems through a human-centred design perspective. It gives us the tools needed to form a deep understanding of the user, to iteratively re-define the problems and create contemporary solutions that can be evaluated and iterated further.

#### 5.1.2 Development Process

The project adopted the Agile development mindset, in which we continuously deliver small increments of software features each iteration to evaluate. A specific Agile development method such as Scrum or Kanban was not used, since it would create too much overhead for a project of this scale. The programming was done exclusively in Unity with frequent testing with the Oculus Quest 2. When programming, the HMD was connected to the computer via an Oculus Link, and thus with

the Unity platform, which allowed us for quick and easy, and on-demand verification of new features and environment elements.

### Visual Studio Code

The code editor *Visual Studio Code* was used for editing scripts and JSON files. A Script is a code file that can be attached to a Game Object and assign a specific behaviour to said Game Object. JSON files are used for storing simple data using Javascript Object Notation Structure (JSON). For this project, it was used for storing information about planets such as name, temperature and fun facts.

### Version Control (GitHub)

GitHub introduced a sound foundation to this project by allowing us to keep track of current versions and store our code in the cloud. Furthermore, if certain new code makes the system crash or behave in an unexpected manner, GitHub can easily revert the recent changes made. This was at moments very helpful for this project.

### Pair Programming

The coding was done mostly through the practice of *Pair Programming*. One project member had control of the keyboard and mouse and programmed, while the other one watched and spoke their thoughts and ideas. This process promoted discussion of what the overarching structure of the program should look like as well as good code practices. However, there are some drawbacks with this practice as well; since only 1 of 2 people is actively coding it means we produce less code compared to if both had been coding.

### 5.1.3 Meetings & Diary

Formal meetings were regularly held each week to keep track of important dates, discussing where we are implementation-wise in the project, whether we have questions for our supervisor and what has to be done moving forward. Meetings were held three times a week; Mondays, Wednesdays and Fridays. This was an effective layout of meetings so that work done in-between meetings could be discussed. Occasionally our supervisor Josef Wideström attended the meetings (exclusively on Fridays) as well as our contact from Onsala Space Observatory, Robert Cumming.

Meeting (2022-xx-xx)

**Attendants:** Augustas, Marcus

**General information:**  
General information about the meeting (what will be discussed/looked at).

**What have we done since the last meeting:**  
Here is described what has been done since the last meeting.

**Issues/Questions (for Josef/Robert/Thommy):**

- Question number 1
- Question number 2

**Next meeting (what we plan to do before the next meeting, roughly):**

- A list of things that are planned to be done before the next meeting

**Dates (To keep an eye on):**  
day (date): what will happen during this date

**Next meeting:**  
*A date for the next meeting is written here*

**Figure 5.1:** The document template for a meeting.

Additionally, each member kept track of individual contributions and tasks logged in a digital diary. This effectively documented our process and progress and was a useful resource when looking back on what had been done in the previous weeks.

## 5.2 Iteration 1

The first iteration started once we finished writing our Planning Report. Since it was the start of our project, the focus was on ideating and finding solutions to our problem statement.

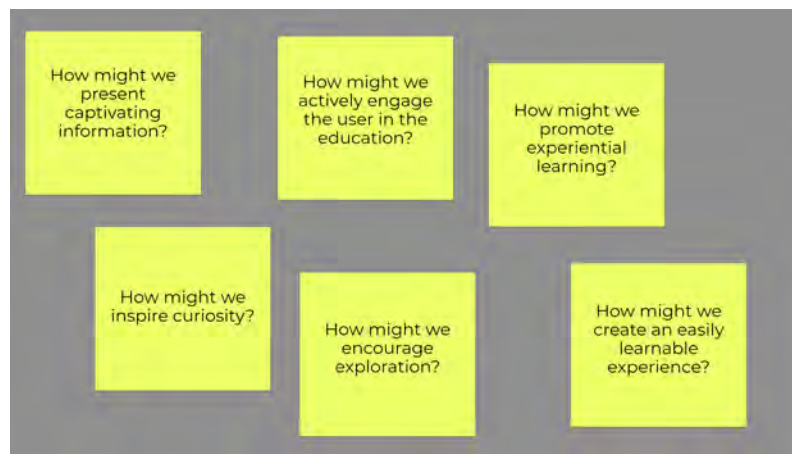
### 5.2.1 Pilot Study

This project is based on a pilot study by researchers at Chalmers University of Technology in collaboration with Onsala Space Observatory, that was conducted during the fall of 2021. The study consisted of workshops that were done with students of two different schools in Kungsbacka, with the purpose of gathering insights and ideas for the science centre that is currently under construction at Onsala Space Observatory. One of the ideas for the exhibition that emerged from the workshops was a vague idea of some kind of telescope to observe celestial objects. Our project can be seen as a continuation of this study, where the aim is to bring one of these ideas to life - and the idea that we chose to pursue was the telescope idea. The

idea was fleshed out during the planning phase of this project, and different ways to implement the idea were discussed. Finally, the decision was made to pursue VR development to bring the idea to life.

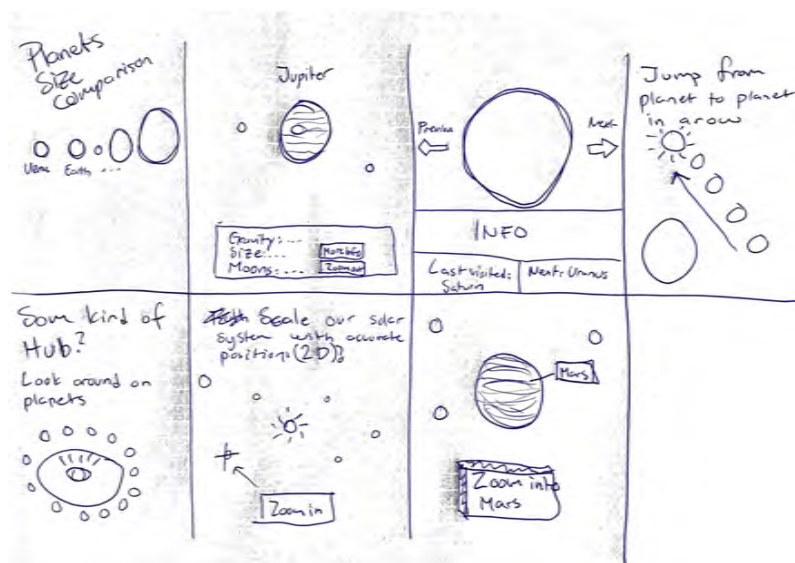
### 5.2.2 Finding a Solution

Based on the pilot study and the problem at hand, the project members began brainstorming to find a possible solution. Firstly, the HMW method was applied in order to rephrase our problems as solutions. Figure 5.2 shows "How Might We" statements deemed essential to consider in this project.



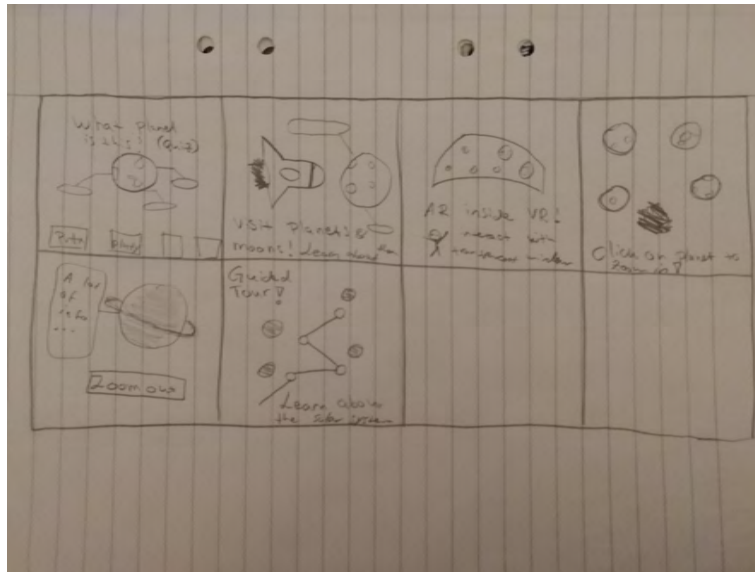
**Figure 5.2:** The HMW statements that were found valuable.

Based on the HMW, a session of Crazy 8's commenced where the goal was to brainstorm solutions to the statements. Both project members were given 8 minutes to produce 8 ideas. The outcome of this session can be seen in Figures 5.3 & 5.4.



**Figure 5.3:** The ideas generated through Crazy 8's.



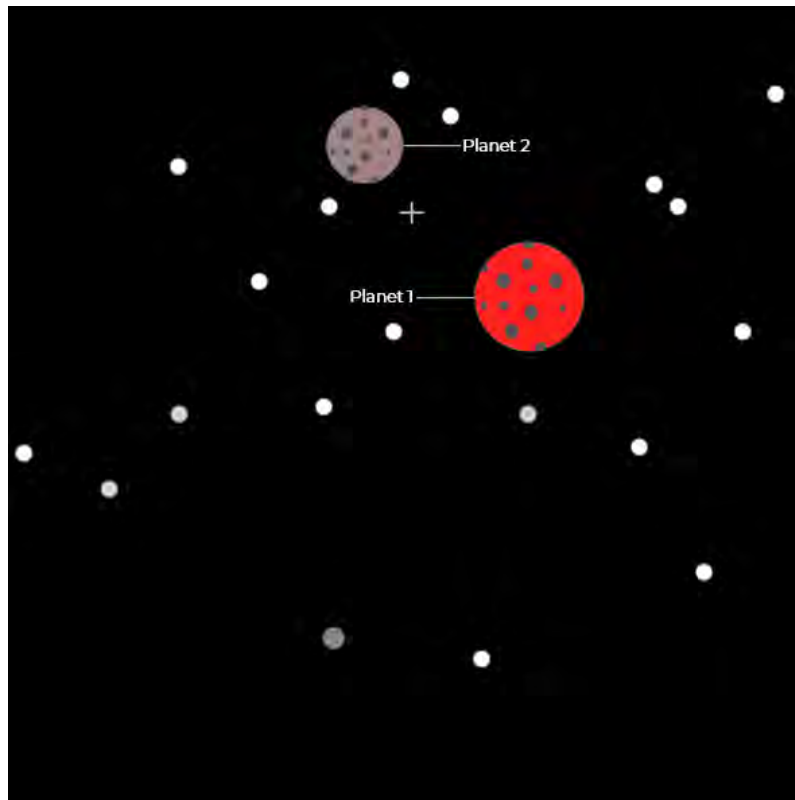


**Figure 5.4:** The ideas generated through Crazy 8's.

### 5.2.3 Designing the UI

The UI in the virtual environment is an important part of the experience that is being built, and therefore it was only natural to spend time refining and perfecting it. Adobe Xd was used to design elements and to connect different frameworks via actions.

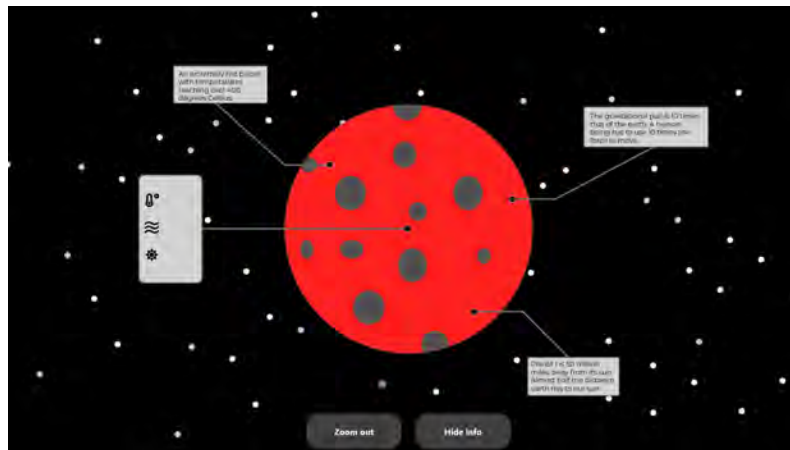
Figure 5.5 shows our initial idea of what the user sees when looking through the telescope. The crosshair marks the visual focus of the user. All planets in a certain radius around it get enlarged, allowing the user to direct their eyes toward it (see Figure 5.6). This enables them to zoom in on the planet where they can learn more about the planet (see Figure 5.7). When not zoomed in, the user can freely explore the virtual environment, and new planets are enlarged near the crosshair (see figure 5.8). User Movement inside this environment is done solely through rotations of the x- and y-axis' through the Oculus Quest 2. Interaction with the game elements, which consists mainly of buttons, is done with the hands. We knew that the Oculus Quest 2 possessed the technology for hand-tracking (although experimental), and it thus motivated us to create an experience without the need for the typical VR controllers.



**Figure 5.5:** Early illustration of what the user sees.



**Figure 5.6:** A "Zoom in"-button appears when the user looks at a planet.



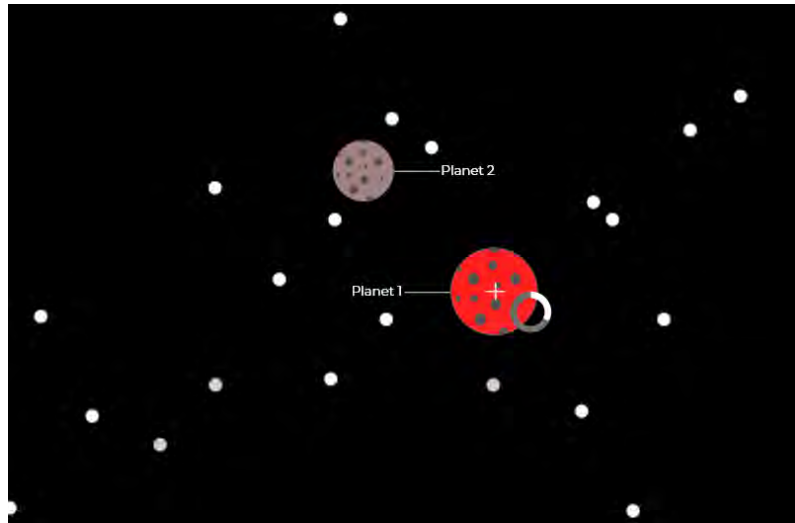
**Figure 5.7:** Planet information is displayed once the user zooms in.



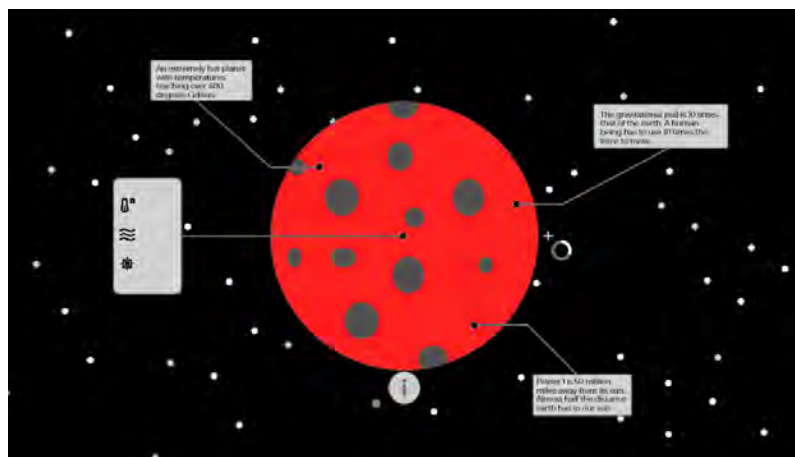
**Figure 5.8:** New planets are revealed when the user moves their gaze elsewhere.

However, we had another concept of interaction that we were considering in parallel with this. Instead of the user utilising their hands, they would solely rely on their vision and the focus of the eyes. In Figure 5.9 we see that no button is presented, but that a "loading" icon appears when the user looks at the planet. If the focus remains on the planet for long enough, it automatically zooms in. When wanting to zoom out, the user simply looks outside of the planet, where the zoom out action is timed just like the zoom in (see Figure 5.10). There are several reasons why we did not choose this type of user interaction. Firstly, only relying on the focus of the eyes for interaction and navigation at the same time restricts the freedom of the user. For example, how do we know that the user is reading a fact about the planet when zoomed in on a planet so that we do not accidentally zoom them out? There is also the issue of triggering actions unintentionally. Finally, we believed that using

the experimental hand-tracking of the Oculus Quest 2 would be an interesting and unique way of interacting in a virtual environment.



**Figure 5.9:** Looking at a planet prompts a loading icon that, when fully loaded, zooms in on the planet.

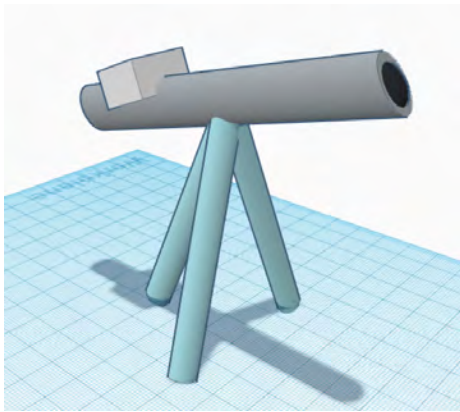


**Figure 5.10:** Looking outside of the planet prompts a loading icon for zooming out.

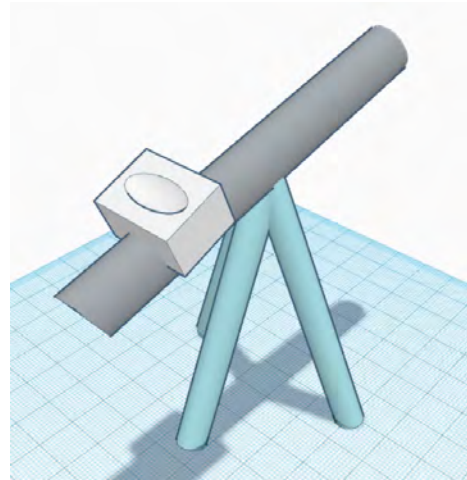
### 5.2.4 CAD Prototype

Firstly, the physical prototype was designed in Tinkercad<sup>1</sup> in order to have a blueprint to more or less adhere to (see Figures 5.11 & 5.12). We envisioned a stable foundation much like any telescope, with the body being pipe-shaped. The HMD is mounted on top of the pipe and is meant to convey the feeling of looking through the body into the stars. It was crucial to design the pipe-shaped body to be smaller in diameter than the length of the HMD since we wanted to avoid blocking the hand cameras located on the sides of it.

<sup>1</sup>tinkercad.com



**Figure 5.11:** CAD model made in Tinkercad.



**Figure 5.12:** CAD model made in Tinkercad.

### 5.2.5 Development in Unity

Once the Planning Report was finished and the design had been worked on, we moved on to developing the VR environment in Unity. This game engine was chosen due to its industry-leading VR tools and extensions and the ease of creating a virtual reality experience in Unity.

#### Setting up for VR development

Before we could start to develop the VR application, we needed to set up both the HMD and the Unity environment for VR development. First off, we needed to prepare the Oculus Quest 2 to be able to load our software onto it. This requires us to link a valid Facebook account and switch to *developer mode*, create a development team in the Oculus Developer Hub, and add our application to it. This was a somewhat frustrating process since it forced us to connect it with our personal Facebook accounts and we had to factory reset the HMD. With the headset ready to go the next step was to prepare Unity for VR development, which was fairly straightforward.

Unity's setup interface guided us through the process, which consisted of downloading packages needed for building and deploying the project. The Oculus Quest 2 operates on the Android SDK, which is something that we were familiar with since we have experience in developing Android mobile applications. With the VR environment set up, the last step was to prepare the project for hand tracking. Since hand tracking is an experimental feature of the Oculus Quest 2, this took a bit longer to set up and understand. Luckily we didn't have to create all the logic from scratch since Oculus provide an asset for the hands which features pre-made tracking for each individual finger. The next step was to activate the feature in the headset, which is done by simply flipping a switch in the development and experimental features tab in the Oculus menu.

To test the hand tracking, we downloaded an Oculus sample scene from the Unity asset store with interactive buttons. We succeeded in building and running the sample scene on our HMD, and after some testing, we concluded that hand tracking was working surprisingly well. Since OSO doesn't allow any wireless connections such as Wi-Fi and Bluetooth, this was a viable option. After considering other options, such as using a keyboard or controller, it was hypothesised that the use of hand tracking was possibly the least disruptive option for interacting with the environment, thus having a positive effect on the immersion. Therefore, a decision was made to pursue this way of interacting.

### Creating the Base

Before creating visuals, the application needed a strong base to build upon. The first step in building the base was to create a class that could hold all information that a planet may need. This includes e.g. the name, location in the virtual world, size, time to complete a revolution, time to complete a full orbit around its star, etc. To build actual objects of this class and create game objects dynamically, a local database and class that builds the objects were needed. A local database in the form of a .json-file<sup>2</sup> was created, containing all relevant information about a planet. This information is then read by a .json interpreter and saved as a list of planet objects, which is then passed on to another class that has the responsibility of dynamically spawning these objects as instances of a *prefab* into the scene.

### The Scene

Creating a new scene in Unity provides a light source in the form of directional light, as well as a camera. However, since the virtual world is supposed to be set in space, the directional light needed to be replaced by a point light originating from the star(s) of a solar system. Furthermore, the provided standard camera would not be compatible with a VR environment. Both the camera and the light source were therefore removed, and an OVR<sup>3</sup> camera rig was added to replace the standard camera. The sample scene also comes with a template skybox to simulate a clear sky, which was replaced by a high resolution 360 image of the night sky.

To spawn the celestial objects into the scene at run-time, game objects were created to host the different scripts that handled .json parsing and spawning celestial objects. On the subject of reading the database and creating objects based on the data received, it is important to mention the script execution order. Unity exhibits a non-deterministic behaviour when executing user-defined scripts, which means that it is not certain that the scripts will be executed in the same order each time the application is run. This can lead to issues if e.g. the spawner script is run before the database has been initialised, read, and parsed. The spawner has a dependency on the database since it relies on receiving lists of objects to spawn into the scene, and will not spawn anything if the list is empty. Therefore, the script execution order needed to be configured to prevent this from happening.

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<sup>2</sup>A lightweight text format for storing and transporting data

<sup>3</sup>Oculus VR integration package

### Prefabs and Scalability

In order to create and spawn a game object into the scene, prefabs were needed. Prefabs essentially allow us to create and store game objects for later use, as well as configure them on the go. This means that we can create a prefab which has a standard configuration, such as a 3D sphere, material, attached scripts, and colliders, to then instantiate it in run-time with the data from the .json-file. By using a simple for-loop in the spawn script, we can create new instances of the prefab using the list of data retrieved from the database. This also means that the code is prepared to handle large amounts of data since we can pick and choose what to instantiate dynamically depending on e.g. where we are looking.

### 5.2.6 Physical Prototype

In the first iteration the goal was to simply create a low-fidelity, quick and cheap prototype (see Figures 5.13 & 5.14). After designing the CAD model, we were inspired by other forms of physical stands, in this case, tower viewers (see Figure 5.15).

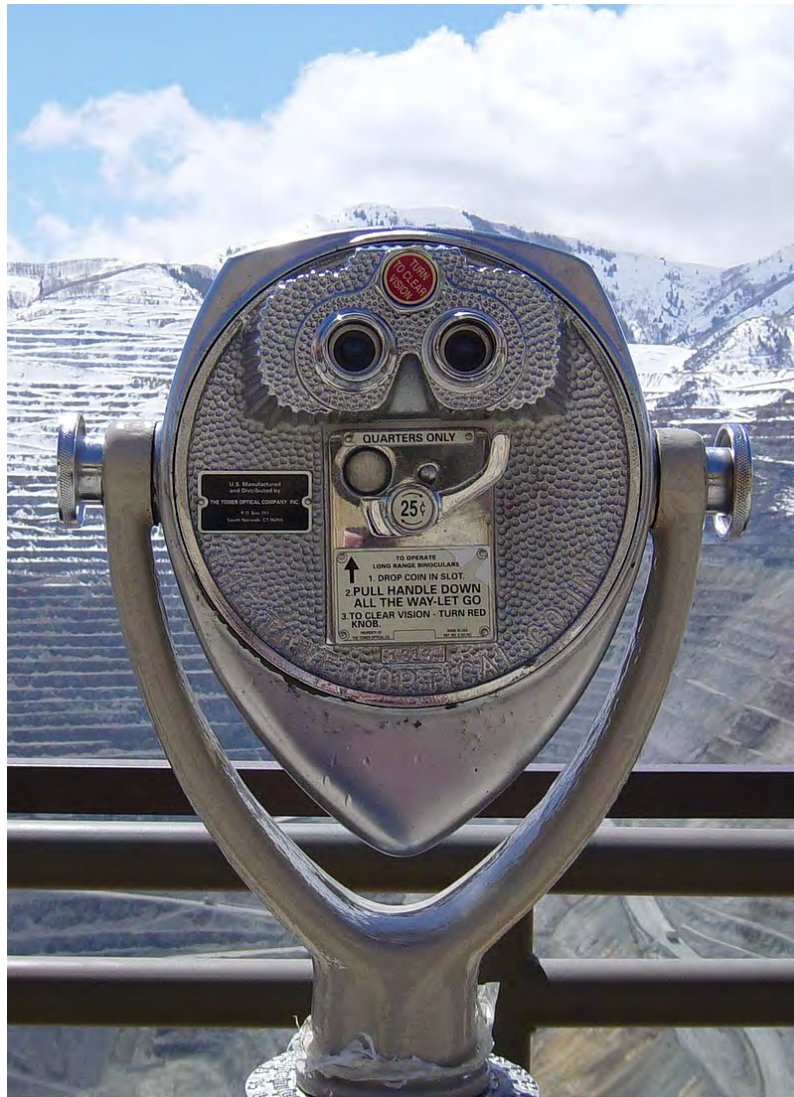


**Figure 5.13:** The first iteration of the physical prototype.



**Figure 5.14:** Marcus testing the HMD with the physical prototype.





**Figure 5.15:** A tower viewer in Utah, USA.

**Source:** Wikipedia, the free encyclopedia (2007)

This prototype consists of a wooden platform with 2 degrees of freedom (DoF) attached on top of a cylindrical stand. The platform itself consisted of two pieces of thin wood attached to a thicker block of wood that is then taped onto the stand. The HMD itself was taped on top of the platform. This prototype had several flaws, such as the hand-tracking cameras being slightly blocked and the overall look being poor.

### 5.2.7 Testing

Testing in this iteration was done by us, the project members. In this early phase, we wanted to make sure no major usability issues existed, and that if there did they would be taken care of instantly. Therefore, we readily tested it with ourselves since it does not require extensive planning and can be done at all times. Each time a feature was introduced it was tested by us regarding usability and learnability.



Additionally, while testing, it had to be taken into consideration how our target audience would react and behave to the information received and displayed.

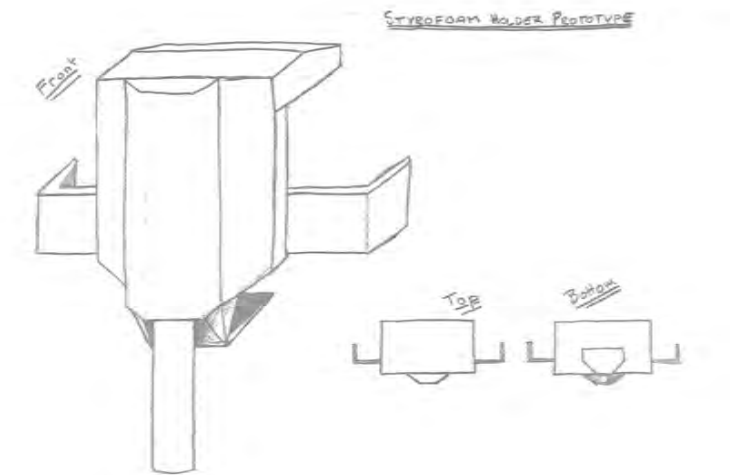
We had initially planned to test our Adobe Xd design with target users, as well as ask them general questions that would help us shape a genuinely interesting experience (see Appendix A for interview template). However, things did not pan out as we expected. We had contacted several elementary schools asking them whether they would want to participate in our user study. Several schools were interested, but the communication was slow and eventually fizzled out. This continued for a while until we realised we needed help and reached out to our supervisor and contact person at OSO. We managed to get in contact with a teacher at Kollaskolan in Kungsbacka, which was one of the schools that participated in the pilot study (section 5.2.1). They were more than happy to participate in our study, and a date was set to conduct user testing during our second iteration.

## 5.3 Iteration 2

The second iteration commenced roughly at the middle of the spring term. The focus of this iteration was to improve our digital and physical prototype, and finally test it with our target group to gather feedback and thereafter implement improvements.

### 5.3.1 Physical Prototype

Realising that the previous physical iteration somewhat blocked the hand-tracking cameras, we decided to construct a more lightweight stand and platform. We outlined a preliminary sketch of what the holder should look like (see figure 5.16). It would need to be fairly robust, since the HMD weights approximately 0,5 kg, while at the same time being made of a material that is easy to work with. Therefore, styrofoam seemed to be a viable option and the decision was made to construct a prototype.



**Figure 5.16:** Sketch of the second physical prototype.

The stand itself (see Figure 5.17 & Figure 5.18) is a stand used for scene lights, (model name?) and fits our purpose surprisingly well. The height is adjustable which makes it highly accessible for varying heights. It has 2 DoFs (x and y-axis) and has a sound foundation with 3 legs.



**Figure 5.17:** The second iteration of the physical prototype.



**Figure 5.18:** The second iteration of the physical prototype.



**Figure 5.19:** Marcus testing the prototype.

The figures above show a sturdy Styrofoam component attached to the HMD. It is designed to hold and support the Oculus Quest 2. However, since we still do not consider it an overly high-fidelity prototype, we use rubber bands to ensure that the HMD doesn't fall off from the Styrofoam component. Furthermore, the Styrofoam component has a 'pocket' where a small cylindrical steel pipe can be fitted. This pipe is then fitted into the light stand, which connects the two components, creating a stable prototype (see Figure 5.17).

### 5.3.2 Development in Unity

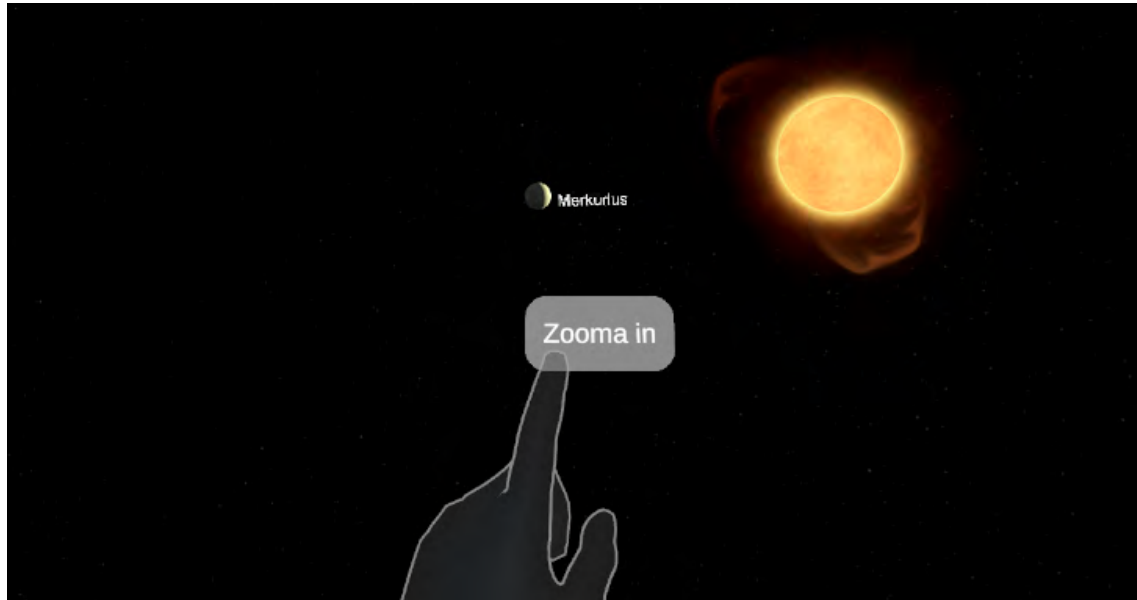
The development of the VR system continued throughout the second iteration. In the first iteration, we focused on setting up the project and starting to code the foundation of the environment, whereas in the second iteration we put our efforts into implementing desired features and functionality.

#### Zooming

Zooming is a key feature in the experience we are trying to create and is therefore an essential part of the Minimum Viable Product (MVP). The process of implementation consists of several parts; firstly, we created a raycaster<sup>4</sup> that originated from our centre camera that had an infinite length, meaning that it would pierce any object the user was looking at. This was our collider, and we created functionality that constantly checked whether a planet or star was within the boundaries of our raycaster. If it was, it triggered a function that displayed a button that says "Zoom

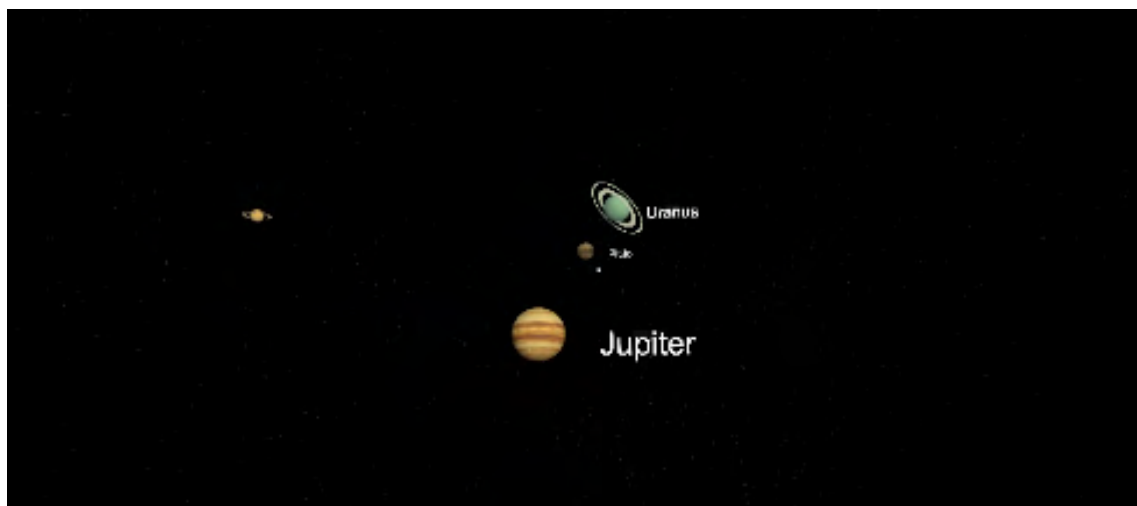
<sup>4</sup>Casts a ray from the origin and returns objects that the ray hits

In", as can be seen in figure 5.20. This button was placed on a canvas attached to the camera, making it accessible at a close range with the user's hands. The button disappears as soon as the ray does not collide with any object.



**Figure 5.20:** Looking at Mercury reveals a "zoom in"-button.

There was a second collider implemented whose purpose was to enlarge planets close to the crosshair of the user. This was done by creating an additional spherical ray caster, and any planet in collision with this spherical ray was increased in size to reveal planets (see figure 5.21). This was used to introduce a feeling of exploration and the goal was to encourage the user to look around and find planets.



**Figure 5.21:** Several planets being enlarged due to the spherical collider.

### Planets

The main focus for the planets was in this iteration to refine the visual elements, as

well as to create interactions between the user and the planets. First off, we wanted to implement some kind of movement in the planets. The first idea that came to mind was to simulate the planet's orbit around its star. After some discussion, it was decided that this would be both too time-consuming to implement and quite superfluous. If the simulation were to be realistic, the users wouldn't even notice the movement during a session of using the application since they would move incredibly slowly. It would also decrease the quality of the experience for some users, since at certain times planets may be at a location behind another object, e.g. the sun. The second idea was to create the illusion of the planets rotating around their axis, which would be much easier to implement. We, therefore, created a script that in each game tick added an offset to the x-axis of the planet's texture, which created the illusion of the planet rotating around its axis.

We created a canvas for the planet prefab (see figure 5.22) which would hold elements that present information about the specific planet, such as its name and unique facts. The canvas had a static direction when spawning the planets into the scene, which proved to be an issue for planets being behind the user at the start. When looking at these planets the canvas was not rotated toward the user, which means that they were displayed "backwards". Our solution for this was to simply add a script to the canvas that at the start of the application rotated the canvas to look at the centre of the scene using the zero vector.



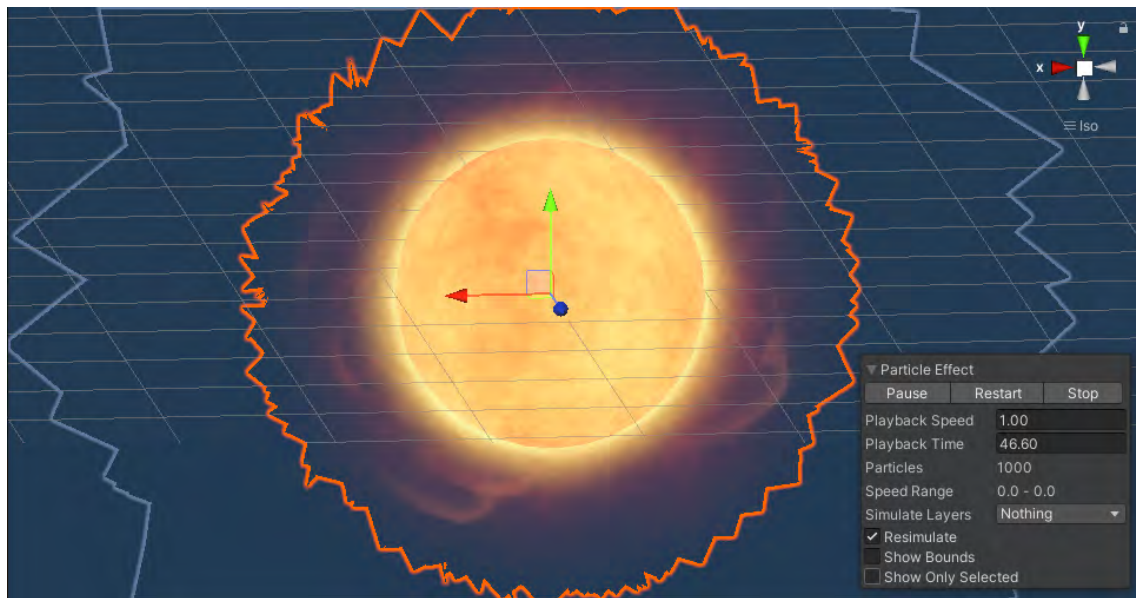
**Figure 5.22:** The zoomed-in view of a planet.

As previously mentioned, the user could now zoom in on the different planets as well as the sun. The planets and stars were prepared with a canvas that could host information, but at this stage, we were not sure of what information would be suitable for our target audience. We therefore chose to wait with implementing anything regarding this until we had performed our user tests.

### The Sun

Similar to a planet, a star is created dynamically through instantiating a prefab,

which is in this case a star prefab. This prefab hosts all the functionality that exists in a planet prefab, but we chose to separate them into different prefabs since we wanted to add particle systems to stars. We added three different particle systems to the star prefab; the surface, corona, and star loops (see figure 5.23). The first particle system, the surface, has particles moving on the surface of a sphere. Each individual particle is made up of a smoke texture, which moves and rotates on the sphere's surface at different speeds depending on the particle lifetime. This creates the illusion of the star being a great ball of fire. The second particle system is intended to give the illusion of a corona, which is the outer-most layer of the star's atmosphere. Last but not least, we created a star loop particle system. This is meant to show the coronal loops that occur due to magnetic flux. These particle systems can be quite demanding but since we currently only have one star showing at a time, it should not cause issues with the performance. Figure 5.24 shows the particle systems of the sun running smoothly on the Oculus Quest 2.



**Figure 5.23:** The suns particle systems.



**Figure 5.24:** The sun being enlarged due to the raycast collider.

### Fun Facts

Our goal is to teach adolescents about astronomy through a virtual environment. It was important for us to find facts about our solar system that are fun, digestible, and memorable. We call these "fun facts" as they are supposed to not only teach the user but also inspire awe and wonder. When creating these facts, we hypothesised that comparisons with the earth and more relatable "everyday" items would be key to making the information digestible for our target users. The following list contains examples that make use of comparisons to convey information:

- Instead of writing about the complex chemical structures of the toxic clouds in Venus' atmosphere, let's compare it to something more relatable: The clouds on Venus smell like rotten eggs!
- The gas giant Jupiter is a lot bigger than Earth. A relatable comparison to get a sense of its size could be: If we imagine the Earth to be the size of a grape, Jupiter would be the size of a basketball!
- To get a sense of Mercury's location in the solar system, we can look at the size of the sun in the sky when standing on Mercury compared to on Earth: If you stand on Mercury and look up at the Sun, it would look 3 times as big compared to on Earth.

Each planet/star would have a set of facts stored as an array value for the respective planet/star JSON structure. It would then be stored in a script and sent to the Planet Prefab and displayed on a canvas near the planet. This view should be hidden when the user is zoomed out. Since it can be quite time-consuming to research and



write these facts by ourselves, we looked for a library with facts already created. Sadly we did not find one that was suitable for the needs of this project, which means that we will have to write them ourselves.

### 5.3.3 Testing

The testing in the second iteration was done in two individual parts. In the first evaluation session, we visited an elementary school in Kungsbacka where we performed Cognitive Walkthroughs and Concurrent Think Alouds with a class of 6th-grade pupils. After compiling the feedback from the evaluation, we set up another session where we invited interaction design experts for a heuristic evaluation of our VR system.

#### Target Audience Evaluation

Since we had no prior experience facilitating user tests with this particular age group, along with the fact that we were to present a digital prototype, we needed to thoroughly prepare the session. First and foremost, we needed to make sure that our application would function as intended in the school environment since we had only tested it in our lab environment. If for some reason it would not function, we would need to have a backup plan. We went through the code and tried to break the application by trying to do things that were not intended. No bugs were found, and we then tried using it outside of the lab in Kuggen, followed by using it at home. This didn't affect the experience, and we felt fairly confident that it would function in any environment. With that being said, a worst-case scenario backup plan was still needed. We, therefore, created a video which showcased us using the application and interacting with the planets in the solar system, which we would then use for evaluation. This would without a doubt be sub-optimal for testing purposes, but if all else fails at least we have something to show. When it comes to the particular target audience that we had chosen to work with, we had to prepare how we would present ourselves and the project to them in an understandable manner. We found it hard to anticipate just how much knowledge a 6th grader possesses, so we had to be prepared to answer a wide range of questions. Therefore, we created a PowerPoint presentation in which we would present ourselves, where we come from, our project accompanied by a short video, and the intent of our visit.

We travelled to Kungsbacka in order to test the VR environment with our target audience. This specific audience was a class of 6th graders. The goal of this evaluation was to assess the virtual environment and receive feedback on its current state. Furthermore, we wanted to gain insight into what type of information about the various planets the pupils want to see. Therefore, we did not bring our physical stand. Additionally, we had to commute there by train and car, which was less than optimal considering the size of the stand.

Once there, we introduced ourselves as well as our supervisor, our project, and the goal of our visit. To make the individual tests run as smooth as possible, we had prepared a short video that briefly explained how the experience works, and



how to interact with objects in the virtual environment. The 24 pupils were then divided into three groups, and we moved into a separate classroom to conduct the individual tests. Each group was given the opportunity to experience the virtual space through the Oculus Quest 2 we brought. Approximately 120 minutes were disposed to this evaluation. Thus, each pupil had ca. 2 minutes to test the VR experience. They were asked to *think aloud* and give feedback as they tested. During the individual tests, the facilitator gave further instructions if the user got stuck, and asked questions regarding the interaction and usability while the note-taker documented the session (see Appendix B for notes). Finally, when everyone was done with their individual tests a *survey* (see Appendix C) was handed out to each pupil where they provided us with feedback on the experience as well as suggestions for future development. The idea of the survey was to catch any ideas that might have surfaced after the individual tests as well as to preserve their privacy, allowing them to present any negative feedback without us being able to trace the data back to any individual. See Appendix D for survey results.



**Figure 5.25:** A pupil in group 1 testing the virtual environment.

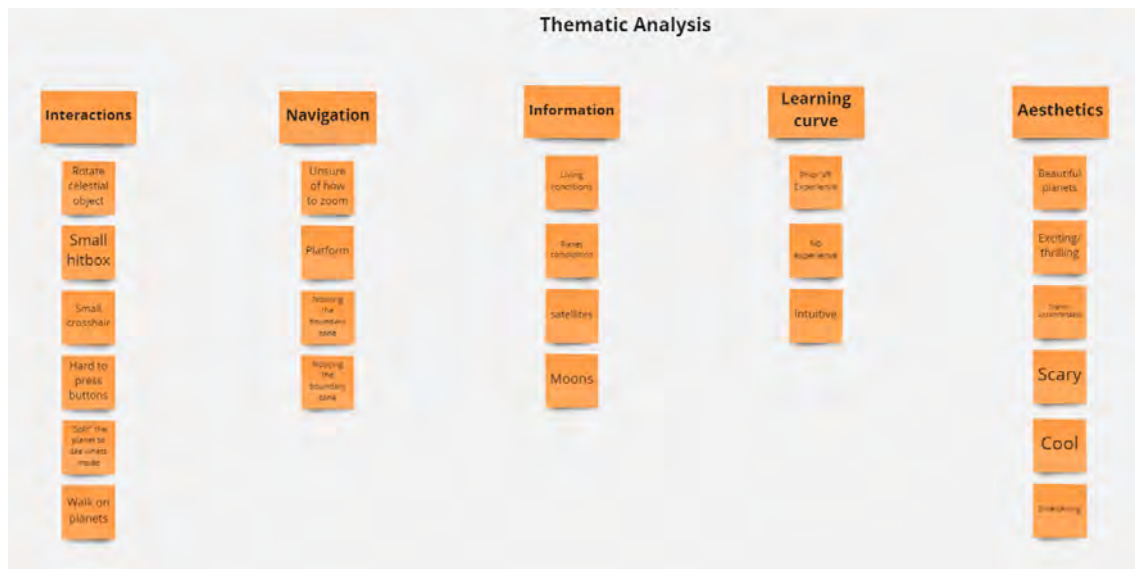


**Figure 5.26:** A pupil in group 2 testing the virtual environment.

The pupils provided us with valuable feedback and ideas on how to further improve the VR experience. Even though this was the first prototype, it was well received and the majority of the pupils were excited and positive. Their enthusiasm was a success in itself since it proved to us that we were on the right track using VR technology to spur interest in school subjects. Furthermore, the feedback that we received was in line with what we set out to achieve in regard to experiential learning and constructivism (section 2.6), in the sense that we provide adolescents with adequate tools to interpret our virtual space and create their own understanding through exploration.

### Thematic Analysis

To structure the data that we had received from the user tests and survey, we conducted a thematic analysis (see Figure 5.27).



**Figure 5.27:** Thematic analysis of user test data.

### Expert Evaluation

3 Interaction Designers were invited to evaluate our virtual interface based on a modification of Nielsen's Heuristics. It was initially planned that all 10 of Nielsen's heuristics mentioned in Chapter 3 would be utilised, however, in hindsight some of the heuristics were not suitable as evaluation material for our virtual interface. The list of heuristics was modified to fit not only the goal of our evaluation but so that it is relevant to our specific interface. The heuristics used were:

- **User Control and Freedom:** "Users often perform actions by mistake. They need a clearly marked "emergency exit" to leave the unwanted action without having to go through an extended process" (Nielsen, 2020b).
- **Consistency and standards:** "Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform and industry conventions" (Nielsen, 2020b).
- **Recognition rather than recall:** "Minimise the user's memory load by making elements, actions, and options visible. The user should not have to remember information from one part of the interface to another. Information required to use the design (e.g. field labels or menu items) should be visible or easily retrievable when needed" (Nielsen, 2020b).
- **Aesthetic and minimalist design:** "Interfaces should not contain information that is irrelevant or rarely needed. Every extra unit of information in an interface competes with the relevant units of information and diminishes their relative visibility" (Nielsen, 2020b).
- **User location knowledge:** "Getting lost is not fun. Getting lost in an app or website is even less so. Just like most streets and roads have signs with their name to let pedestrians know where they are, so must user interfaces" (Steven, 2017).

At the start of an evaluation session, the participant was given a briefing about the

heuristics they had to keep in mind while testing the prototype. Afterwards, they were given time to familiarise themselves with the UI and environment and explore freely. Once they felt ready, they were tasked with evaluating the virtual interface based on the chosen heuristics. The results of the Heuristic Evaluation can be found in Appendix E.



**Figure 5.28:** Expert user evaluating the user interface of the virtual environment.



**Figure 5.29:** Augustas taking note of the participant's comments.

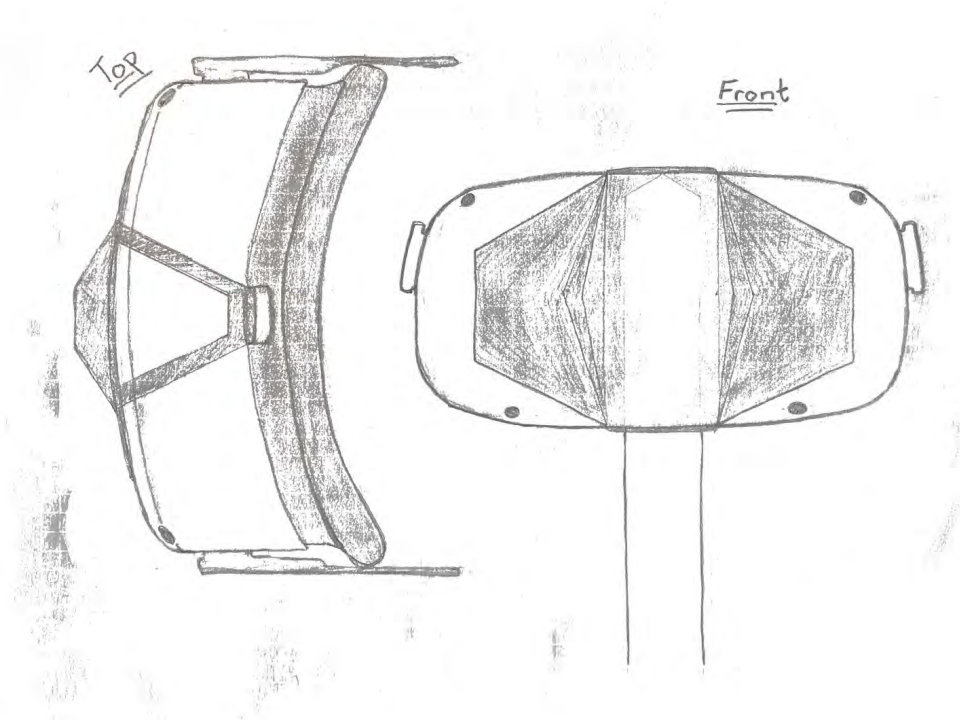
## 5.4 Iteration 3

This was the final iteration of this project where the outcome would be our final product. The goal of this iteration was to finalise our physical and digital prototypes and to create one coherent product that allows for a pleasant VR experience.

### 5.4.1 Physical Prototype

For the physical prototype of this final iteration, the goal was to create a stable, aesthetically pleasing "holder" for the HMD that would be attached to the stand. This holder was designed in Tinkercad for 3D printing. It was separated into a total of 4 unique components that would be assembled and create the holder (see Figures 5.35 & 5.36 to view the finished design of the holder).

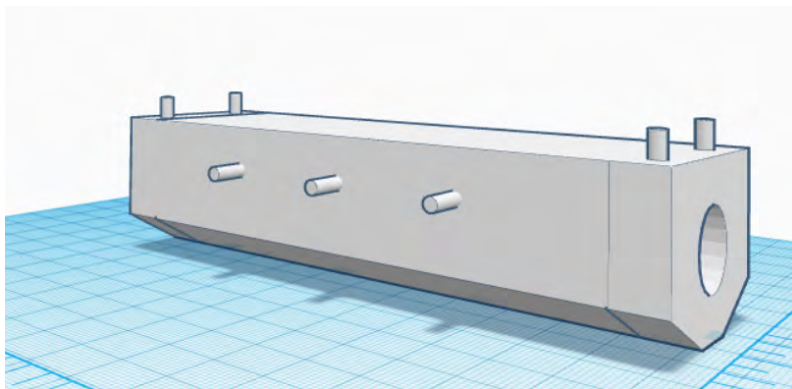
However, before we started with the CAD prototype, we sketched what we believed would be a solution. When doing this, we had to consider how the holder would not only look aesthetically pleasing but that it would also be an effective solution. We were however concerned that the holder would reduce the quality of the hand tracking or even remove it entirely. Therefore, it was important to minimise thickness and not cover the cameras. Figure 5.16 shows our solution sketch for the holder.



**Figure 5.30:** The main component of the holder.

### Main Component

The CAD model of the main component can be seen in Figure 5.31. This is the core of the holder and all other components will attach to it. The cylindrical hole allows a pipe to be fitted into it that is connected to the stand. The small, cylindrical stumps are shaped to fit inside small pockets of the other components. Two side components will be fitted on the sides of the main component, while two other components (a lower and upper component) will be placed on the stumps facing upward.



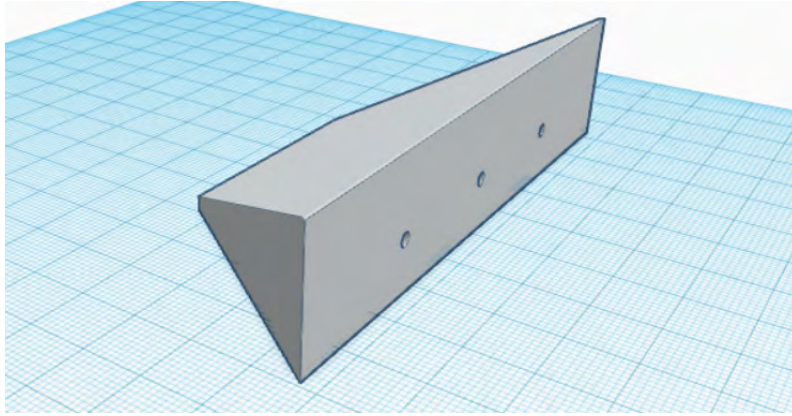
**Figure 5.31:** The main component of the holder.

### Side Component

Figure 5.32 shows the side component, whose purpose is to add mass and stability



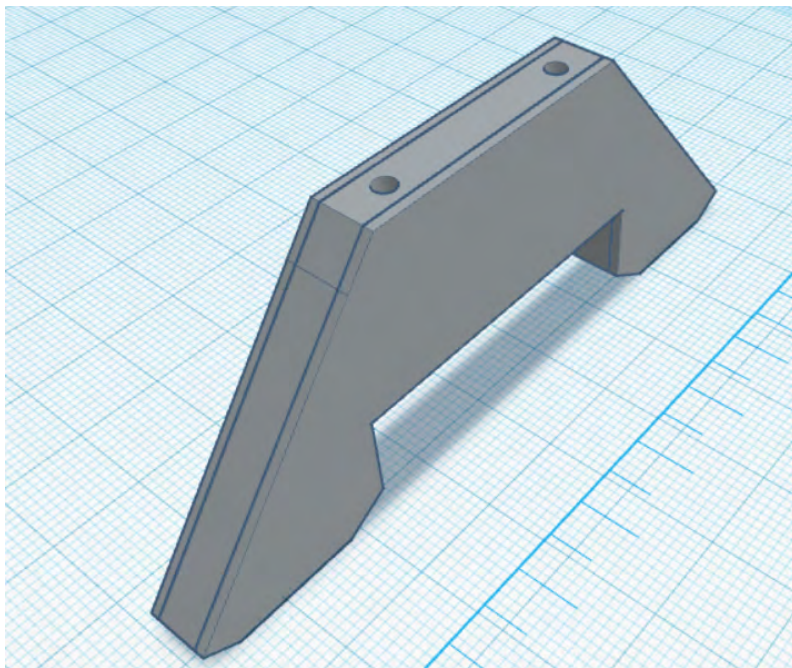
to the holder by extending horizontally on the HMD. The holes indicate where to connect it with the main component. Two in total are required since we need one on each side.



**Figure 5.32:** The side component of the holder.

### Lower Component

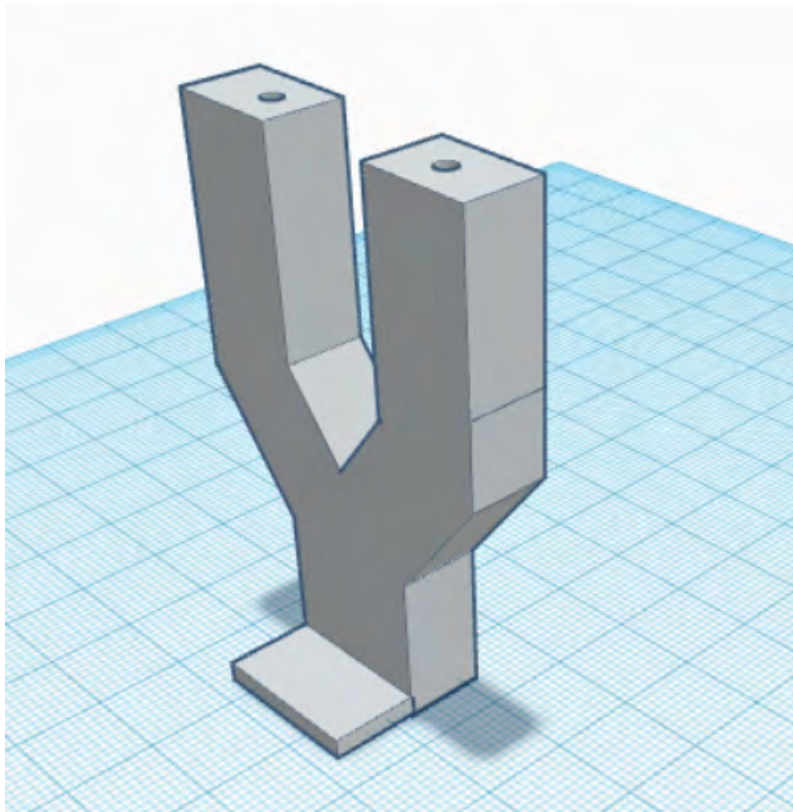
The lower component (see Figure 5.33) is designed to support the bottom of the HMD so that it does not fall off the stand. It is shaped like an elongated 'V' since otherwise, it would collide with the user's nose. Furthermore, the HMD's cameras for hand tracking have to be considered so as to not block them.



**Figure 5.33:** The bottom component of the holder.

### Upper Component

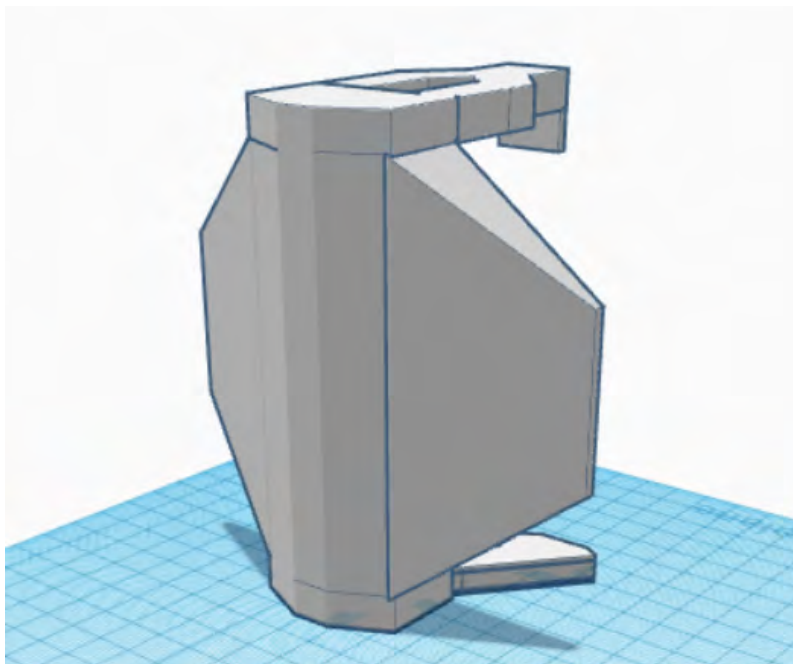
The upper component (see Figure 5.34) is designed to 'Hook' itself onto the Oculus Quest 2 and ensure that it does not fall off the stand. The small extension at the bottom will hook itself into the top of the Oculus Quest 2.



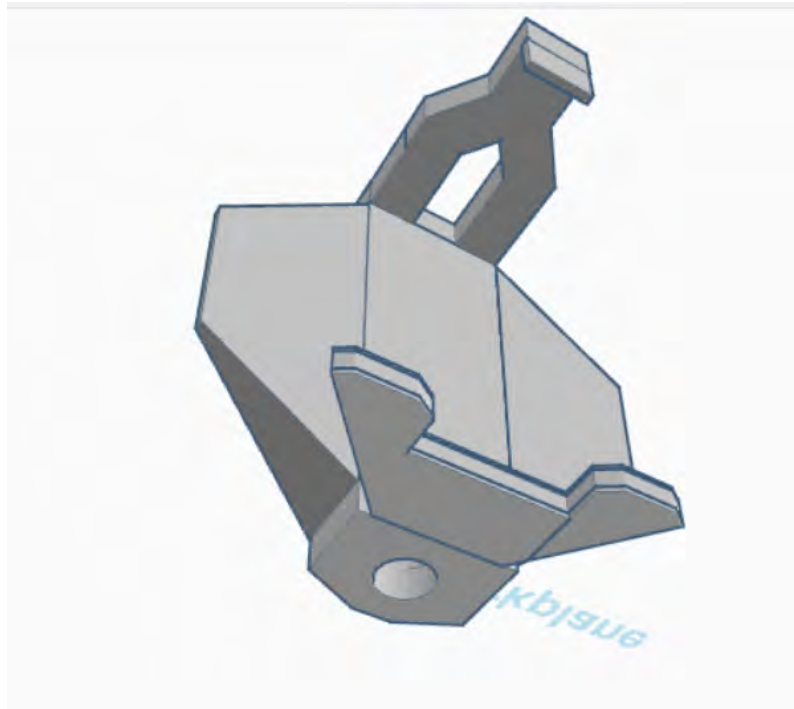
**Figure 5.34:** The upper component of the holder.

**All pieces assembled**

Figures 5.35 & 5.36 show all the components assembled into one construct.



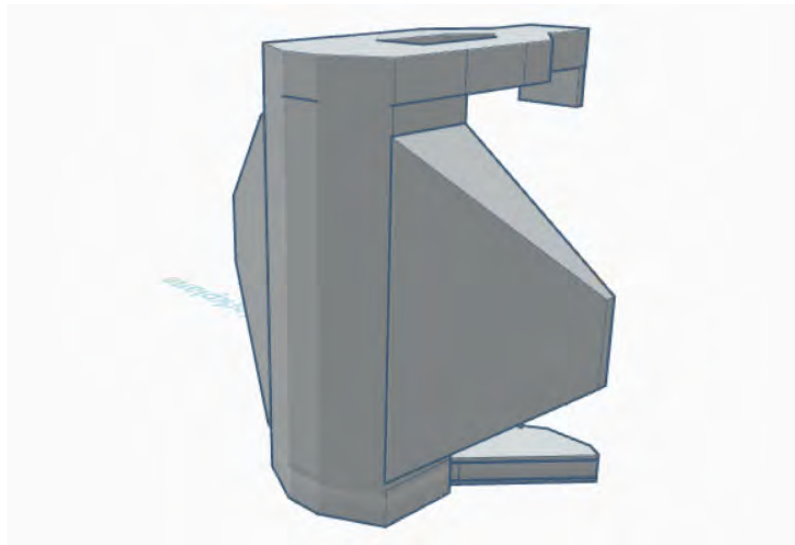
**Figure 5.35:** Frontal view of the holder.



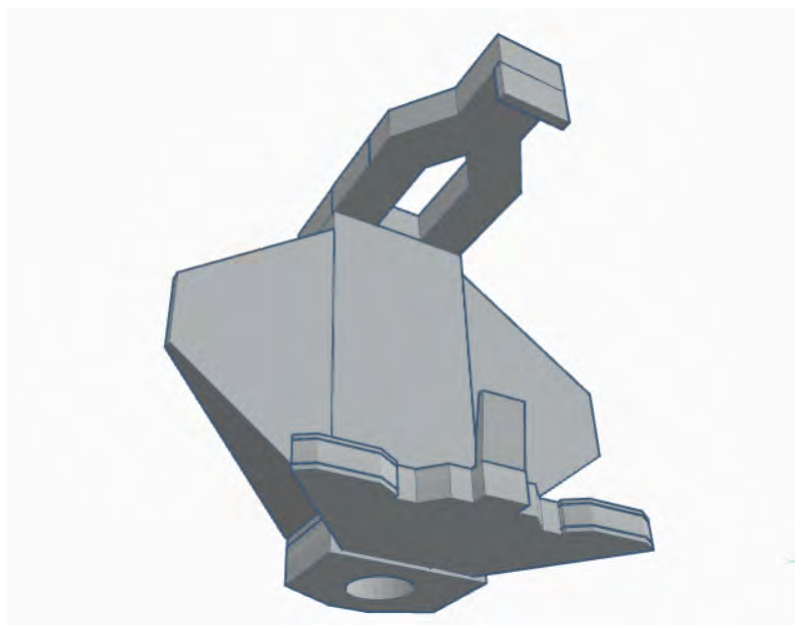
**Figure 5.36:** Back and bottom view of the holder.

### **Adjustments to the Prototype**

The first print of all the components did not produce an outcome that satisfied all our expectations. Several measurements were off, which meant that the holder was not adequately stable and could therefore not be utilised in testing. New measurements were made and the CAD components were resized and their form adjusted to tackle the problems we encountered with the holder. For example, the sides of the side component now have a sharper angle so that there is no risk of interfering with the hand cameras. Additionally, the bottom component was reshaped so that more effectively supports and lifts the HMD. Figures 5.37 and 5.38 show the holder as a whole after the changes were made.



**Figure 5.37:** Frontal view of the holder.



**Figure 5.38:** Back and bottom view of the holder.

### 5.4.2 Development in Unity

In the last iteration of the project, the main focus was to implement features that were requested during the user tests in iteration 2, as well as making quality of life improvements and fixing minor issues.

#### Fun Facts

During this iteration, fun facts were added to each planet, moon and the Sun. These facts are displayed in separate panels positioned around the zoomed-in planet (see Figure 5.39). Depending on how many facts the planet holds, the corresponding



amount of information panels will be displayed. Furthermore, the leftmost central panel is dedicated to "general" and basic information about the planet, such as the average temperature, atmospheric and geological composition, size and mass, gravity, etc. Most of these facts are taken from NASA's interface for learning about and exploring our solar system (NSSE<sup>5</sup>). We believe that NASA is a sound source for all things space.

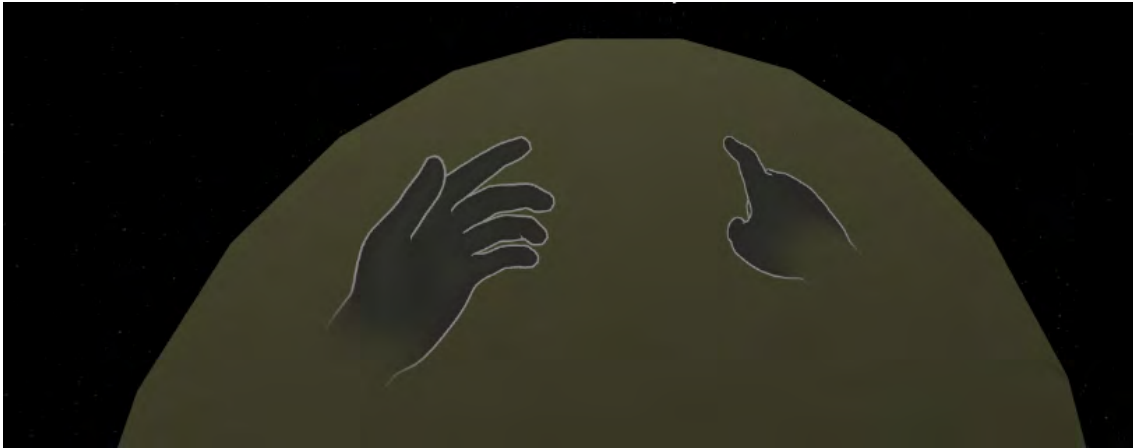


**Figure 5.39:** Various panels display facts about Venus.

### Minor Additions

A platform was added at the starting location to give the user something to stand on (see Figure 5.40). This was a result of the feedback received from user testing during the second iteration. Furthermore, several new celestial bodies were added into the environment. Our moon, as well as a handful of other moons were added to flesh out the experience and allow the user to explore additional celestial bodies. However, we deemed it pointless to add all existing moons in our solar system since the minuscule size of some compared to the planets they orbit would make them difficult to spot.

<sup>5</sup><https://solarsystem.nasa.gov/planets/overview/>



**Figure 5.40:** A platform for the user to stand on.

### Quality of Life Improvements

There are several "quality of life" improvements that were introduced in this iteration of development. Firstly, the distance of the zoom-in to a celestial object was previously varied depending on the targeted planet. This was due to the zoom-in distance being calculated based on how far away a specific object was located, which sometimes led to the user being placed too close to a planet or too far away. Previously, we used a three-dimensional vector that originates in the centre of the virtual space and points toward the centre of the target planet which we then multiplied by a value, e.g. 0.8. This would make the user travel along the vector toward the target planet and stop at 80% of the distance. The new and improved way of calculating the point at which the user will travel makes use of vector multiplication and normalisation, which puts the user at exactly the correct point in space no matter the distance to the planet.

Additionally, the planet information panels were not properly angled toward the user, which would have made it difficult to read the facts introduced in this iteration. This was solved by using the *Vector3.LookAt()* function in the planet canvas script. The function basically takes in a game object as an argument, and then rotates the current object in the x, y, and z axes to face the target. Certain other improvements were made, namely, descriptive icons were added to the text for clarity, and the text size was adjusted for better readability and space management.

### 5.4.3 Testing

The final iteration of testing our VR experience was done at Universeum in Gothenburg. Before the third iteration, we contacted Universeum asking if it would be possible to conduct a user study at their premises with curious visitors. Permission was given, and it was decided that the most suitable and natural location for our stand would be in their space exhibition.

In preparation for this, the components for the Oculus Quest 2 holder were printed and assembled. Our assumption was that it would be crucial to signal who we are,

where we are from, and why we are there. Therefore, an IxD poster (see Figure 5.41) was distributed to the project for the purpose of promoting Chalmers and to signal why we are there. Displaying the prototype at Universeum is similar to our purpose of producing an experience that will be placed at the exhibition in OSO, it is reasonable to categorise the visit to Universeum as a field study since the product/service is moved to its "natural" context where users can interact with it. Therefore, it was deemed beneficial to avoid structuring the study heavily and allow the user to freely experience what was offered. The key was to observe the user as they interact and explore the VR environment without extensive guidance and interference.



**Figure 5.41:** The testing setup at Universeum.

Once the equipment was prepared and set up (see Figure 5.41), we eagerly awaited curious passers-by. Interested gazes were welcomed to test our prototype, where one project member documented what the user experienced, what they said and their general reaction to the experience. The other project member aided the participant whenever necessary. However, it is important to note that in a natural setting, little to no help would be provided to the user when trying the prototype. Therefore, we were careful to aid the user only when the user was perceived to not be able to access important functionality. Most of the visitors at the exhibition were children and adolescents which matched our target group, although all ages were encouraged to test the prototype.

While testing, the user was allowed to do whatever they wanted. During their exploration, they were asked for their opinion about various aspects of the environment. Most commonly they were asked about the planet information provided, the accessibility of the UI and enjoyment. Due to the nature of the setting, the amount of feedback received varied from participant to participant. Some participants were eager to give feedback, while others were reluctant and wished only to move on to other exhibition installations.

The data received was qualitative and highlighted the strengths and flaws of our prototype. These findings are discussed below. See Appendix A for the extensive documentation of the user testing at Universeum.

### **Impressive Planet Information**

Firstly, it was apparent that the planet information the environment provides was received positively. Some participants, especially the younger ones, were expressing awe and amazement as they learnt about the unique conditions of the planets, such as extreme heat or cold. This also showed that the information could be comprehended by users of the target group and not be deemed too difficult or unclear.

### **A Mixed Button**

The one interactive UI-element currently in the environment is the zoom-in and zoom-out buttons. This button received mixed reviews. It was described as fully functional and non-problematic by some participants, while also being described as clunky and difficult to interact with by others. Based on this evaluation, we believe that the placement of this button can be adjusted so that it is in closer proximity to the user. The placement was initially based on the project members' long arms and thus not optimal for smaller users with shorter arms. This resulted in older users interacting with ease, while younger ones had a slightly worsened experience.

### **A Mixed Crosshair**

The crosshair is used for detecting eye-collision with planets and consequently displaying the zoom-in button. However, during our testing, it became evident that in rare cases the user did not look at celestial objects with the crosshair by moving their head and properly aiming the crosshair but rather solely moving their eyes, as if the prototype implemented eye-tracking. This meant that even though they were technically observing a planet, a zoom-in button did not appear. We recognise that not everyone is familiar with the purpose of a crosshair and therefore it has to be designed more intuitively.

### **The Light Stand**

This was the first opportunity to test the Light Stand and the evaluation provided this project with eye-opening insights. Firstly, the legs of the stand, although providing stability for the prototype, were disadvantageous based on the fact that they extended outward, preventing the user from moving freely with ease. If the user wants to, say, look behind themselves, they have to rotate the HMD on the stand. The legs make this process difficult, especially for shorter users. Secondly, the stand

has a limit on how much you can lower or raise it. This means that very young and/or short users simply cannot reach the Oculus Quest 2 attached to it. Furthermore, the raising and lowering can be tricky and require too much effort, and thus discouraging a passer-by to interact with it.

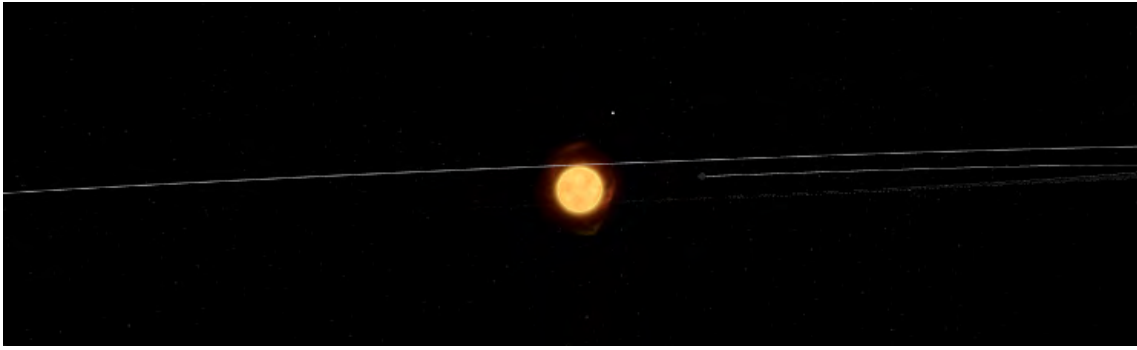
### **Planet Positioning & Orbit**

It was at times mentioned that the positioning of the celestial objects was confusing and that it was difficult to discern the proximity of planets and the moon. Occasionally, the users' could not tell which planet was furthest away, and which one was closest. This was due to the short distances between celestial objects, both on the x-axis and z-axis. This issue can be dealt with by creating lines around the sun/planet that visualise the orbit of each celestial object. Finally, the differing y-axis value of each planet was too significant, which does not adhere to reality where the planets are co-planar. This can be fixed simply by placing the celestial objects more or less on the same y-axis and scattering them across the x-axis to help users identify the distance order of the celestial objects.

## **5.5 Final Touches**

We have been reluctant to implement celestial body orbits, due to the time that has to be spent implementing it as well as issues concerning objects being at times hidden. This can for example occur if a planet is behind e.g. the sun in its orbit, which would make it impossible to spot from the user's perspective. The feedback that we have received does however suggest that orbits would be a good addition since it has been requested several times by different users. We, therefore, decided to add this to the experience.

Luckily, we had already prepared the code for handling orbits. Each star has an id which corresponds to a solar system id in the planet objects, and each moon object has an id that corresponds to a parent planet. This made it straightforward to connect planets with their stars and moons with their planets. When spawning celestial bodies we first instantiate stars and save them in a list. This list is then iterated when instantiating planets to find which star each planet belongs to, and the same process is repeated when instantiating the moons. At each game tick, the planets and moons revolve around their parent in a circular motion. Although we are aware that it is not always the case that celestial bodies have circular orbits, we decided that this is realistic enough and less time-consuming. We found that there is a sweet spot in regard to orbit speeds, where it is not *too slow* to even be noticed and not *too fast* to make it difficult to zoom into the objects. To make the orbits more noticeable, a trail effect was added that lingers for approximately 60 seconds before it starts to fade out at its tail (see figure 5.42). To actually see the orbits that are represented by the trail gave a greater sense of the scales and distances in our solar system.



**Figure 5.42:** Orbits of Mercury and Venus around the Sun.

In addition to the orbits, a few issues that we encountered during the evaluation at Universeum were fixed. The zoom-in button was not in reach for some users, and was therefore moved closer in the UI. Furthermore, we added the special case of the Earth's moon to orbit around the platform, as if the platform is the Earth. The texture of our moon rotates at the same pace of its orbit, meaning that the user can't see the "dark side" of the moon unless they are zoomed into the moon.

# 6

## Results

This chapter will present the results of the thesis. More specifically, it will first present the final version of the VR environment, before moving on to the final version of the physical prototype. After this, the combined outcome of the physical and virtual prototypes will be presented. The chapter will be concluded with the result from user and expert evaluations.

### 6.1 Unity Virtual Reality Prototype

The resulting VR prototype is a virtual space developed specifically to be used with Head-Mounted Displays, and is primarily intended for the Oculus Quest 2. It was developed using Unity, a free to use game engine with extensive tools and support for building and deploying VR applications.

#### 6.1.1 Interacting with the Virtual Environment

Because of the connectivity limitations of the project described in section 1.6, the final VR environment implements hand-tracking using the headset's integrated optical sensors. Even though the lack of wireless signals such as Wi-Fi and Bluetooth limited the project by quite a lot in regard to functionality, it is apparent that hand-tracking weighs up the cons with its pros - that is the interactions with elements in the environment. By allowing the users to interact using their hands instead of controllers the virtual world becomes intuitive, feels real, and provides a gentle learning curve even for users that lack prior experience with VR. This technology also allows for a greater sense of presence while experiencing the virtual world, since the user doesn't have to think about e.g. what buttons to press on their controllers and if the controllers are strapped on correctly. Additionally, it adds to the robustness of the prototype since there is no equipment other than the headset that could potentially break or be damaged.

The user can look around in the environment and, among the vast amount of points of light, see distinct celestial objects in the distance. These objects are either stars, planets, or moons. Celestial objects that are in close proximity to where the user is currently looking are scaled up slightly, to make it apparent that these objects can be interacted with. If the user aligns the crosshair with a celestial object, a "Zoom-In" button will appear which the user can press to travel close to the object (see figure 6.1). In contrast to looking at a celestial object through an ordinary

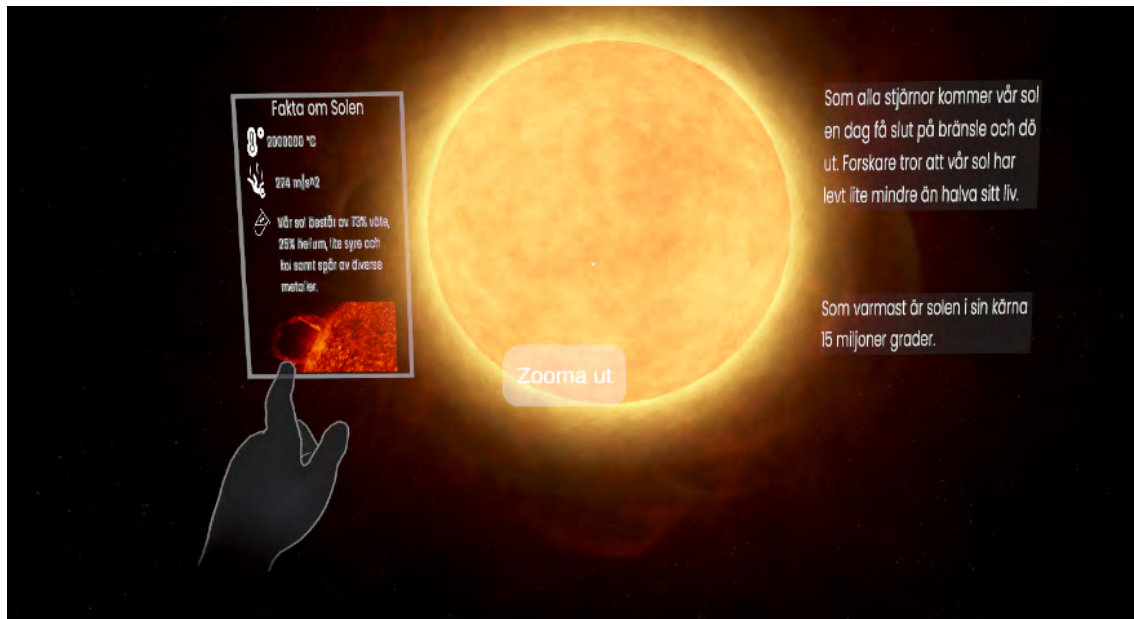
telescope, this allows the user to feel like they are actually travelling the distance at tremendous speeds to arrive at the object's location.



**Figure 6.1:** User reaching for the Zoom-In button.

When zoomed in on a celestial object, a canvas with different panels filled with informative text is presented. The type of information is a combination of what we have chosen to call "*fun-facts*" and more traditional facts (see figure 6.2). The more traditional facts contain information such as the celestial objects' gravity, temperature range, as well as its composition. The fun facts are carefully tailored facts to fit the target audience, which have been evaluated and iterated multiple times. These facts are created to not only teach the user about astronomy but also to be comparable to "everyday" things so that the facts are intriguing as well as easily digestible for our target users.

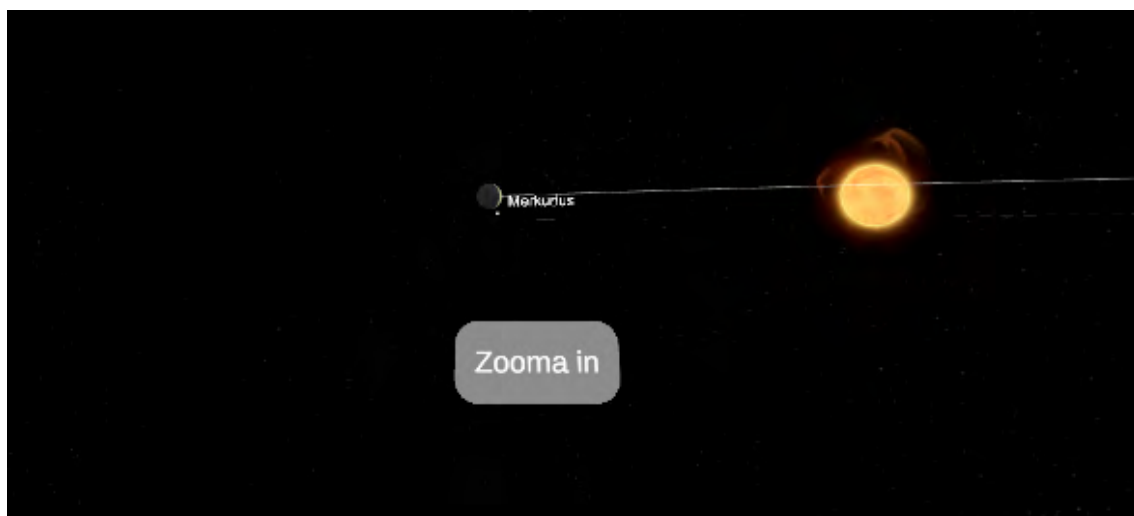




**Figure 6.2:** User learning about the Sun.

### 6.1.2 Size, Distance & Orbits

Contrary to real life, the objects in the virtual world appear quite large in the distance. The reason for this is that if the different planets and moons would be exactly in scale in regard to size and distance from one another, it would be too time-consuming to locate them. This was not feasible in the context of placing the experience in an exhibition, where participants only have a minute or two until they move on to the next installation. Therefore, the object was made large enough to draw attention, but small enough so that the user will want to look closer and explore it. Figure 6.3 shows Mercury being scaled up when looking in its general direction.



**Figure 6.3:** Planet being scaled up when looking in its general direction, as well as showing the Zoom-In button.

The positioning of celestial objects are dictated by a three-dimensional vector that is retrieved from the local .json database at application compilation time. Due to the implementation of planet and moon orbits, these positions change every game tick (see figure 6.4). Each planet has an assigned parent star which it orbits, which also applies to moons. The only exception to this is the Earth's moon, which orbit the platform which the user stands on instead of a planet. To further illustrate the orbits, the application implements celestial object trails. This essentially means that each celestial object that has an orbit leaves a semi-transparent trail on the path that it has travelled, which then starts to fade out at its tail after approximately 60 seconds. Furthermore, celestial objects rotates around their own axis. This is done by offsetting the texture of a celestial object by a very small amount each game tick.



**Figure 6.4:** The orbits of Mercury and Venus can be seen, as well as the orbit of other planets in the distance.

## 6.2 Physical Prototype

The physical prototype, which can be seen in Figure 6.5, is a combination of a light stand (*Manfrotto*) and a specialised holder for the Oculus Quest 2. These two are connected via a small metallic pipe fitted into a pocket of each component.



**Figure 6.5:** The final assembled prototype.

### 6.2.1 Light Stand

The light stand (see Figure 6.6) is designed for flexibility. It's height is adjustable, and the pocket where the pipe is fitted allows for rotation of the holder. Furthermore, the upper part of the stand can be angled up or down, thus letting the user look upward or downward with the Oculus Quest 2. When not in use, the stand can be compressed into a compact portable piece.



**Figure 6.6:** The Manfrotto light stand.

### 6.2.2 HMD Holder

The Oculus Quest 2 holder can be seen in Figures 6.7 and 6.8. It's composed of 5 different components meant to support and stabilise the Oculus Quest 2. It's height is measured to 105 mm, which is slightly taller than the Oculus Quest when it lies on its long side. A 16 mm cylindrical hole is used to connect the holder with the stand. The side components are the triangular pieces stretching out over the side of the Oculus Quest 2. They extend with a width of 39 mm and have a height of 77 mm. The top and bottom components are the pieces extending under and above the Oculus Quest 2. The top component is Y-shaped with a thickness of 8mm, a max width of 39mm and a height of 61mm. The bottom component is W-shape with a width of 89mm, a length of 38mm and a thickness of 8mm. Figure 6.9 shows a small, rectangular hook part of the top component clutching down on the Oculus Quest 2 to create. Figure 6.10 shows the hook of the bottom component extending upward. Both these hooks secure a firm attachment between the Quest and the holder.



**Figure 6.7:** Top view of the holder attached to the Oculus Quest 2.



**Figure 6.8:** Bottom view of the holder attached to the Oculus Quest 2.



**Figure 6.9:** Top hook clutching the upper part of the Oculus Quest 2.



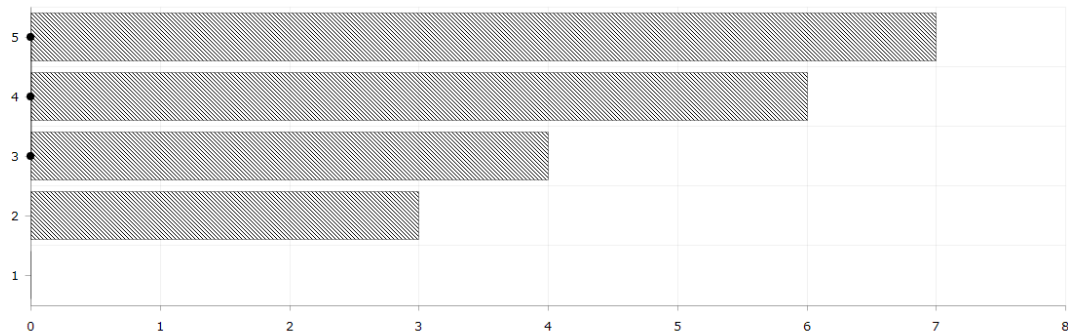
**Figure 6.10:** Bottom hook clutching the lower part of the Oculus Quest 2.

## 6.3 User & Expert Evaluation

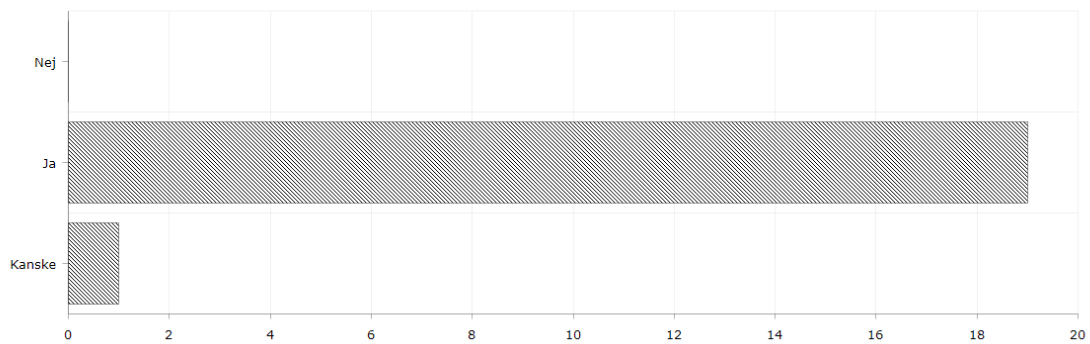
Thorough evaluations of the prototype were conducted a total of three times during the lifetime of this project. The first two were purely formative evaluations where the focus was to improve the experience based on feedback and insights. The final user testing at Universeum was a combination of formative and summative evaluation since certain feedback can still easily be implemented, however, more significant adjustments are left for the future due to the project nearing its deadline. Therefore, a handful of changes deemed beneficial that were found during the last evaluation will be written under "Future Works".

### 6.3.1 Evaluation at Kollaskolan

The evaluation at Kollaskolan in Kungsbacka highlighted extensive interest and admiration for VR and experiential learning. Figure 6.11 shows that 7 out of 20 (35%) pupils rated 5 on the scale of interest. 6 (30%) rated 4, 4 (20%) rated 3, 3 (15%) rated 2 and finally 0 pupils rated 1 on the experience. In Figure 6.12 it is visible that a majority of pupils (95%) believe that VR can be used for teaching. 5% said "Maybe" while nobody answered "No".



**Figure 6.11:** The survey answers to the question "How interesting was this?"



**Figure 6.12:** The survey answers to the question "Do you believe this is a good way of learning?"

The remaining data gathered from the survey was exclusively qualitative and can be found in Appendix D. Notably, the most common answer to the question "What is your opinion about using your hands to click and select things?" was "good" followed by an explanation of why that is. The answers to the question "What information do you want to see about the planets?" were varying. The most frequent answers were "don't know", "temperature", "size" and what the planet is composed of. For the final question "Do you have any other comments?" most pupils answered "no".

### 6.3.2 Expert Evaluation

Three expert participants were invited to perform heuristic evaluations on our prototype during the second iteration. They were asked to judge the constructed virtual environment based on 5 heuristics deemed relevant (see Appendix E). When evaluating **user control and freedom**, our participants found that the movement is free and that it is possible to explore wherever one chooses. The system is not "deep" and the only mistake one can make is by zooming in accidentally. However, it is easy to simply zoom out since the zoom-in button is permanently stuck on the interface, as one participant noted.



In regards to **consistency and standards**, one participant commented that the environment and UI are simply consistent. Another one stated that there are no issues with the expectation of what will happen. However, zoom-in distance varies from planet to planet and spacing between game objects is slightly inconsistent. Finally, there was a need for more button pliancy.

When asked about **recognition rather than recall**, one participant stated that information is easy to access and recognise. Additionally, another participant noted that information and actions were easy to retrieve, however, the crosshair needs to have a bigger collision box. Finally, one expert said he felt clueless once he put on the headset. However, the UI is easy to learn and one remembers it after a single use.

Concerning **Aesthetic and minimalist design**, the experts more or less agreed that the UI was clean and nothing unnecessary cluttered it. This allowed relevant information and elements to be the centre of attention. One participant simply stated that the design was perfect but would have preferred the buttons to be more space-themed.

Finally, **User geolocational knowledge** received mostly positive feedback. One participant claimed they were always aware of their position. Another one stated that since one is being sent around physically in the VR environment it is clear to understand the user position. One expert commented on the potential benefit of including the earth in the environment as a means to keep track of the position.

### 6.3.3 Evaluation at Universeum

A total of 21 user observations were made during the visit to Universeum. These observations were documented, and the behaviour, reaction and comments from the users were noted. Opinions shared across users were recorded as "general feedback". Raw documentation of the observation can be found in Appendix X.

Figure 6.13 shows four common emotions elicited from the participants during the testing. Each user is categorised into one or several emotions based on their behaviour, comments and reactions. We define *confusion* as user difficulty to grasp navigation, use UI elements, and the general state of not being able to access the whole experience. *Indifference* is defined as no particular opinion of the experience or a brief interaction without any feedback. A user is categorised into *enjoyment* when they express joy and affinity to the experience coupled with extended testing. *Excitement/shock* is defined as user eagerness where the user experiences a thrilling sensation of, for example, experiencing something new and unique.

The most prevalent emotion elicited by the VR environment is that of *enjoyment*. 15 out of 21 ( 71%) participants expressed some form of enjoyment. *Confusion* and *Excitement* were expressed by 8 ( 38%) participants. Finally, we found that 6 ( 29%)

participants felt indifferent toward the experience.



**Figure 6.13:** Different emotions elicited by the VR experience

The notes taken during the visit were revised, and homogeneous insights for each user observation were classified as "general feedback" (see Figure 6.14). A total of 6 significant conclusions were made. Firstly, the manoeuvring (outside and inside the VR) can be tricky and difficult at times. Secondly, the stand, in its current state, worsens the experience. Additionally, the stand has a limit for how far down it can be lowered, which poses an issue when younger, shorter visitors want to interact with the prototype. Certain participants could not reach the HMD on the stand. We also found that in the setting of an exhibition, the user is present in an unfamiliar environment and therefore is prone to act more cautiously and not dare to explore freely due to for example fear of embarrassment.

Visitors of different ages have varying head sizes, which poses a challenge since the Oculus Quest 2 needs to be constantly adjusted to the users' head size in order to avoid a blurred image and consequently a substandard experience. Finally, the y-axis (height) of each celestial object varied unrealistically. This also required the user to look up and down with the stand which introduced an additional challenging interaction with the stand.





**Figure 6.14:** General feedback based on the visit to Universeum.

The data collected suggests that there is potential to make adjustments and improvements especially in the physical prototype, but that there are also certain tweaks in the digital environment that would be beneficial. Nonetheless, a majority of the participants during the various testing sessions held a positive opinion of VR and our digital environment, and there was genuine interest in exploring and learning about our solar system.



# 7

## Discussion

This chapter will discuss the results from the previous chapter; why and how the prototypes turned out the way they are, what affected and impacted the final result, and what can be deduced from the user testing. Furthermore, it will be discussed how we used the different design methods that were decided on during the planning phase, and how appropriate they turned out to be. We will reflect on the results' generalisability, validity, and ethical aspects, and conclude the discussion by describing the potential for future work. We will situate our findings in terms of the hypotheses and research question stated in the introduction of the thesis (section 1.5), which have been restated below:

### **Research Question:**

*"What considerations are essential when designing an interactive and inviting learning experience using Virtual Reality with the purpose of engaging adolescents in the advanced and hard-to-grasp subject of astronomy?"*

### **Hypotheses:**

1. Virtual Reality makes learning more appealing in comparison to traditional educational methods
2. Virtual Reality can be used successfully as a tool for learning
3. Virtual Reality technology sparks an interest for an otherwise hard-to-grasp subject

## 7.1 Results Discussion

The results of our work suggest that Virtual Reality is suitable for educational purposes in the subject of astronomy. User evaluation has shown that it spurs interest in the subject, and by carefully tailoring the representation and presentation of the content it is possible to make hard-to-grasp subjects digestible for adolescents. In regard to our research question, this project has highlighted several essential considerations when developing a VR experience in the context of teaching and science centres. These considerations appear in the following paragraphs in order of value and priority.

Firstly, it is of utmost importance to continuously test ones concept and ideas with the target group. This will ensure that the designers do not design from themselves but for people that will in the end use the product/service. Furthermore, this will

indubitably capture user requirements and thereby increase the quality. In our case, the continuous inclusion of target users in our design has constantly guided us in adapting and adjusting functionality to the liking of the end user. Additionally, it prevents the designer/developer from introducing unwanted and unnecessary features.

Virtual Reality has the benefit of being a unique and somewhat new technology that has only recently entered the wider market. This means that many new user's of a VR HMD consider it a thrilling and interesting experience, no matter what program is running. We deduced from our user evaluations that many people find it an interesting device to interact with and therefore making it easier for them to like the environment they are discovering. Therefore, we found that it is more important to focus on creating a coherent experience, simple and intuitive interactions and represent and present data in a digestible manner rather than focus on auditory and visual details of the virtual environment, which we believe has a lesser importance.

The testing environment affects the results of an evaluation significantly and has to be considered and analysed. In our case, it was evident that the pupils at Kollaskolan were more engaged and interested in our prototype due to our device being the focus of the visit, and there were no other distractions. Additionally, the participants were located in an environment they are comfortable with and visit nearly every day. This is in stark contrast to the visitors at Universeum that are in an unfamiliar environment, where our prototype is not the only focus and where there are numerous other installations that distract the visitor. The degree of interest and motivation in Universeum varied greatly from participant to participant, which suggests that the setting ultimately affects the data we gather and might shape it in a way that would otherwise not be true. Another aspect that has to be taken into consideration is the sample of participants we had during our user test. Regarding our visit at Kollaskolan, we tested the digital prototype with one out of three available classes. It may be the case that we were lucky and got a class of highly interested and engaged students, which could potentially skew the results of the evaluation quite heavily. If this is the case, it would however also mean that the feedback we received was genuine and of high quality. It was in contrast evident that the increased variability of participants at Universeum might have yielded feedback that was less unbiased and objective.

Furthermore, the results suggests that adopting constructivism and focusing on creating an experience that facilitates experiential learning is a successful way of engaging students in the subject of astronomy. It has been discovered that providing adequate tools for exploration and discovery while avoiding excessive control and guidance incentives further exploration of the subject.

Finally, we found that when working with a product that has two parts, in our case a physical in the form of a stand, and a digital in the form of a virtual reality environment, it is important to focus on the coherence of these two parts in order to create a pleasant experience. We discerned, from working with this project, the

fact that it can be quite challenging to create two separate parts and later on assemble them and still produce a flawless prototype. It requires extensive testing and adjusting for one part to not interfere with the quality of the other. The whole has to be as great as the parts. Additionally, since we do not have much experience in designing and constructing high-fidelity, tangible physical products, we used materials and resources based on availability and difficulty to work with. Our goal was for the target users to guide us in the design of the physical prototype which is the reason for how the final prototype looks. We do however think that if more time and effort was allotted to researching on and refining the physical aspects, the final prototype could have looked more inviting and conveyed a different mental model. Nonetheless, we do think that it is likely that the base functionality and form factor would have remained unchanged, as a consequence of the restrictions introduced by the headset and limitations at Onsala Space Observatory.

**Hypothesis 1: Virtual Reality makes learning more appealing in comparison to traditional educational methods**

To validate this hypothesis, we will have to measure the engagement och enthusiasm in the user evaluation sessions of the project. Although it is not evident that this holds true for *all* adolescents, our data suggest that Virtual Reality is in fact an appealing way to learn in comparison to the traditional reading. More specifically, a majority of our participants from Kollaskolan rated the VR experience highly. On a scale from 1-5, where 1 is *highly uninteresting* and 5 is *highly interesting*, 85% rated the experience 3 or higher. We believe this indicates a positive view on VR as a tool for experiential learning. It has been obvious to us that VR is inherently exciting to a large majority of the participants in our study, which is most likely due to VR being a new and interesting technology that many have not tried before. Throughout the evaluations we had, it was evident that using a HMD and physically exploring an environment resulted in a pleasant experience, and that it made them curious about all surrounding celestial objects. This then resulted in exploration of the objects and learning about them in an alternative way.

**Hypothesis 2: Virtual Reality can be used successfully as a tool for learning**

Similarly to *hypothesis 1*, the validity of this hypothesis can be determined through the results of our various user evaluations. When asked if VR can be used for teaching, 95% of the participants in our usability visit at Kollaskolan answered yes. This without a doubt confirms that it is indeed suitable for learning purposes. In addition to that, our visit to Universeum gave insight into the eagerness to explore an unknown VR environment and thereby learn about celestial objects in a unique manner. Generally, we found that the interest from adolescents was elevated by the uniqueness of the technology, and it was discovered that the use of hand tracking greatly enhanced the intuitiveness of the experience.

**Hypothesis 3: Virtual Reality technology sparks an interest for an otherwise hard-to-grasp subject**

It is possible to validate this hypothesis through our own observations. Based purely

on the user reactions, comments and emotions elicited from our user evaluations at Kollaskolan and Universeum, there was a widespread interest which can imply that certain individuals who had no interest in the subject of astronomy initially, found it enjoyable once interacting with our VR prototype. However, it would have been beneficial to possess user data about the participants' prior level of interest in the subject, which would have supported us in determining the validity.

## 7.2 Methodology Discussion

The design process that we settled on was Design Thinking (see section 3.2). Relying on this process provided a rigid structure on which to base our design work. A common issue for us as designers is the tendency to design for ourselves - to then correct the design solution to fit the actual user. The human-centric nature of Design Thinking aided us in *really* designing for the end-user and seeing problems, as well as opportunities, from their perspective. We would argue that if we had not adopted a human-centric approach with a great focus on understanding the target group, the results of the thesis would have been very different and most likely less insightful.

In the planning phase of the project, we picked out a set of design methods that we hypothesised would be suitable for the project. Some of them proved to be beneficial, others were not as useful, and some we didn't end up using at all. An example of the latter is Wizard of Oz (section 3.4.4). We intended to use this method to test our concept in the early stages of the project, using a laptop with a digital prototype and a cardboard box to simulate a telescope. This is something that we didn't end up using, because of issues finding test participants in our target group in the early phases of the project. When we got to the stage where we had participants, we already had an existing system that we could evaluate. The method that we had the most success with was Concurrent Think Aloud (section 3.4.5), which was used to let participants express their thoughts and emotions as they explored our prototype. This method gave us invaluable feedback that we could then use to improve our design.

Regarding the software development process, we chose to adopt an Agile work methodology while *not* using any particular frameworks, such as Scrum or Kanban. This is because while these frameworks can provide structure in large projects, they require too much overhead to be viable in a project of this scale. Since we have prior experience with using these frameworks this was something that we were aware of, and therefore chose not to adopt them. We contend that simply working in an Agile manner was suitable for this project, and with the addition of pair programming (section 3.3.1 & 3.3.2) and code review, it was more than satisfactory in order to achieve our goals. We believe pair programming had a positive impact on the project outcome. By programming together on one device, we could share our knowledge, thoughts and discuss best practices and possible ways of implementing certain functionality. However, one drawback we noticed is that we only produce half the code we could produce with 2 people programming.

### 7.3 Generalisability & Validity

The results of the project work suggest that certain aspects are more important than others when designing for Virtual Reality with the purpose of teaching adolescents about astronomy. It is for example evident that realistic or high-fidelity visual and auditory aspects don't affect the experience nearly as much as a coherent design and well-thought-out interactions. We would argue that this could implore designers to put a greater emphasis on human-centred design and understanding the end user's needs, thereby creating more meaningful and coherent interactive experiences. Our results also highlight the importance of making the content easily digestible for the target group, which is crucial to keep the user interested. If the user does not understand the content and 'feels stupid', there is a high likelihood that they get discouraged and lose their enthusiasm in continuing.

Our results can aid other similar projects in designing for the science centre or exhibition format, in particular when using Virtual Reality. Since participants in an exhibition rarely spend more than a couple of minutes on a particular installation, it is important that a VR experience is intuitive, features interactions that feel natural, and has a gentle learning curve. The user should not have to read a manual before even starting the experience, nor should they have to occupy the installation for a longer time than necessary just to understand how to use it. This is the case in particular for VR experiences since only one user can experience it at a time. Additionally, similar projects can draw inspiration from our work to create a robust prototype. This is crucial when designing for an exhibition since some users handle the installation with less care than others. This is especially the case when designing for groups of elementary school pupils since they, in their excitement, could potentially cause unintended harm to the equipment.

The validity of our results is backed by the pilot study, a literature study, as well as rigorous user evaluation that gave invaluable insights and served as a basis for our work and therefore affected the results.

### 7.4 Ethical Aspects

There are several ethical aspects that we have considered during the project. In the planning phase of the project, we briefly touched upon the accessibility aspect of our experience. We considered the fact that the experience will exclude people with certain (major) vision impairments, people who are bound to a wheelchair or have similar physical disabilities, as well as people with hypersensitivity to Virtual Reality. Furthermore, the user's age, if diverging from our target group, does impact the accessibility due to the physical limitations of the stand as well as the Oculus Quest 2. A user younger than our target group will most likely find it difficult to operate the prototype. Although it is evident that the final prototype has issues regarding inclusivity, we decided that this is outside the scope of the project. While we recognise that these aspects are of great importance, we argue that there

is simply not enough time to cover the accessibility aspect. The second aspect that is of importance is the validity of the information that we show the user. To ensure that we do not teach pupils false information, we only collected factual data from trusted sources, such as NASA.

Privacy preservation is another important ethical consideration that we have discussed during the project, particularly regarding user evaluations. It was crucial that we made it clear that no data that could be used to trace back to an individual would be saved during evaluation. Both at Kollaskolan and Universeum, we made sure not to record names or document pictures where faces were visible. Regarding the final prototype itself, no data is actively collected. The technology that we use does however bring up questions regarding privacy. Meta (formerly Facebook) practically has a monopoly on consumer-grade VR technology. We have no way of knowing with absolute certainty that Meta doesn't collect data in our application. We also want to add that the process of setting up our Meta Oculus Quest 2 for development involved connecting it to our personal Facebook accounts, which didn't feel quite right. We do ponder why we have to connect our personal accounts to be able to develop in Virtual Reality, and What purpose it ultimately serves.

### 7.5 Future Work

For future development of this project, we have identified a few possibilities, with the first being 'more of what already exists'. Since we made it a priority in the early software development stage of the project to create a solid base, it is fairly straightforward to add new content. We have made it possible to create new planets, stars, and moons in a relatively short time. The code is somewhat prepared to handle galaxies, but a decent amount of work would have to be put in to fully implement these celestial objects. We made an effort to make the code extensible, which means that we don't have to modify things that already work to introduce new features. Another possibility is therefore to add new interesting features that were requested during our user evaluation sessions, such as being able to pick up celestial objects and hold them in your hand, "split" planets in two to see their layers and the contents, and jumping between planets instead of having to return to the starting point each time.

Improvements to the physical prototype can be made, both in regard to robustness but also in ease-to-use. Developing this concept further would however require more testing with the target audience, preferably in the context of OSO's science centre, which is under construction. It was evident from the final evaluation at Universeum that the stand was not optimised for a flawless experience, and it introduces certain challenges in the exploration of the virtual environment. It was the first time we tested it with our target group, and we did expect there to be certain flaws in the design and accessibility. From this point, the issue of the physical component of our product can be tackled in two distinctly separate manners. Firstly, the stand could be improved by means of removing or scaling down the legs, thus removing an obstacle for the user's legs. Furthermore, the rotation has to be made a more smooth



activity, and the lowering of the stand should be preferably unlimited. With these changes, we believe the quality of the experience can be increased significantly. The second option is to eliminate the concept of the stand and focus on a hovering, airborne solution, which was a suggestion made during the final testing at Universeum. The Oculus Quest 2 would be suspended mid-air by e.g. elastic cables stretching above it. The user can then freely move around and look around, without being disturbed by any obstacles on the ground. However, this solution would remove the feeling of observing through a telescope and the mental model accompanied by it.



# 8

## Conclusion

This thesis aimed to pinpoint what considerations are imperative when designing a Virtual Reality environment in the context of a science centre setting with the purpose of educating adolescents on the subject of astronomy. The result of this thesis was a prototype that through the use of VR technology provides the user with the tools needed to freely explore the subject and learn through experience. From the analysis of qualitative data collected through extensive user tests, it can be concluded that the resulting VR experience is an engaging and interesting alternative to traditional forms of teaching the subject of astronomy.

The results of the thesis highlight considerations that proved to be crucial in the development of the prototype. Human-Centred Design practices need to be prioritised to understand the end-users perspective and tailor the experience to their needs. Additionally, it has been discovered that the feedback received from user evaluations is heavily influenced by the environment. Conducting tests in an environment that is familiar to the users, where they feel secure, yields different results than in an environment that is less familiar. The VR experience itself should not necessarily rely on high-fidelity visual and/or auditory elements, but rather on a coherent design and an attentiveness to the interactions. Adopting the theory of constructivism and thus encouraging experiential learning proved to be successful in teaching about astronomy. Furthermore, it can be concluded that VR experiences that take place in a science centre environment need to be intuitive and have a gentle learning curve. Users are constantly distracted by other installations and if the experience takes too long for the user to understand, they will abandon it for another installation. Additionally, the robustness of the physical aspects of a prototype needs to be prioritised since users may not handle the equipment with care. This is particularly the case with adolescents, and especially in the context of school visits with groups of excited students using the installation at a time.

Finally, this thesis project taught us several valuable lessons regarding design, development, and management. Throughout the course of this project, it was true that no design is perfect and that there is always room for further development. After each user evaluation, we gained new insights and suggestions for potential improvements and when testing a new design iteration, new feedback appeared that suggested further refinements to our prototypes. The process of continuously evaluating also taught us how to properly prioritise what features to implement and which not to, based on demand and difficulty of implementation. Testing and evaluation with a specific target audience have been thoroughly examined in this thesis project and

shaped the outcome significantly and essentially guided the design. However, the challenge with testing, as we found, is that one evaluates a sample on the target audience and that it does not necessarily have to reflect what the majority desires, though we do believe that we successfully managed to capture the needs and requirements of our target group through randomised testing at a science centre in a free, uncontrolled environment. The school visit provided the project with immensely valuable feedback and undoubtedly steered it toward a more refined prototype, however, our prototype was the focus of the visit and the engagement was high from the pupils possibly because astronomy was a subject they regarded highly. This fact and realisation about user evaluations are important to consider when designing a concept, so that truly desired changes are the only ones that make it through. Our project, guided by a Research through Design approach, is a valuable asset and base of knowledge to the field of Interaction Design as well as to researchers in the domain of VR education.

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# A

## Iteration 1: Interview Template

### Intervju

Börja med att presentera oss; varför vi är här och vad vårt projekt handlar om. Bjud på godis. Berätta att de är okej att lämna intervjun vid vilket tillfälle som helst om de inte vill vara med längre, deras deltagande är anonymt. När deltagaren är redo, påbörja intervjun.

### Frågor:

1. Hur gammal är du?  
(a) **Svar:**
2. Har du någon tidigare erfarenhet av VR?  
(a) **Svar:**
3. Vad tycker du om VR?  
(a) **Svar:**
4. Vad tycker du om astronomi? Varför tycker du så?  
(a) **Svar:**
5. Tror du att användandet av VR hade gjort astronomi mer intressant? Varför?  
(a) **Svar:**

### Visa konceptet och förklara det kortfattat:

1. Ser det intressant/roligt/lockande ut? Vad tycker du om den? (fysisk modell)  
(a) **Svar:**
2. Ser det intressant/roligt/lockande ut? Vad tycker du om det? (UI)  
(a) **Svar:**
3. Tycker du något saknas för att det ska bli en rolig upplevelse. Vad?  
(a) **Svar:**



# B

## Iteration 2: Notes from user tests

Notes taken during the evaluation of the prototype in Kungsbacka. These are documented comments, reactions, feedback and thoughts from the pupils.

### GRUPP 1

Personer 1:

- Mycket spännande och mycket skratt
- Utforskar
- Händerna laggar lite
- Känner sig förvirrad (första gången med vr)

Personer 2:

- Fattar att man måste titta exakt på planeten för att kynbna zomma in
- funkar bra med knappen tycker han
- funkar bra med händerna
- Har Vr, men inte använt bara händerna.
- Lite svårt att trycka kanske, håller på att trycka i luften
- Undrar var jorden är (kanske bra att ha en jord)

Person 3:

- Tyckte det var coolt!
- Utforskar alla planeter
- Tycker att det är lite svårt att trycka på "zoom in" knappen
- Händerna fastnar säger han. Kanske dåliga sensorer idk
- Kanske fixa en save state för senaste planeten man tittade på? svårt att titta rakt på planeten och trycka på knappen

Person 4:

- Det går bra, tycker hon, spännande
- Tyckte det funkade bra att zooma in på en planet.
- 

Person 5:

- Tycker det är intressant
- Lite konstig zoom-in knapp, svårt att zooma in
- Lyckades inte zooma in på planeten, valde att zooma in på en annan planet

Person 6:

- Tycker det är coolt.
- Verkar kunna zooma in helt ok, klagar inte på knapparna

Person 7:

- "oj!"
- Ja, svarade hon på om det är kul.
- Tycker det är enkelt att trycka på knappen, men tar ett par försök vad jag kan see
- Märkte zoonen

Person 8:

- Funkar inte att zooma, kanske svårt att träffa med 'crosshair'
- Provar zooma in på Solen. Använder händerna inte så ofta, så lite svårt att navigera runt

Figure B.1: Notes from Think Aloud.

- Tycker det känns lite konstigt och skumt, första gången de använder VR.

ANALYS: fanns en hög efterfrågan att få prova igen

## GRUPP 2

Person 1:

- coolt
- Ibland försvinner knappen
- nej, inget konstigt
- Varför är planeten blå? Neptunus?
- Hur många satelliter har varit på planeten? typ sådana frågor

Person 2:

- Lite svårt, men funkar till slut
- Det känns coolt annars
- Inte svårt att zooma in längre
- Ja, det hade varit kul att kunna testa att stå på planeterna

Person 3:

- för upptagen att svara på frågan, ganska
- Undrar hur man tycker på faktan, men det finns ingen fakta
- Lite svårt att trycka på knappen
- Lite läskigt

Person 4:

- Skrattar lite, har svårt med balansen
- Kollar runt lite och har sig
- skulle vara bra med ljud tycker gruppen
- Funkar jättebra att klicka på knappen
- Snurra på planeterna för att se andra sidan

Person 5:

- Det är najs
- Det borde finnas en platta under, annars känns det konstigt
- Lite svårt att trycka på knappen
- Hur många månar?
- Vad planeterna är gjorda av, typ vilka metaller och sånt om det är en stenplanet

Person 6:

- Zoomade in direkt på solen
- Funkar bra att trycka på knapparna
- nej det går bra, svarade hon på att om det ska finnas en platform.
- Halvtransparent platform att stå på, så man kan se ner men ändå ha en bas
- Snurra på planeten vill hon göra

Person 7:

- Håller inte händerna framför sig, initialt. svårt att använda headsetet då.
- Provar att trycka på en knapp och zooma in, men funkar inte så jättebra.

Lärare:

Figure B.2: Notes from Think Aloud.

- Tycker det funkar väldigt bra med händerna, förvånad då han har kört VR innan
  - Lite för petig kanske att man måste vara exakt på planeten för att klicka på den
  - Kunna simma till planeten (tyckte 2 pers) hade varit coolt.
- Lärare 2:
- Trycka på knappen tyckte hon var enkelt.
  - Men att kolla på samtidigt och trycka är lite svårare
  -
- Feedback:
- GRUPP 3**
- Person 1:
- Hur varma är planeterna i mitten?
  - Verkar vara väldigt coolt
  - Solen är ganska vacker. Lite snabbare rotation på planeterna och stjärnorna
- Person 2:
- Konstigt. Refuses to elaborate
  - Ibland är det svårt att trycka på knappen
  - Hade velat veta hur varm solen är.
  - Hade velat se jorden, kanske stå på jorden i början
- Person 3:
- Funkar bra att zooma in
  - Lite förvirrad i början
  - Skära i mitten och kunna se alla lager och få lite info om det
- Person 4:
- Ganska amazed av hur det funkar
  - Lite svårt att klicka, eftersom det är svårt att titta direkt på planeten
  - Använda händerna för att klicka direkt på en planet genom t.ex. raycast
- Lärare:
- Väldigt spännande, tycker hon.
  - Har lite svårt att förstå hur hon ska zooma in på planeter, men annars går det bra
  - Lite obehagligt att inte ha en platform, känns som att man går på ingenting (inte en dålig sak tror jag )
- Person 5:
- Ser lite rädd ut
  - Verkar hantera all funktionalitet väl utan att påpeka något
  - Landa och gå på planeter hade varit kul
  - Tycker crosshair är ganska liten och svårt att träffa planeter.
- Person 6:
- Tycker det är läskigt med att zooma in
  - utforska lite tyst sådär

Figure B.3: Notes from Think Aloud.

- Hade velat gå på planeterna
  - "kommer attackera mig" säger hon när hon tittar på Mars.
  - Bara någonting att stå på hade varit bra, spelar ingen roll om det är jorden eller en genomskinlig platform
  - Vill veta t.ex. hur varm en planet är vid ytan.
- Josef:
- Tycker inte det är svårt att zooma in på en planet.
  - Känns lite sådär att behöva zooma ut för att zooma in igen.
- Lärare 2:
- Tar det lugnt och sansat.
  -

**Figure B.4:** Notes from Think Aloud.

# C

## Iteration 2: Survey

Undersökning 2022-06-30

Chalmers Tekniska Högskola

Var vänliga och svara på nedanstående frågor.  
Svaren förblir anonyma och kommer användas för att förbättra vår produkt.

För frågorna 1-2 kryssar du i den cirkel som överensstämmer med din åsikt

1. Hur intressant tyckte du det var? (1-5)

☐ ☐ ☐ ☐ ☐

Inte alls

Mycket

2. Tror du detta är ett bra sätt att lära sig på?

☐ ☐ ☐

Nej

Ja

Kanske

3. Vad tycker du om att använda händerna för att klicka och välja saker?

Svar:

4. Vad hade du velat se för fakta om planeterna?

Svar:

5. Har du någon övrig kommentar?

Svar:

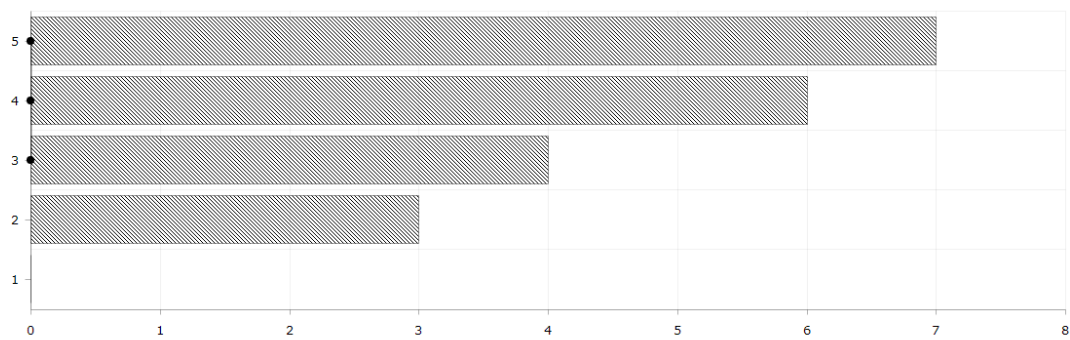
Figure C.1: Post user tests survey



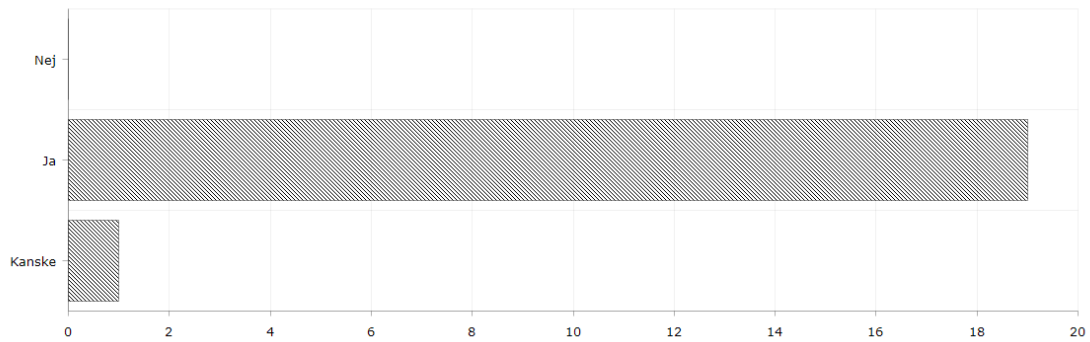


# D

## Iteration 2: Survey Results



**Figure D.1:** Answers to survey question 1.



**Figure D.2:** Answers to survey question 2.

## D. Iteration 2: Survey Results



Figure D.3: Answers to survey question 3.



Figure D.4: Answers to survey question 4.



Figure D.5: Answers to survey question 5.

# E

## Iteration 2: Heuristic Evaluation

### Participant 1:

- **User Control and Freedom:** Very free movement, very clear how to zoom in and zoom out. Easily understandable how to zoom out in case you were to zoom in by mistake.
- **Consistency and standards:** More pliancy from the button maybe. The button has feedback that indicates that it is a button. It is evident that you are looking at an area and that area is zoomed in intuitively. It allows for the realisation that one can zoom in closer.
- **Recognition rather than recall:** Information is easy to access and easy to recognise.
- **Aesthetic and minimalist design:** Very little information is shown, and therefore not much to compete against. This allows for relevant information to be extremely visible.
- **User geolocal knowledge:** It is clear to understand where one is since one is being sent to that location physically inside the VR. If you press on the sun, you get sent to the sun.

### Participant 2:

- **User Control and Freedom:** You can't go too deep into the system. Hard to get lost. In regard to freedom, I have the possibility to explore however I choose.
- **Consistency and standards:** It is consistent.
- **Recognition rather than recall:** as soon as you put on the headset you are clueless. However, once you see the text for i.e zoom in it becomes clear. If you've seen it once you will remember it.
- **Aesthetic and minimalist design:** Perfect. Would've been cool if the buttons were more space-themed.
- **User geolocal knowledge:** Always aware of where I am. Very clear when you are not in the middle and somewhere else.

### Participant 3:

- **User Control and Freedom:** Only mistake possible is to zoom in by mistake, but it is easy to zoom out if that would happen since that button is always stuck on the interface.
- **Consistency and standards:** No issues of what can or will happen. However, the zoom-in distance is varied from planet to planet which is not consistent. Small inconsistency of fact box of the sun compared to the planets, not

rounded corners. Venus has a lot of space between the fact box and sphere, Spacing between game objects has to be checked.

- **Recognition rather than recall:** easily retrievable information and actions. The zoom in button needs to be more available with the crosshair. Maybe people will not realise that planets are zoomable if you cant hit with the crosshair.
- **Aesthetic and minimalist design:** I think its consistent, nothing unnecessary, maybe the planets should be slightly bigger before zoom-in? Personally, I would maybe not notice Pluto. Maybe the planet name should be visible at all times?
- **User geolocational knowledge:** Would want to watch the earth; easier to keep track then. However, maybe not stand on the earth initially?
- **General feedback:** use information in relation to what they know and in relation to planets. If there is a purpose to interact with the planet, then the button is poor