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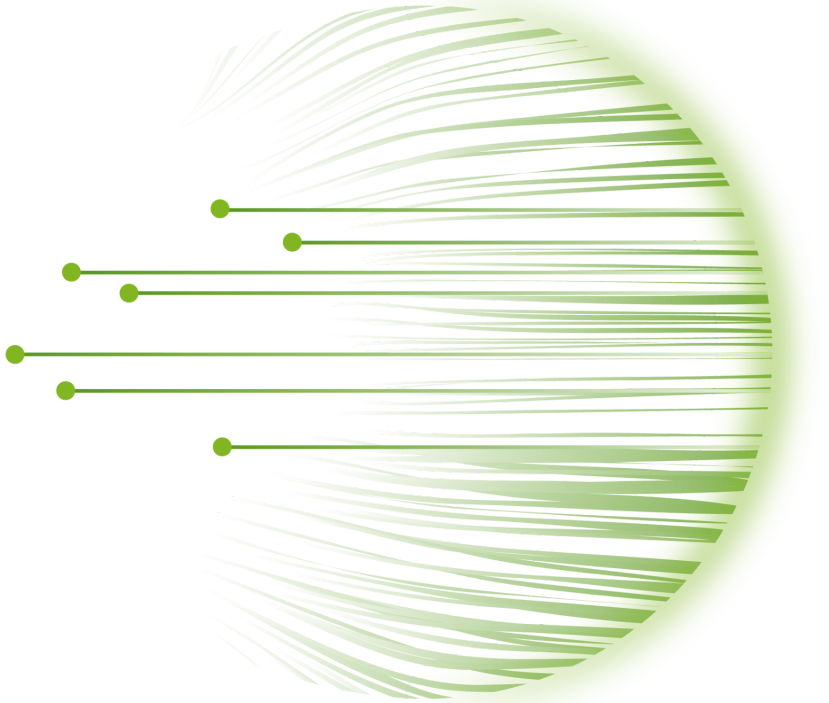

SUSTAINABILITY & VIRTUAL REALITY

THE IMPACT OF IMMERSIVE TECHNOLOGY ON BEHAVIORS AND ATTITUDES

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ABSTRACT

This project is a bachelor thesis conducted for Chalmers University of technologies, with the partner of this project being Visual Arena at Lindholmen Science Park.

The purpose of this project is to investigate if VR can be used as a tool to engage individuals in sustainability. To accomplish this, a custom VR prototype was built in which the user symbolically travels from a linear economy to a circular economy, having a narrator leading the way and explaining how linear and circular systems can apply to ordinary products. After a test week in which 22 testers participated in testing the prototype, the results pointed to VR being an effective communication and engagement tool for sustainability. The large majority of testers affirmed feeling more engaged and motivated to live more sustainably after having experienced the custom built VR prototype, as well as generally feeling more knowledgeable about sustainability than they did before the experience.

This report will extensively go into the making of the VR prototype and the choices made in creating it, as the result from the testers solely hinges on this experience. It will also provide information about the testing, the evaluation criteria, and the interviews in which the result was being concluded from.

Lastly, the report will discuss the prototype quality and how it affected the users, potential engagement improvements, the choice of target group, and aspects of sustainability and ethics.

ACRONYMS AND TERMINOLOGY

Build is a terminology in game development for “version” of a game (Unity Technologies, n.d.-a). A build is being made to run the application being made outside of the game engine. Also known as a “release” or “release candidate.”

Cradle to Cradle (C2C) is a sustainability concept that promotes a circular economy where waste is seen as a resource. It utilizes resources effectively and encourages sustainable product development to function in a similar way. C2C focuses on minimizing waste and maximizing resource efficiency from the beginning (Sustainability Guide, n.d.).

The Experience to Insights lab is a program that guides and facilitates student teams through an innovation and design process, with the aim of generating insights, learnings and evidence that can make a difference in solving real-world challenges. Visual Arena is a key part of this program, providing tools and guidance to help participants interact with sponsors, stakeholders, experts and users, and to create results that matter.

The linear economy (take-make-waste economy) is a system that extracts resources to create products that become waste, without maximizing their potential. It is polluting, degrades natural systems, and contributes to global challenges like climate change and biodiversity loss (Ellen McArthur Foundation, n.d.).

The circular economy is a sustainable approach to production and consumption that involves sharing, leasing, reusing, repairing, refurbishing, and recycling materials and products to extend their lifespan. By doing so, the circular economy aims to minimize waste and reduce the need for new resources (European Parliament, 2023).

Virtual reality (VR) is a computer-generated 3D environment that immerses users through a head-mounted display. It includes both computer graphics and 360-degree video, with hand and body tracking provided by gesture recognition or handheld controllers. Haptic feedback can be added to simulate touch, and room-based systems allow for movement in a 3D space with multiple users (Britannica, 2023).

Augmented Reality (AR) integrates digital information into the real world in real time. Unlike virtual reality, which creates a completely artificial environment, AR overlays perceptual information onto the user's actual surroundings. It can visually alter environments or provide additional information. AR blends digital and 3D elements with the user's perception of reality, delivered through devices like smartphones or glasses (Gillis, n.d.).

TABLE OF CONTENT

1 INTRODUCTION

As the acute threat of climate crisis is more relevant than ever before, engagement is in dire need to make a change. The purpose of this project is to investigate if Virtual Reality (VR) can be used as an engagement tool to help individuals get more engaged about reaching their sustainability goals. VR offers immersive experiences that can engage and communicate in ways that are difficult to achieve with traditional media, which is one of the reasons for the increase of using VR technology for educational purposes, such as real life simulations of flying an airplane or driving a vehicle. For the majority of people it is easier to remember and learn when being involved and immersed, rather than taking the outside perspective of being shown or told, which is the aspect of VR this project seeks to explore. By studying the linear and circular economy, cognitive theories and the use of VR, a custom VR experience is created with the intention of engaging people to act more sustainable by providing information about our society today and how individuals can implement sustainable practices in their everyday life.

1.1 Background

This project is a bachelor thesis conducted for Chalmers University of technologies. Mentor for this project is Olof Wranne, lecturer at Design and Human Factors.

Visual Arena is the company partnered up with, having a general problem description of *"Can VR help organizations in Gothenburg City include and engage people in a way that supports their challenging long-term sustainability targets?"*. Martin Högenberg, coach and leader at Visual Arena, worked as a mentor for this project and provided a number of the tools, methods and guidance needed from the company. Many organizations today set ambitious sustainability goals which they struggle to accomplish. Visual Arena works in the fields of visualization, both in using it as a tool for culture, art and media, as well as a tool to promote sustainability and innovation. In conjunction with the problem description, four student groups with different backgrounds conducted projects to come up with a solution to the problem description with freedom to interpret it how they saw it fit. This is the so-called "Experience to Insights Lab", see acronyms and terminology. In this project specifically, the individual approach to sustainability is in focus, rather than the organization as a whole. Sustainability is generally a "big" concept without any concrete numbers or targets for the individual, which is one of the reasons believed why it is difficult to create engagement in this area. Furthermore, since Visual Arena is big in the field of VR and this is an effective tool for immersion and communication, the decision was made to make a custom VR prototype as a solution to the problem description.

1.2 Problem description

Visualization is a crucial component of the core problem for organizations struggling to engage people in achieving their long-term sustainability goals. Lack of understanding and engagement at an individual level is a key issue that needs to be addressed in order to drive change on an organizational level. To overcome this problem, virtual reality experiences can be used to introduce sustainability techniques and provide simple examples of sustainability issues to create genuine interest and engagement. Research has shown that virtual reality has the potential to promote understanding of environmental issues and encourage necessary behavioral changes (Chamusca et al., 2023).

As indicated in the report 'Visualization in virtual reality: a systematic review by

Elif Hilal Korkut and Elif Surer visual appliances, such as data visualizations and scientific visualizations, can increase users' engagement by offering more interesting and compelling ways to view and interact with information. For example, interactive 3D visualizations can provide a true sense of depth perception and spatial relations, which can enhance the comprehension capabilities of students and the public. Additionally, visualizations can impress upon the user that a significant amount of time and research has gone into the creation of the content, which can make them more likely to read and share it with others. Overall, visual appliances offer a more engaging and immersive experience for users, which can increase their interest and involvement in the content.

1.3 Purpose and research question

The purpose with this project is to validate a VR-prototype to make people feel more engaged and motivated about reaching their sustainability goals.
The main question to be answered in this project is the following:

- Can VR help include and engage people in a way that supports their sustainability goals?

The following are extended research questions which is needed to be answered in order to accomplish our purpose:

- Do people feel more engaged and motivated to tackle their sustainability goals after having experienced the VR prototype made in this project?
- Do these people feel like they have gained knowledge about sustainability after the VR experience to make more sustainable choices than previously?

1.4. Objective

The objective of this project is to investigate the usefulness of virtual reality (VR) as an engagement tool by using a self-developed VR prototype. By setting up a research study, the aim is to explore how visualization through using VR can be used in engaging people to reach their sustainability goals and what benefits it can offer. A series of tests and evaluations is performed to investigate the user experience and their response of using this technology.

1.5 Target group

Our target group consists of individuals between 16 - 60 years working in organizations located in Gothenburg city who are keen to explore strategies to become more involved in achieving their sustainability goals. These individuals are motivated to identify and implement innovative approaches to address environmental, social, and economic challenges and create a positive impact in their workplaces and communities. They are interested in learning about various tools and methods that can help them to effectively engage.

1.6 Limitations

There are two main types of limitation, one concerning the scope of the research, and the other one concerning the scope of the VR prototype.

Research limitations include narrowing the scope of sustainability to focus on the subject of circular economy, which is an important long-term sustainability goal that the organizations within Gothenburg City are concerned about. The VR prototype limitations include that the validated prototype is not a fully rendered, multi-room experience. This is mainly due to time limitations, and the lack of skill needed to compose a fully rendered, larger world, VR prototype. Moreover, the prototype will also only include basic user features, such as walking, gravity and object boundaries. The prototype's purpose is mainly creating an engaging VR experience with the help of visuals and storytelling, rather than game-like features.

The project is furthermore geographically limited to the city of Gothenburg as well as technologically limited to the equipment being provided for us at Visual Arena and Chalmers. In addition to this, we will also limit ourselves to focus on long term sustainability, rather than short term solutions.

2 THEORETICAL BACKGROUND

2.1 Virtual Reality

Virtual Reality (VR) refers to a computer-generated environment that can be experienced through the use of specialized equipment such as head-mounted displays, haptic feedback devices, and motion tracking sensors. The goal of VR is to create a sense of presence and immersion in a digital environment that is indistinguishable from the real world ("History Of Virtual Reality," n.d.).

The concept of VR can be traced back to the 1960s, when computer scientist Ivan Sutherland developed the first head-mounted display system. However, it was not until the 1990s that the technology began to mature and become commercially available. Today, VR is used in a variety of fields such as gaming, education, healthcare, and training. At the heart of VR is the concept of presence, which refers to the feeling of 'being there' in the virtual environment. Presence is achieved through a combination of sensory inputs such as visual, auditory, and haptic feedback. By creating a high degree of presence, VR can evoke strong emotional responses and enable users to engage with digital content in a way that is not possible through traditional media ("History Of Virtual Reality," n.d.).

Donga et al. (2021) presents one of the key challenges in VR, which is achieving a high degree of realism in the virtual environment. This involves creating realistic 3D models of objects, textures, and lighting, as well as accurately simulating physics and interactions between objects. Advances in computer graphics and processing power have made it possible to create increasingly realistic and immersive virtual environments. Another challenge in VR is minimizing the negative side effects such as motion sickness and eye strain. These can occur when there is a mismatch between the visual and vestibular (inner ear) signals, or when the frame rate of the display is too low. To address these issues, VR developers are exploring new techniques such as foveated rendering and adaptive refresh rates

VR has the potential to transform a wide range of industries, from entertainment and education to healthcare and therapy. By enabling users to experience new environments and perspectives, VR can help to broaden our understanding of the world and enhance our empathy and social connections. As the technology continues to evolve, it is likely that there will be even more optimistic applications of VR in the future (Hamad & Jia, 2022).

2.2 Softwares and platforms

In this project, the software tools being used are Blender and Unity. Blender is a 3D computer graphics software used for creating 3D models, animations, visual effects, and video games, while Unity is a game engine used for developing games and interactive applications, in this project to build the VR-environment. In the following sections, theoretical backgrounds will be provided on these softwares.

2.2.1 Blender

Blender is a free software and open-source 3D computer graphics software for creating animated films, visual effects, art, 3D printed models, and video games. It is a powerful tool for artists and

designers, providing a range of features and tools for modeling, texturing, animation, and rendering (Blender Foundation, n.d.-b).

Blender was first developed in the late 1990s by Ton Roosendaal, and since then it has grown into a popular and widely-used software package. It is available for Windows, macOS, and Linex, and it is constantly being updated and improved by a community of developers and users. One of the key features of Blender is its flexibility and versatility (InspirationTuts, 2020). It can be used for a wide range of tasks, from creating simple 3D models to producing complex visual effects for films and games. Its node-based material editor and support for scripting and programming allow for a high degree of customization and automation. Blender also has a steep learning curve, which can be a strength and a weakness. On one hand, its depth and complexity make it a powerful tool for professionals and advanced users. On the other hand, its interface and workflow may be intimidating for beginners or casual users (Blender Foundation, n.d.-a).

Overall, Blender is a powerful and versatile tool for 3D modeling, animation, and visual effects. Its free and open-source nature, along with its active community and support for open standards, make it a unique and valuable resource for artists, designers, and developers.

2.2.2 Unity

Unity is a 2D/3D game engine used for developing games and interactive applications across multiple platforms, including desktop, mobile, and virtual reality. It is free and designed to be user-friendly and flexible, allowing developers to create games and simulations using a range of programming languages and workflows. Unity uses C# code language, which is an object-oriented, component-oriented programming language.

As reported by Sinicki (2021) one of the strengths of Unity is its so-called ‘Asset Store’ where developers and creators can upload their work, materials, shaders and other assets, and make it public for other people to use. Also, its cross-platform support, which allows developers to create games that can be deployed on a range of devices and operating systems. It supports a wide range of platforms, including Windows, macOS, iOS, Android, Xbox, PlayStation, and virtual reality headsets such as Oculus and HTC Vive. Another key feature of Unity is its components-based architecture, which allows developers to create complex game objects and behaviors by combining simple components. This makes it easy to prototype and iterate on game designs, and also facilitates collaboration among developers and designers

2.2.2.1 URP vs HDPR

URP and HDPR are both render pipelines created by unity to render scenes, making it possible to show what you have built in unity on a screen. The Universal Render Pipeline (URP) is a prebuilt Scriptable Render Pipeline, made by Unity. URP provides artist-friendly workflows that let you quickly and easily create optimized graphics across a range of platforms, from mobile to high-end consoles and PCs (Unity Technologies, n.d.-e). The HDPR is a high-fidelity Scriptable Render Pipeline built by Unity to target modern (Compute Shader compatible) platforms (Unity Technologies, n.d.-b).

2.2.2.2 Unity’s XR interaction toolkit

The XR Interaction Toolkit package is a component-based, interaction system for creating VR and AR experiences in Unity (Unity Technologies, n.d.-f). The core of this system is a set of base Interactor and Interactable components, and an Interaction Manager that ties these two types of components together. In other words the ability to “grip” and in other ways interact with objects in the unity environment through VR devices. It also contains components that you can use for locomotion and drawing visuals.

2.2.3 Miro

Miro is a versatile digital whiteboard and collaboration platform that allows teams and individuals to work together remotely. It provides a virtual canvas where users can create and organize various types of content, such as sticky notes, images, diagrams, and drawings. Miro is designed to facilitate brainstorming, planning, project management, and visual collaboration. The platform's intuitive interface and extensive toolkit make it suitable for a variety of use cases, including agile workflows, design thinking, product development, strategic planning, and more. Whether used for team collaboration, visual thinking, or project management (Miro, n.d.).

2.2.4 NEXT

NEXT is a platform for teams which lets you “validate big-picture and day-to-day product decisions with user insights” (*NEXT | Product Discovery Platform*, n.d.), and is employed and recommended by Visual Arena. Therefore, this platform is used in this project for sharing information with Visual Arena and the other students working on the same problem.

The NEXT platform gives access to a number of tools for different stages in the design methodology process. Mainly, NEXT works as a board for structuring ideas and insights gathered from research and interviews that allows you to move and prioritize tasks in an effective manner. NEXT also provides information on needs analysis, user research, and presentation tools which of many have been used in this project.

2.2.5 Sketchfab

Sketchfab is a platform that makes it easy to discover, edit, buy, and sell 3D content directly through their web-based service and is home to 4 million 3D assets (Epic Games, 2021). It provides a viewer based on the WebGL and WebXR technologies that allows users to display 3D models on the web, to be viewed on any mobile browser, desktop browser or Virtual Reality headset.

2.3 Sustainability

Sustainability is the concept of balancing economic, social and environmental concerns in order to meet the needs of the present generation without compromising the ability of future generations to meet their own needs (Frick & Hedenmark, 2016). As global demand for resources continues to rise, it has become increasingly important to develop sustainable models of production and consumption.

The linear economy is a traditional economic model that follows a ‘take-make-dispose’ approach. Resources are extracted from nature, transformed into products, and then disposed of a waste. This model relies on a continuous supply of resources and is not sustainable in the long term, as it creates waste and pollution and depletes finite resources.

In contrast, the circular economy is a model that aims to create a closed-loop system in which resources are used and reused in a continuous cycle. The circular economy is based on the principles of reduce, reuse, and recycle. By reducing waste and pollution, using resources more efficiently, and designing products for longevity and recyclability. The circular economy can help to minimize our impact on the environment and create economic and social benefits. The circular economy includes two sections: the biological section and the technological one.

The biological section of the circular economy focuses on the use of renewable resources and encourages the use of materials that can be naturally cycled back into the environment. This includes the use of biomaterials that are biodegradable and compostable, as well as the use of sustainable agricultural practices to grow crops and raise livestock. According to Pär Frick and Magnus Hedenmark, they explain in their book ‘Vad är cirkulär ekonomi?’ that the circular economy is not just about recycling, but also about designing products and services in a way that maximizes resource efficiency and minimizes waste. This includes using renewable energy sources, adopting new business models that focus on sharing and access rather than ownership, and creating closed-loop systems in which waste from one process becomes a valuable input for another process.

The technological section of the circular economy focuses on the use of technology to facilitate the recovery and reuse of materials. This includes the use of advanced recycling technologies that can recover and purify materials from waste streams, as well as the use of digital technologies to optimize resource use and reduce waste.

Frick and Hedenmark argue that the circular economy can provide numerous benefits, including reducing resources depletion and waste, creating new business opportunities and jobs, and increasing resilience and stability in the face of global challenges such as climate change. Generally, the circular economy represents a fundamental shift in how we think about and approach economic development, emphasizing the importance of sustainability, resource efficiency, and social and environmental responsibility. By promoting a shift towards a circular economy, we can reduce our environmental impact, create new economic opportunities, and enhance our overall well-being.

2.4 Cognitive theories of learning, engagement and visualization

Research suggests that people learn more effectively with visualization and when information is presented using a combination of images and spoken or written words, rather than solely relying on spoken or written words (Mayer, 2010). The way this combination is presented can lead to different learning outcomes, including no learning, superficial learning without a deeper understanding, or meaningful learning. To promote meaningful learning, multimedia tools should present only relevant information and avoid extraneous information, such as unnecessary music tracks, that may affect the learning process negatively.

An important principle in cognitive theory is the Coherence Principle, which suggests that learning is most effective when the learner is not presented with too many unfamiliar words, sounds, or images. Adding extra information solely for entertainment value can impede the building of knowledge by

making it harder to extract, organize, and integrate relevant information with pre-existing knowledge. To ensure the learning goal is not lost, it is important to prioritize the presentation of relevant information.

In terms of cognitive theories, it has been explored how people learn and get engaged in the best way, and how VR affects people's behavior and learning styles. According to David Kolb, a psychologist and educational theorist, people have different preferences when it comes to how to learn in an effective way. It can be difficult for each person to learn effectively in a group because each individual has a unique learning style (Adaptas, 2012). VR allows for a distraction-free environment and can suit different individuals with different learning preferences, and is what is known as experiential learning.

The Chinese proverb "Tell me, and I will forget. Show me, and I may remember. Involve me, and I will understand" is relevant to this study and project. To experience is a great way to learn for people with different learning preferences since, the person in a VR experience is being told and guided by a storyteller, gets to see by being in the virtual world and is being involved by interacting with the objects. The positivity of the combination is supported by Mayer's theories on multimedia learning (Mayer, 2010).

3 METHOD AND IMPLEMENTATIONS

In the following chapter the methods used in this project will be described. The chapter will commence with a description of our general design methodology, which thereafter will be followed by the methods used for planning, user research, idea generation, development and evaluation. The methods will be described in the order in which they are being used throughout the project, although several methods will appear throughout the project.

3.1 Design methodology - Double diamond

The workflow in the project is based on the double diamond design process, created by the British design council in 2005, which is a way to visually describe the steps taken in any design and innovation process regardless of methods and tools (Ball, 2019). In this project, the first diamond phase will be referred to as “iteration period one”, and the second one “iteration period two”, see *figure 1* below.

This method generally follows, as the name suggests, a two diamond-shaped process. The first diamond emphasizes research, and the second emphasizes design. Simply put, the process is starting from the left hand side with the initial challenge or problem, creating a clear definition in the center, ending with a solution on the right. The four phases of the double diamond, cited from the design council’s official website (Ball, 2019), are as follows:

- **Discover:** The process starts by questioning the challenge and quickly leads to research to identify user needs.
- **Define:** The second phase is to make sense of the findings, understanding how the user needs and the problem align. The result is to create a design brief which clearly defines the challenge based on these insights.
- **Develop:** The third phase concentrates on developing, testing and refining multiple potential solutions.
- **Deliver:** The final phase involves selecting a single solution that works and preparing it for launch.

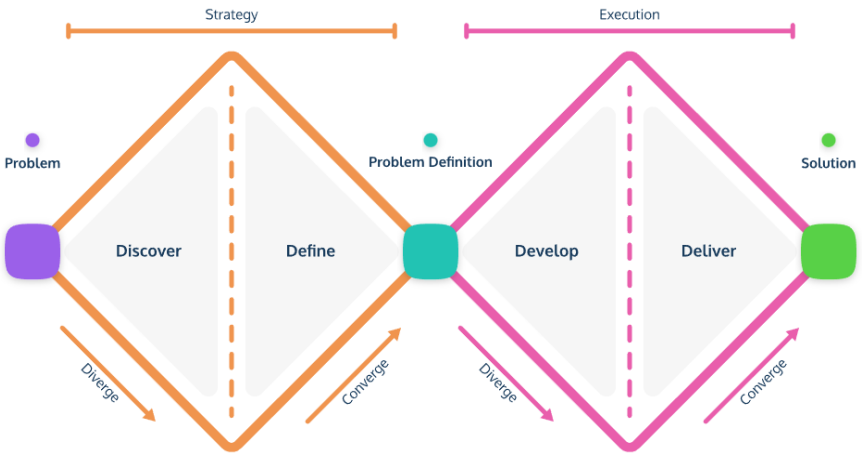


Figure 1. The double diamond process, taken from ProPad (ProdPad, n.d.).

3.2 Research methods

The research phase is active during the entirety of the project, although more extensive in iteration period one, see chapter 3.1 “Design Methodology". The research is divided into two areas: Sustainability research and soft-/hardware research. Soft-/hardware will primarily lie heavily on understanding VR, including the functions of the software Unity and limitations when using VR as a tool. This is done by experimenting in the software itself, creating a minor program, and relying on information available on the internet such as Unity’s official learning platform (Unity Technologies, n.d.-c).

3.3 Needs analysis

Before building a solution a clear framework needs to be built on understanding the factors around the project. It is important to know the external and internal motivations of this project, which is why a number of methods were employed to create a solid ground in iteration one, see chapter 3.1 “Design Methodology”, before proceeding with making the major design choices. The needs analysis methods are listed below.

3.3.1 “Who is who”

“Who is who” is used to establish a customer-centric approach early on and to prepare the team for outside-in thinking (*NEXT | Product Discovery Platform*, n.d.). This is done by compiling a list of existing customers/users (if there is any), as well as reviewing potential future customer segments and competitors and their customer/users.

3.3.2 Passion and purpose

“Passion and purpose” overview was done to tap the individual intrinsic motivation for doing this project, as well as to discover what each member can bring to the topic and have a heart-to-heart as a team (*NEXT | Product Discovery Platform*, n.d.). This was done by individually reflecting on the topic and filling out a canvas (see appendix 1), where later the common themes and surprising aspects were pitched and discussed.

3.3.3 KPIs

KPIs, Key Performance Indicators, are done to focus the teams efforts on common visible objectives, measure and communicate progress (internally and externally) as well as create and maintain alignment in the project objectives (*NEXT | Product Discovery Platform*, n.d.). These performance indicators help teams work toward concrete, set outcomes and solve issues that stand in the way of those goals. There are different indicators of performance, and depending on the project and business these some are more suitable to use than others. Most, however, fall under two categories: Qualitative and quantitative (*What Is a KPI?*, 2022). A quantitative KPI uses numbers to measure progress toward a goal, such as number of sales, or annual revenue. Qualitative KPI tracks non-numerical data such as employee engagement or customer comments and reviews. This, along with quantitative KPIs, can help the team figure out how people are responding to the product and how to keep improving it.

3.3.4 Stakeholders

Stakeholder mapping is done to gain clarity on who the project stakeholders are and why they are, as well as identifying the project's strongest allies and co-creators with a vested interest the the project's success (*NEXT | Product Discovery Platform*, n.d.). In this project this was done by filling out a matrix with the corresponding roles of people or actors who had been interviewed or otherwise engaged with, see *figure 2* for stakeholder mapping template.

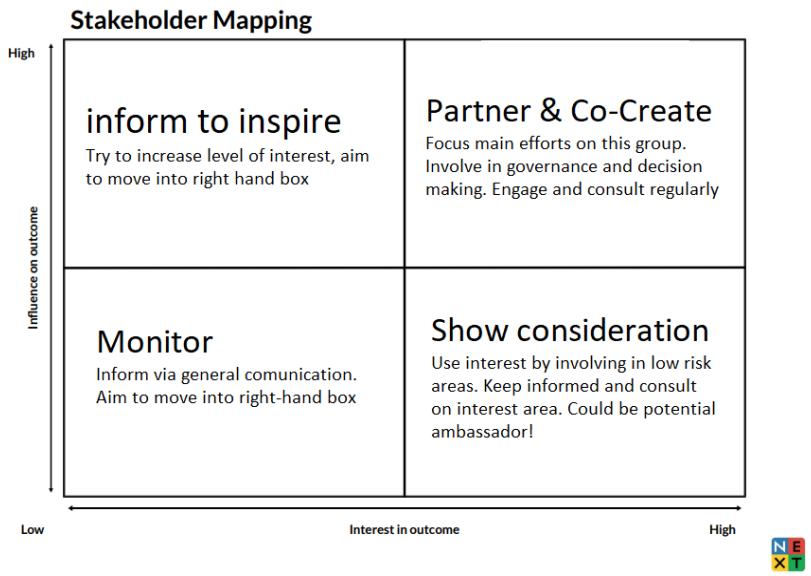


Figure 2. Stakeholder mapping template, used with permission (*NEXT | Product Discovery Platform*, n.d.).

3.3.5 Personas

Personas are fictional characters, created to represent the different user types which might use your solution (a product, digital or physical, or a service). Creating personas will improve understanding of your users' needs, experiences, behaviors and goals and can help you step out of yourself (Dam & Siang, 2022). They can also help you identify with the user you're designing for. Personas make the design task at hand less complex, they guide your ideation processes, and they can help you to achieve the goal of creating a good user experience for your target user group.

3.3.6 The Rose, Thorn and Bud method

Rose, Thorn, Bud is a reflection method where situations are categorized as positive (rose), negative (thorn), or potential (bud). It helps analyze projects and problems, guiding decision-making. Participants write sticky notes for each category: roses for positives, thorns for negatives, and buds for potential areas. It encourages better understanding and focus on next steps . This is a method used in Miro, see section "2.2.3 Miro" in Method and implementations.

3.4 User research methods

The following are methods used to understand the users' and other involved parties' needs, behaviors, demands and motivations in regard to the project.

3.4.1 Interviews

An interview can vary from a highly structured, closeted interview style to an open spontaneous conversation (Hamill, 2014). Semistructured or open-ended interviews are commonly used in qualitative research, and also the interview technique mainly being used in this project. This type of interview is aided by an interview guide or schedule which contains topics or open questions to be covered, rather than standardized questions. The intention with a semistructured interview is that the interviewer remains flexible, responsive and being able to probe more deeply into initial responses to gain a more detailed answer to the question being asked. The interview data is recorded and thereafter transcribed to produced text that can be analyzed.

3.4.2 Focus groups

A focus group generally consists of a group of 6-10 people led by a moderator (Chrzanowska, 2010). It is characterized by a non-direct interview style where the goal is to get a rich amount of perspectives on what is being discussed. The moderator's task is to introduce discussion topics and create an atmosphere in which the participants feel safe to express their personal opinions on the matter. The goal of the focus groups is not to reach a conclusion amongst the participants, but rather to bring different experiences and insights of a matter into the light. Focus groups are well suited for exploratory studies in a new area, since a lively group discussion often can bring out more spontaneous and emotional expressions than the individual interview (Kvale & Brinkmann, 2014).

3.4.3 Observations

Observation is a way of collecting data through observing. This may involve watching, listening, reading, touching, participating and/or recording behavior and characteristics of a phenomena (Dudovskiy, n.d.). Observation as a method can either be structured or unstructured. In structured or systematic observations, the data is collected accorded to a pre-defined schedule and variables. Unstructured observations, however, are conducted without pre-determined variables. There may also be so called semi structured observations, which are generally unstructured but with some pre-defined variables included.

Observations can moreover be either "overt", where the research subjects are aware that they are being observed, or "covert" in which the data collection is happening unbeknownst to the sample group (Dudovskiy, n.d.). Covert observations are considered to be more effective since the sample group is less likely to disrupt their natural behavior, as they might do if knowing they are being observed. Advantages of observation data collection methods include direct access to research phenomena, high levels of flexibility in terms of application and generating a permanent record of phenomena to be referred to later. However, there are also some disadvantages to be aware of, such as high levels of observer bias, and impact of observer on primary data, in a way that presence of observer may influence the behavior of the research subjects.

3.5 Idea and concept generation methods

In this phase, various methods are to be utilized to generate and develop raw ideas. Initial concepts are expressed through sketching, writing, and communication using whiteboards and paper. SCAMPER, an element of the brainstorming method, is used to compare the ideas with those already in existence, either to prevent copying or to improve upon them. The resulting ideas are innovative solutions that will later be expanded and combined using the Six Thinking Hats method, which involves eliminating ideas.

3.5.1 Brainstorming

Brainstorming is used in ideation and part of design thinking. It is a method which teams use to freely generate ideas to solve clearly defined design problems and draw links between them to find potential solutions (*What Is Brainstorming?*, n.d.). Brainstorming is a free thinking process, but with 8 “house rules” that must be followed:

1. Ideas need to be developed within a set time limit
2. Begin with a problem description/brief
3. Refrain from criticism
4. Encourage weird and wacky ideas
5. Aim for quantity over quality
6. Stay visual (with eg. diagrams and posts)
7. Build on others ideas
8. Only allow one conversation at the time.

3.5.2 SCAMPER

SCAMPER is a quick, easy and direct form of creative brainstorming. The acronym stands for Substitute, Combine, Adapt, Modify, Put to another use, Eliminate and Reverse. This refers to the different questions you ask about already existing solutions, products or services which will help you develop and come up with new ideas (Dam & Siang, 2020).

4 RESULTS

In this chapter the results of research, interviews and testing will be documented, along with the process of building and validating the final VR prototype. For clarification the results of each iteration phase (previously described in section 3.1 “Design methodology - Double diamond”) will be documented separately.

4.1 Iteration period one

Iteration Period 1, is the initial phase of this project and also the first diamond, which involves conducting research and development, establishing evaluation criteria, generating ideas, hosting a workshop, and finalizing a concept.

4.1.1 Research and development

The purpose of the research was to identify easily understandable and relatable examples of everyday objects that individuals can use to contribute to a more sustainable future. The findings of the research were intended to be incorporated into a VR experience. Specifically, the study focused on four common “objects”: the phone, coffee, fridge, and the kettle. These objects were chosen based on their relevance to people's daily lives and their potential to illustrate sustainable practices. Following paragraphs will provide more detail to the examples.

Mobile phones contain around 40 metals, many of which are considered rare. It's now more economical to extract gold from a ton of old mobile phones than it is from a ton of gold ore. These devices hold a variety of highly complex and valuable materials, but unfortunately, only 17 of these metals can be recycled for profit. The rest of these metals, along with other components, are considered waste (Frick & Hedenmark, 2016).

Coffee is another resource whose potential is not being fully utilized. According to Eric Hoffman who wrote the article ‘5 Steps For Growing Mushrooms In Coffee Grounds’, Coffee grounds can be used for various purposes, such as obtaining one meter of water-repellent fabric, animal feed, floor mats, insulation material for refrigerators, and even paint. Additionally, coffee grounds can be composted to grow mushrooms (Frick & Hedenmark, 2016).

Another example was taken from Layla Acaroglu where she mentions in her TED talk that the crisper drawer in refrigerators, is not designed to keep things crisp and often results in half-eaten produce being thrown away. This leads to not only wasting the food itself but also the resources used to grow it, such as land clearance, planting, fertilizers, nutrients, water, and sunlight. To tackle environmental problems, better designs for things like the crisper drawer are needed to reduce food waste.

Also, Layla mentions that overfilling kettles is a common occurrence that leads to unnecessary energy use from boiling excess water. In the United Kingdom, it has been estimated that the energy wasted from overfilling kettles in just one day is enough to light up all the streetlights in the entire country for a night. By being more mindful of the amount of water used by each individual, a reduction can be made of unnecessary energy consumption and contribute to a more sustainable future (Acaroglu, 2013).

4.1.2 Research and needs analysis

The research conducted includes the analysis of the who's who, passion and purpose, KPIs, stakeholders, and personas to achieve the desired outcome of this project. The result of the who's who identified the current and future customer types or segments, including companies within Gothenburg city and people or companies interested in sustainability, with a focus on the circular economy.

The passion and purpose result revealed the opportunity to use virtual reality as a tool to communicate sustainability knowledge more effectively and engage people in taking action towards the environment. The KPIs identified for the project's objective were the number of testers acquired and customer satisfaction score (CSAT), with a target of 10 people. The stakeholders include a storyteller, Visual Arena intern, Visual Arena supervisors, Visual Arena communicator, Chalmers supervisor, an expert working as strategy manager in the department of development and analysis, and an expert working as a planning manager in the environmental management department.

Two personas, Ulla and Magnus, were made as representative of the target customer segment. Ulla is a 55-year-old politician who tests the VR experience and feels empowered to improve sustainability in her personal and professional life. Magnus is a 25-year-old teacher who gains a positive understanding of sustainability and sees it as something to look forward to. The project aims to introduce sustainable practices to individuals and techniques through the use of VR as an engagement tool.

4.1.2.3 Expert interviews

For the interviews, three experts were interviewed in Gothenburg city to gain their general opinions and expertise on sustainability, trends and the use of new techniques to engage reaching sustainability goals in Gothenburg city or create an understanding of how the society is changing from a linear to a circular economy. The first interviewee works as an environmental analyst and innovation leader at the City of Gothenburg, helping the city's administration with systematic environmental monitoring (C. Ceder, personal communication, Spring 2023). The second interviewee is a planning leader working in the democracy administration department in Gothenburg city, specializing in service development and analysis (U. Ramstedt, personal communication, Summer 2023). The third interviewee is a Sustainability Strategist and Innovation Manager, coordinating the strategy for Sustainable Living at the City of Gothenburg (T. Lund, personal communication, Spring 2023).

During the interviews, it was noted that climate and environmental problems come to the forefront during events such as floods or extreme heat waves, but people tend to forget about them quickly. One interviewee emphasized the need to keep the issue alive and to find a balance between not scaring people into giving up and motivating them to take action. Another interviewee noted that it may be difficult to make significant changes among the older generation, but younger people are driving trends and will likely lead the way. Another emphasized the need to make sustainability fun and appealing by reducing food waste and promoting local produce. The goal is to get people to try new things and see the benefits of sustainable practices, not to invoke pessimism and hopelessness.

4.1.3 Evaluation criteria

During iteration period one, the evaluation criteria is established in the form of questions to verify the completion of the project's purpose and needs, see section 1.3 Purpose and research question. This is

done to gain a better understanding of the development goals for the VR experience and determine focus areas. In iteration period two, the evaluation criteria for the VR experience prototype will be used to interview the target group after testing the prototype. The assessment from the evaluation questions will include the level of engagement during the experience and the extent to which it contributes to achieving a sustainable society. The value of the experience for the user will also be evaluated, along with a comparison to alternative experiences. In addition, the level of motivation to tackle sustainability challenges after the experience and the amount of knowledge gained about sustainability will be assessed. Furthermore, the relevance of conveying this type of knowledge through VR will be evaluated, and overall satisfaction with the experience will be measured. Refer to section “9.5 Evaluation Criteria" in the appendices for a complete list of the evaluation criteria questions.

4.1.4 Idea generation

The idea generation process to build the VR experience is based on various sources, including interviews with experts in Gothenburg city, research and needs analysis, and studies on multimedia learning and cognitive theory. The sustainability experts emphasized the need to make sustainability fun, relatable and prioritizing individuals over organizational change, and avoid scaring people of environmental problems. These insights were incorporated into the VR experience by incorporating the concepts of Engage, Involve, and Reflect.

In the idea generation stage, the studies on multimedia learning and cognitive theory discussed in section 2.4 "Cognitive Theories of Learning, Engagement, and Visualization" played a crucial role. These studies highlight the importance of coherence in storytelling and the use of multimedia to enhance learning, as well as the significance of active user involvement in the learning process. All of this information was used to guide the idea generation and concept development towards creating a meaningful and impactful VR experience that aligns with the needs and priorities of this project.

The idea generation process began with a brainstorming session, see section 3.5.1, where ideas were generated for a virtual reality experience aimed at increasing awareness about sustainable living and create engagement. The ideas were written down on a whiteboard, and iterated over until a concept took form. Following quote by Confucius was source for inspiration:

> *"Tell me, and I will forget. Show me, and I may remember. Involve me, and I will understand"*
>
> - Confucius

With this in mind, a concept with three storytelling beats was developed with focus on individual engagement and reflection. These steps are the following:

1. “Engage” - Introducing the user to the experience, garnering and maintaining interest
2. “Involve” - Involving and engaging the user in the topic
3. “Reflect” - Allowing the user to reflect on gained knowledge

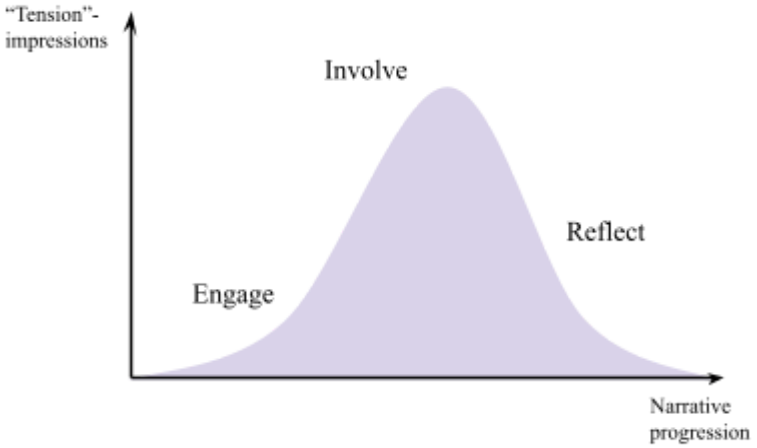


Figure 3. Storytelling progression.

Like a classic storytelling arc with a buildup, climax and end, this experience is built in a similar manner, see *figure 3*. However, where the classic story building arc increases in tension closer to the climax, this experience will have a build up of "impressions" which will be further explained step by step below.

Engage - "Did you know?": In scene one, "The Tunnel", the user is introduced to a long dark tunnel with a light at the end and a line in the floor, abstractly representing the concept of linear economy. Impressions are minimal: dark tunnel, little to no visuals or sound effects. As the user progresses through the tunnel information of the linear economy and today's (un)sustainable practices will be introduced. This information will be presented in a questioning and mindful way ("did you know?") to avoid information overload. The information will be received by the user through the means of an ordinary product, such as a phone, which most people can relate to. The purpose of this stage is to garner interest, as well as create tension to the story. The user should be naturally drawn to the light by the end of the tunnel, but will also receive guidance from a voice over and a line in the floor to enter the light to proceed to stage two.

Involve - "What if?": Scene two, "The Kitchen", will fade in from the light by the end of stage one. The user will have entered a gray/white rather dull kitchen, complete with items which can be found in such an environment: A fridge, a kettle and a coffee cup. The "did you know" questions will continue here, describing problematic examples of unsustainable practices relating to these items. These questions will however in time deliberately turn into a narrative of "what if" instead, prompting a discussion, an alternative, to the user. What if the coffee grounds in our coffee instead are being distributed to, for example mushroom plantages, where instead of contributing to an enormous waste they are used to grow X amount of food in a year? This takes the user on a journey that bends from a linear path to a circular one, indirectly introducing the concept of circular economy and cradle to cradle by the use of relatable objects. As the objects in the kitchen are being discussed colors will sprout from the objects to bring attention to them, as well as light sound effects making the kitchen more inviting. This is more impression heavy than the first stage, with more information being introduced along with both animations and sound effects.

Reflect: Scene three, “The Nature”, will fade in from scene two. Here the user will be introduced to nature, a beautiful landscape with birds twittering and wind breezing in the distance. The user will be standing on a small road, bending in the distance until forming a big circle. Compared to the more intense and impression heavy kitchen, this meant to work as a reward to the user for making it through the journey, and in a symbolic way will represent the arrival of a circular economy. The line seen in the floor at the tunnel is seen here as well, which is a way to guide the user along the path. After a few moments of taking in the surroundings, the user is asked to look down at their feet, from which they will be presented more concise information to the bio- and technocratic aspects of circular economy (see chapter two for theoretical background on this), summing up the information they absorbed in the kitchen and providing a more general context. The user is therefore allowed to take the time they want to stroll around in nature and reflect, and asked to remove their headsets whenever they feel ready to do so. As an incentive to keep the user in the scene for a bit longer, a few visual cues from previous scenes can be found along the road, such as coffee grounds or an overgrown refrigerator. If the user is of a curious enough mind to approach these, text bubbles will pop up above them when coming close providing information, a quote, a question or something of similar sort.

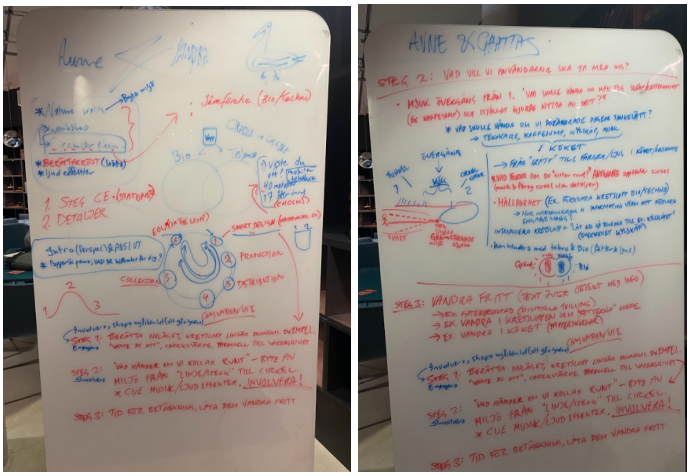


Figure 4. Brainwriting on a white board.

These ideas were the result of brainwriting and iterating over ideas discussed previously, written down on a big white board, see *figure 4.* Although the general ideas were agreed upon, how the visuals actually take form is often individual. A general “kitchen” or “tunnel” most likely looks different to people depending on the frame of reference they have, which is why the idea generation was continued with drawings of the different scenes. After discussing various styles for the scenes, a general simple storyboard was agreed upon. See the general storyboard created with fast sketches in *figure 5* below.

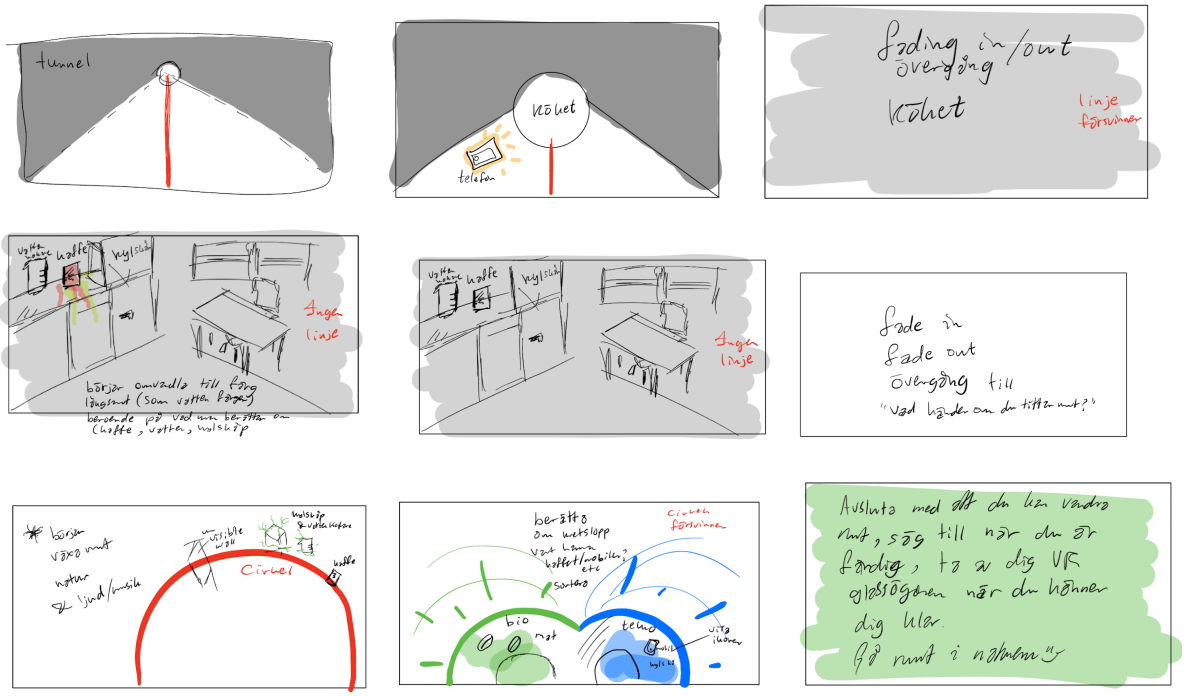


Figure 5. General storyboard with fast sketches.

4.1.5 Workshop

On March 3, 2023, a workshop was conducted at Visual Arena, hosted by nine students who are involved in the 'Experience to insights Lab' project (See acronyms and terminology for a definition). The workshop aimed to explore various virtual reality environments and test their advantages and disadvantages by showing three focus groups of five 60 to 90-second 360 degree videos. The videos were shown to three focus groups, which had 6 participants each, see *figure 6*. After each video, the focus group was asked to write down their thoughts, feelings or first impressions on a post-it note. At the end of the workshop, a 10-minute discussion was held with each group to discuss the ideas and thoughts that emerged from the experience.

Figure 6. Pictures of the 5 videos that were shown in the workshop.

The five videos chosen to provide insights into the intended visual and audio aspects of the VR-experience were based on three main scenes resulting from our previous idea generation. The first video features a dark and psychedelic environment with a worm leading the focus group through a tunnel filled with colorful figures and intense, dragging melodic music in the background. The second video showcased a dance performance at the opera, defying societal norms, closeness, primarily focusing on the music and visuals as in the first video. The third video provided informative visuals of Stockholm city, including a bird's-eye and underground perspective of the tunnel construction, accomplished by a speaker, text and realistic imagery. The fourth video was in nature, flying through Lauterbrunnen in Switzerland, with a combination of text, a speaker, and soothing background music. Lastly, the fifth and last video featured a tranquil sunset view, with the focus group situated in the boat close to the water, with some sound effects of the water and birds in the background.

4.1.5.1 Workshop conclusions

After the workshop, all post-it notes were collected and analyzed using the Rose, Thorn, and Bud method to initiate observation, see section 3.3.6 "The Rose, Thorn and Bud method". The Rose category contained what worked well in relation to the project, while the Thorn category contained challenges and what worked poorly. Under the Bud category, potential and future development were noted. Based on this, further observations were made. It was observed that collaboration between music, narration, animations, and text is important to create a complete experience, but the quality of these factors can affect the individual's experience and potentially give a false feeling. Additionally, physical discomfort that may arise during VR experiences, such as motion sickness, must be taken into consideration. It was also noted that a clear sense of direction and a guidance in the VR experience can reduce the feeling of potential discomfort and emptiness.

Observations were made during the workshop that can be implemented in the continued development of the VR experience. For scene 1, 'the tunnel,' it was noted that a clear direction is important to maintain curiosity and avoid discomfort. Therefore, efforts should be made to create a direction that is easy to follow. For scene 2, 'the kitchen,' the information must be easily absorbed and easy to orientate. For scene 3, 'nature,' it was observed that a natural environment provides a 'wow' experience and was very positively received. However, it is important to ensure that this feeling does not override any information that needs to be conveyed. Balancing the different elements is crucial to create a well-balanced experience.

4.1.6 Final concept

After conducting the ideation process and analyzing observations from the workshop, a final concept for the experience has been developed and is presented in table X. The VR experience will feature a storyteller, visualizations and sound effects, and it will consist of three scenes designed to engage, involve, and reflect the user. Eventually a short animation in the form of a GIF was drafted, see *figure 7.* This was practical to see how the ideas might translate into three-dimensional forms in Unity and Blender, and helped identify any potential issues that might need to be addressed.

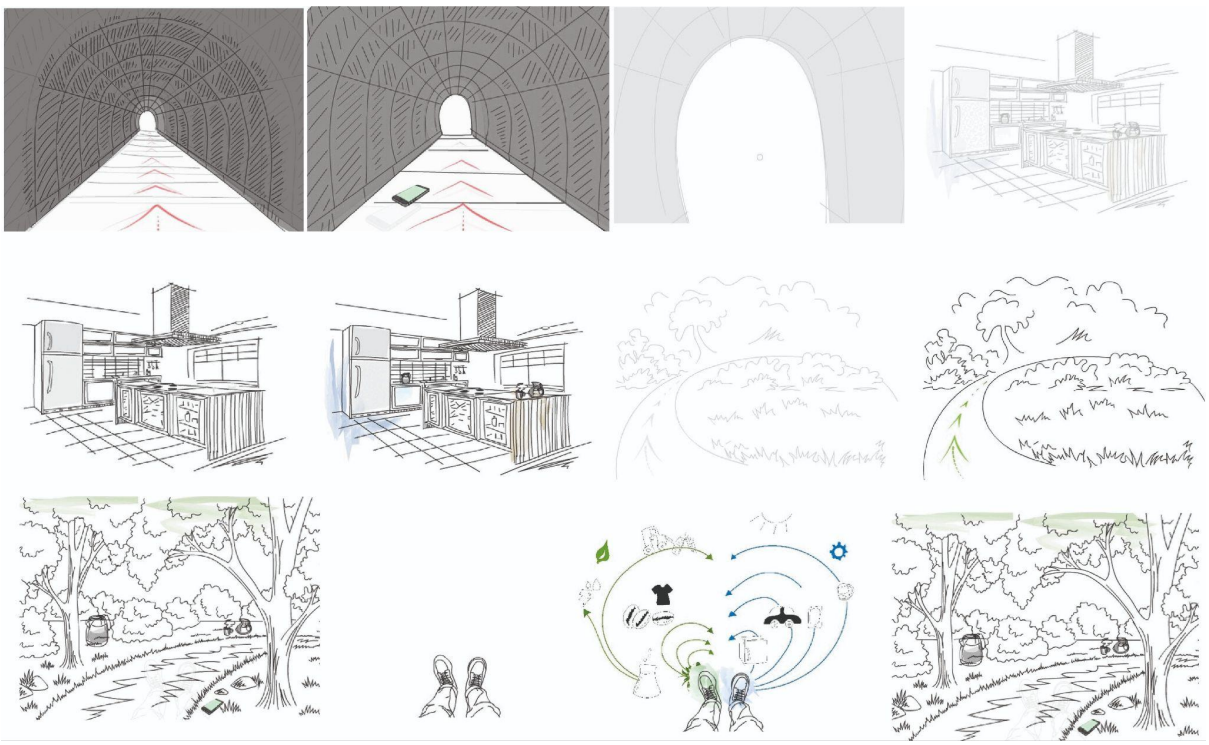


Figure 7. GIF shots of story progression.

Scene 1 will take place in the kitchen with ambient music and will provide the user with information about society today, specifically linear economy practices, and give a factual example related to the phone. This scene is to let the user feel mainly engaged and curious of what's coming next. Scene 2 will be set in the kitchen with ambient and nature sound effects and will involve the user in learning about relatable unsustainable practices they might not be aware of, such as when using a kettle, fridge, and coffee grounds. This scene is to let the user feel involved and create a better understanding. Finally, in Scene 3, the user will be transported to a natural environment, the nature, where the circular economy and the butterfly diagram will be introduced, see *figure 8*, motivating the user to adopt sustainable practices for the future. The scene will also provide the user with time to reflect on their experience and is designed to elicit emotional and motivational responses. See *table 1* for final concept summarization

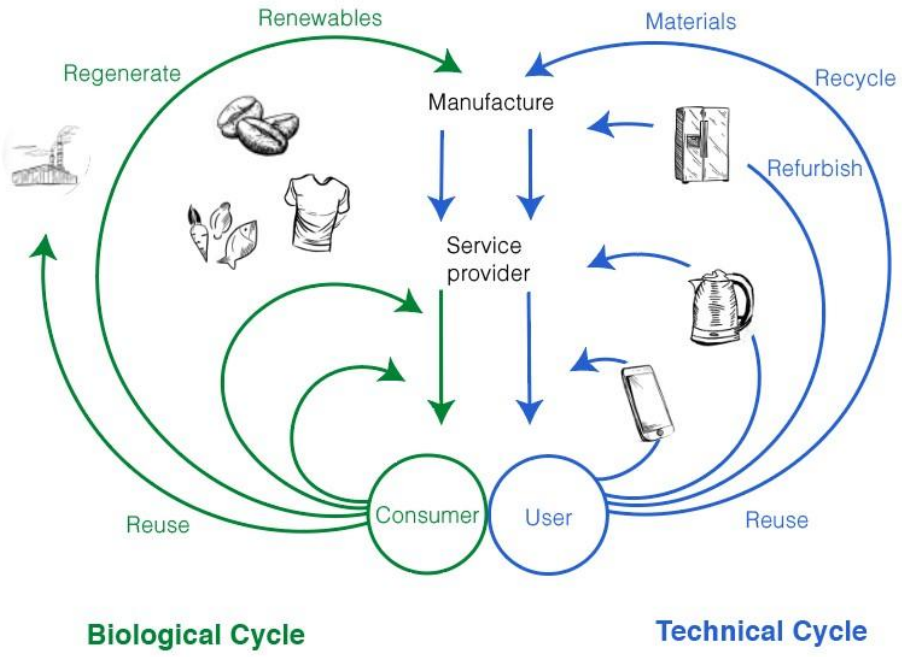


Figure 8. The butterfly diagram.

Scene	Environment	Sound effects	Story	Main	Aim	Information type
scene 1	Tunnel	ambient music + phone buzzing	Society today - Linear economy	phone	Engage - *curiosity, slight discomfor*t	Factual
scene 2	Kitchen	ambient + nature sounds	Relatable examples of unsustainable practices	kettle, fridge, coffee	Involve - *relatability, understanding*	Attitudinal
scene 3	Nature	nature sounds	Our future society - Circular economy	The butterfly diagram	Reflect - *calmness, comfort*	Emotional & Motivational

Table 1. Final concept summarization.

4.2 Iteration period two - Development, Testing and Evaluation

This is the second phase of this project which is also described as the second diamond. Here the final concept in iteration period one is implemented with the help of Unity to create an application for the VR headset Meta Quest 2 and recording of a manuscript. Due to the nature of Virtual Reality certain minor details were changed or added to the final prototype, such as adding more interaction to certain elements of the story after an early pilot testing. After creation of the prototype the tests were conducted during a week's time with a total number of 22 participants.

4.2.1 General technical aspects

The development was initiated in a 3D URP environment. URP was chosen, due to its capabilities to function with multiple platforms more efficiently when compared to HDPR, see chapter 2.2.2.1 in theoretical background. The project makes use of Unity's XR interaction toolkit for pre-built tools such as the VR rig to set up compatibility with VR devices. Furthermore a tunnel vignette was added early on in development to reduce the sense of nausea and motion sickness (Unity Technologies, n.d.-d), since this had been an apparent problem for many users during the workshop in iteration period one, see chapter 4.1.5.1 "Workshop conclusions".

The manuscript in the story is mainly played by the use of "colliders", meaning that they play the sound when the player collides with a unity collider. This usually being invisible "boxes" that define certain areas, or smaller boxes around certain objects. Minor parts of manuscripts were timed, due to technical difficulties with certain colliders.

It was a difficulty to accomplish scene transitions without noticeable waiting time between scene changes, especially between the tunnel and the kitchen scene. This presumably because the kitchen scene was heavy for the hardware. This and other occasional minor bugs were prevalent throughout the experience.

4.2.2 Asset creation

The first scene, the tunnel, is a darker, simple environment with not much to it except the tunnel itself, the floor and a mobile phone. It was therefore mainly modeled by hand in Blender and Unity by hand. The only imported asset at this stage was the texture floor tiles, which was taken from a Unity extension texture package "World Materials", as well as the mobile phone from the creator matthewgromov199. The mobile phone asset was sourced from the platform Sketchfab, see theoretical background for more info. All 3D asset creators are credited in chapter 9.

The kitchen scene was sourced from sketchfab, see chapter 2.2.5 in theoretical background, with some smaller changes such as additions of a window, fridge, coffee cup, kettle and cabbage. The kitchen itself was sourced from Sketchfab and made by the creator dylanheyes. The fridge, coffee cup, kettle and cabbage was made by Susidko Studio, Ju Designer, Gorzi and Yu respectively. The outside environment as seen from the window was part of an extended Unity asset from Unity Technologies, "Unity Terrain - URP Demo Scene".

The last scene, nature, was entirely reliant on the aforementioned Unity Terrain demo scene. It also made use of the previous assets: fridge, kettle and coffee cup, with alterations to the texture to make them seem overgrown with nature. Addition to this scene was a “poster” that introduces the circular economy, see *figure 8.*

4.2.3 Pilot testing

A small number of pilot tests were being performed when building the prototype. The purpose of the pilot testing was to evaluate how easy it was to go from one scene to another, visuals and sounds, navigation with the controllers, level of motion sickness and general observations. At this stage the VR prototype was far from complete, as the second and third scene was still in early development and the storyteller and manuscript was yet to be added. The reason for testing in an early stage is to catch apparent problems with the aforementioned areas, as well as gather general ideas and perspectives from users seeing it from an “outside” perspective. These interviews and tests are not counted in the final result, and used solely as a means to quickly take note of opinions and potential improvements to be made in the further development. Three pilot tests and interviews were made on three separate occasions. One being with an experienced VR player, one being a beginner, and the last interviewee never having played VR before.

The first interviewee who has proficient experience using VR was the first person to test. They only tried the first and second scenes as the third was not playable at this point in time. They suggested adding elements in the tunnel to define the shape of the walls, as it was a bit disorienting. For the kitchen scene, they appreciated the freedom to explore, and would have liked having a narrator's voice to guide the experience while maintaining that sense of freedom. However, the overall kitchen area felt unfinished and they suggested adding textures and details to make it more relatable for the user and give it a polished feel. They also suggested having the objects talked about in the kitchen highlighted (by some kind of rotating or floating animation), to put more emphasis on them. They appreciated the sounds, and thought they were suitable for a wide audience, but wondered if there were enough scenes to convey a story. They appreciated the non-gamified feel of the experience and experienced no motion sickness, but added that this possibly was due to his familiarity with VR.

The second interviewer, a beginner in VR, responded positively to the experience. Unlike the previous tester, they also got to try the third scene as it was in this stage playable. They thought it was difficult to understand the connection between the two first scenes without a narrator. They thought the experience was suitable for different groups and was easy to use. The interviewee found it soothing but did feel motion sickness in the kitchen scene, suggesting that slowing down the speed could help. The last scene surprised them, and they wished to stay longer and build a life in the nature scene. The experience was immersive and story-driven, not like a game. The interviewer suggested adding object interaction in a way that would contribute to the experience or storytelling, without being too distractive.

The third interviewee, who had never used VS previously, felt a mix of calmness, nausea and being “a child on an adventure”. Notable with this interviewee was that she had an idea of the manuscript, since at this point a manuscript had been completed and she had read it before the prototype testing commenced. She believed that the experience was suitable for teenagers and older age groups and could be educational for young people and university students. The interviewee suggested that the addition of more sound effects, such as singing or background music, could enhance the experience.

The controllers were easy to use with guidance, but the interviewee wanted more interactivity with the objects to feel more engaged. She found the nature scene impressive, but also added that the first and last scenes didn't seem to connect well. However, the transition from the kitchen to the other scenes was smooth. Overall, the interviewee found the experience fun and educational.

Based on the feedback from the three testers, it is clear that the VR experience has the potential to be engaging and enjoyable for a wide range of users. However, it is also evident that certain improvements need to be made to enhance the coherence of the scenes, the addition of a clear storyline, and more interactivity with objects. There were three areas which needed to be improved for further development:

- **Nausea:** Two out of the three interviewees felt nauseous in the experience. The controllers, movement speed and rotation speed needed to be looked over. Further casual testing with employees at Visual Arena who worked in the field of VR confirmed this, and added that the turning element could possibly be the cause of this as the pivot point seemed off center.
- **Interactivity:** All interviewees thought that interaction would add engagement to the experience, though it also was a general consensus that too much interactivity could detract from the story.
- **Finishing touches:** The scenes would be looked over to feel more “finished”, adding textures to the kitchen and elements to make the tunnel less disorienting.

Incorporating these improvements will help create a more immersive experience and improve the overall user experience. This testing phase has been valuable in helping to identify the strengths and weaknesses of the first draft of the VR experience and will play a crucial role in its further development.

4.2.4 Additions and custom interactions

After the first pilot testing some changes were made to the prototype. Controllers were seen over and rotation was fixed, making the nausea experienced noticeable less. The turning and move speed was also further lowered to prevent nausea.

To make the experience more engaging, interactivity with objects were added. This was something previously thought would bring distraction from the information and therefore was not prioritized. However, seeing that all the pilot testers wished for this element it was swiftly added. Colliders that trigger the manuscript were confined to objects in such a way that the story would only proceed when the user picked up an object, this with the purpose of making the user feel as though they had more agency and “fun” while expectantly not distracting from the information given. Additionally, custom scripts were written for the kitchen scene, making it so the user could not proceed to the next scene without having first interacted with the three objects: the coffee cup, kettle and cabbage head. An addition of a particle system resembling water and a custom script was also made, to make it seem as though water dripped out of the kettle when tilted more than 90 degrees “down”. This also makes the world feel more interactive and engaging.

Lastly, the kitchen scene was touched up with new textures and “color animations” were removed as they had little purpose in an already colorful scene, as opposed to our initial vision with a completely

white kitchen. The kitchen was still kept relatively sparse and minimal in its design, to not distract from the interactable objects that would “pop up”, timed with the manuscript.

4.2.5 Manuscript

This script is designed to be engaging and easy to understand for a storyteller guiding testers through the VR experience. It draws on relatable examples taken from research in the 4.1.1 Research and Development section, and mainly uses a storyteller approach, as studies have shown this to be the most effective for learning, as described in section 2.4 on Cognitive Theories of Learning, Engagement, and Visualization. For full manuscript, see 9.3 Script in appendices. Following paragraphs are a summary of the manuscript.

The only text used in the experience is in the tutorial room, where the user is instructed on how to navigate with the controllers and interact with objects before starting. Once the user is ready, they are guided to move through the door to Scene 1, the tunnel. There is a drawing in Scene 3, Nature, that includes illustrations of the biological and technical cycles. Otherwise, the experience is entirely voice-guided.

In Scene 1, "Engage," the user begins in a dimly-lit tunnel with a red line on the floor leading to a bright light in the distance. The narrator introduces the concept of a linear economy and the environmental impact of waste from discarded electronic devices, such as mobile phones. As the user approaches the end of the tunnel, they encounter a white door that leads to the next scene.

Scene 2, "Involve," places the user in a white kitchen and tells them how to reduce waste by repurposing coffee grounds, as well as using only the amount of water required in a kettle. The narrator also introduces the concept of sustainable design and the impact of fridges on food waste by bringing an example of a lettuce in the fridges crisper drawers that aren't designed to do its purpose.

Scene 3, "Reflect," takes the user to a beautiful landscape of lush green trees, rolling hills, and a serene lake. The narrator encourages reflection on the impact of individual actions and the importance of sustainability for the future. Also, introduces the circular economy that is the opposite of the linear economy that is introduced in scene 1.

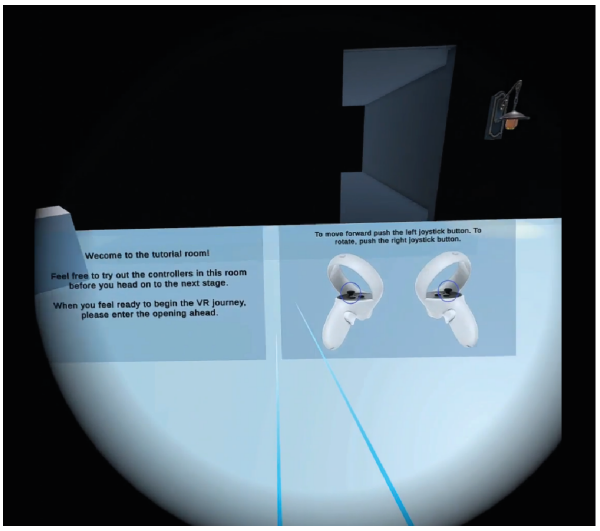
4.2.6 Final prototype

This section features images of the final prototype, including the tutorial room where testers receive instructions on using the controllers to navigate through the VR experience and interact with objects. Most importantly, showing all three main scenes in this section: the tunnel, the kitchen, and the breathtaking nature scenes. The total duration of the experience is 10 - 13 minutes for only one individual at a time. The experience starts in a tunnel where the tester follows a straight path representing the linear economy, but it ends with an open space in nature, symbolizing the transition to a circular economy. See appendix “9.3 Script” to get an overview of the full manuscript of the VR experience.

4.2.6.1 Tutorial room

The tutorial room introduces testers to the VR environment system and helps them become acquainted with its features. It gives the users an interactive space where they receive detailed instructions on

how to effectively use the controllers to navigate. With informative displays and a table featuring blocks for interactive testing, users could manipulate the blocks using the controllers before entering the VR experience that contains the three main scenes. This room provides testers with time to practice and gain confidence in their virtual interactions, ensuring a smoother experience in the following scenes. When the testers feel ready they can take themselves to the door that is in the tutorial room to start the experience. See *figures 9 - 12.*



Figur 9. An overview of the tutorial room.

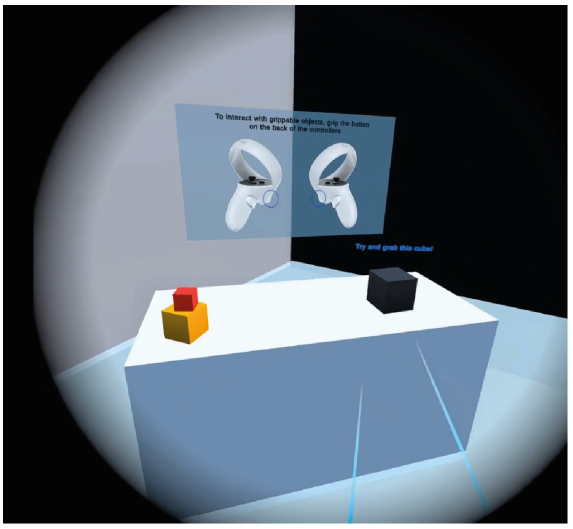


Figure 10. Interactive testing table.

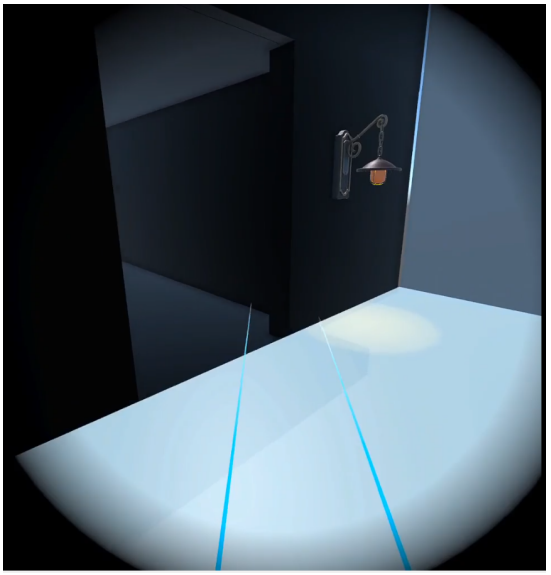


Figure 11. Door to the first scene.

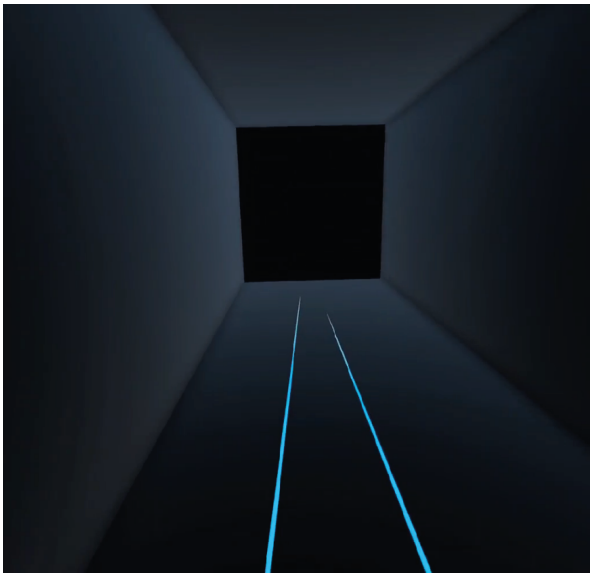


Figure 12. the tester entering the first scene of the experience.

4.2.6.2 Scene one: The tunnel

After the tutorial room, there's a tunnel scene shown in the images below, see *figures 13 - 16*. The testers enter the tunnel and hear a storyteller's voice welcoming them, introducing our linear society today. The straight, dark and long tunnel with the red line is in a symbolic sense meant to symbolize the linear economy we have today. Eventually, a buzzing phone sound catches their attention. They pick up a phone lying on the ground, and the storyteller continues, giving an example of an

unsustainable practice related to phones. The testers move through the tunnel along the red line until they reach a bright light, a door leading to the next scene.

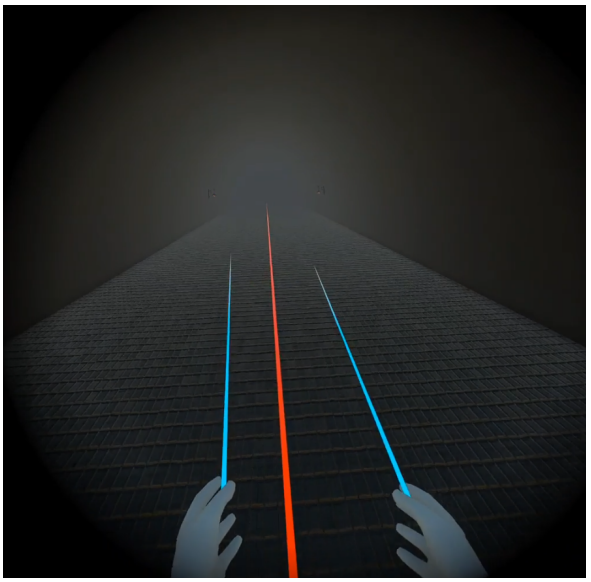


Figure 13. An overall view of the tunnel scene.

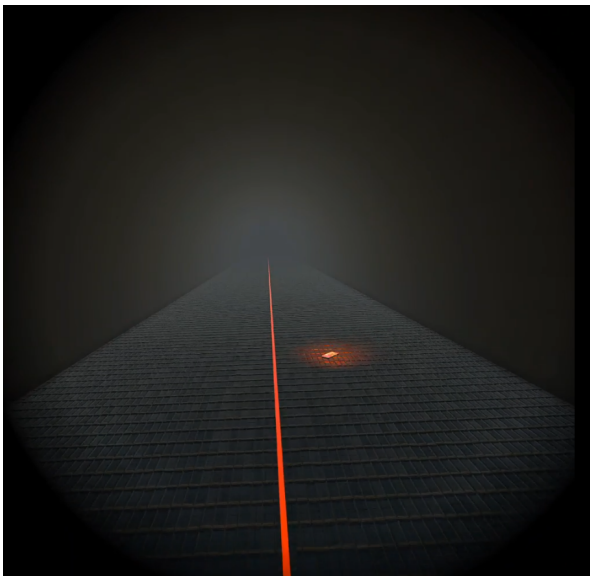


Figure 14. The tester following the red line on the ground.

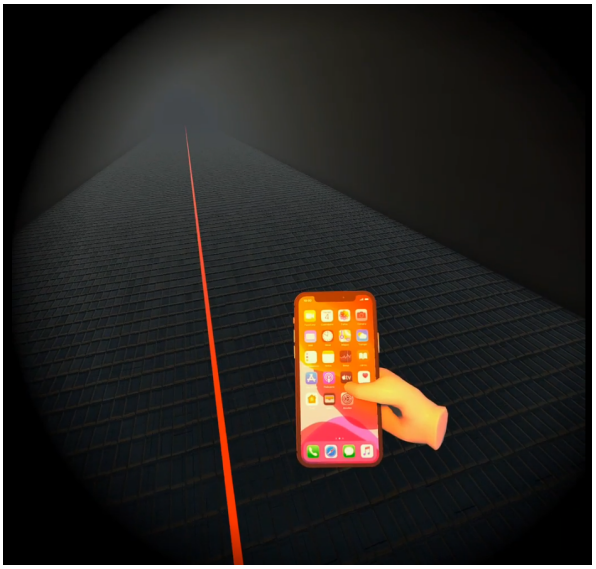


Figure 15. The tester interacting with the phone.

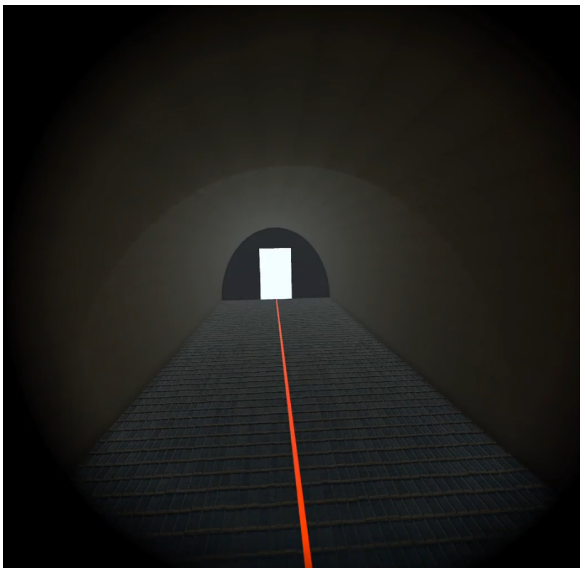


Figure 16. The door that takes the tester to the next scene.

4.2.6.3 Scene two: The kitchen

The testers enter the second scene, which is a familiar environment filled with recognizable kitchen tools. They are prompted to interact with these objects. When the testers select one of the three main objects introduced, it triggers a response from the storyteller. The storyteller presents information in the form of "what if" scenarios, highlighting unsustainable practices that people commonly encounter in their everyday lives. They then suggest how these practices could be transformed into sustainable alternatives. The testers have the freedom to explore and interact with the environment. For instance, they can use the kettle to pour water or water the plants that are growing in the room, creating a feeling of involvement, engagement and fun interaction. As the testers approach the window, which reveals a beautiful natural scene, the sound of birds becomes more audible, creating an immersive

experience. Throughout this scene, the testers can interact with three main relatable objects: coffee, kettle, and lettuce. Once they feel ready, the storyteller guides them to the stair opening, leading to the final scene. See *figures 17 - 20.*

Figure 17. An overall view of the kitchen scene.

Figure 18. The tester interacting with the objects.

Figure 19. The tester pouring water from the kettle.

Figure 20. The stairs that take the tester to the next scene.

4.2.3.4 Scene three: The nature

As the tester enters the final scene, they are encouraged to take a moment to immerse themselves in the captivating environment and get the feeling of refreshing air from the breathtaking view. Upon closer inspection, they notice that the kitchen, although familiar, has transformed and grown. The phone, introduced in the first scene, now rests on the kitchen island. The spilled coffee has sprouted into a cluster of mushrooms, symbolizing the potential of utilizing coffee grounds that are typically discarded in our daily lives. This connects back to the previous scenes where the tester interacted with these and other appliances. As the tester approaches the grown kitchen and explores its surroundings, their attention is drawn to a drawing placed on the kitchen table. Here, the storyteller introduces the

concept of the circular economy, revealing how all the examples previously encountered fit into this societal framework. The coffee grounds become part of the biological cycle, while the phone, kettle and fridge find their place within the technical cycle. The drawing beautifully illustrates the butterfly diagram that has been illustrated before in *figure 8.*The butterfly diagram in the final concept section. Allowing time for reflection, the tester can wander in the serene natural environment, the further they go the more they explore and the more they find, like the beautiful lake and mountains. When they feel ready, they have the freedom to remove the VR glasses, ending the experience. See *figures 21 - 26.*

Figure 21. An overview of the nature scene.

Figure 22. The overgrown kitchen.

Figure 23. Kitchen island and the objects.

Figure 24. The butterfly diagram.

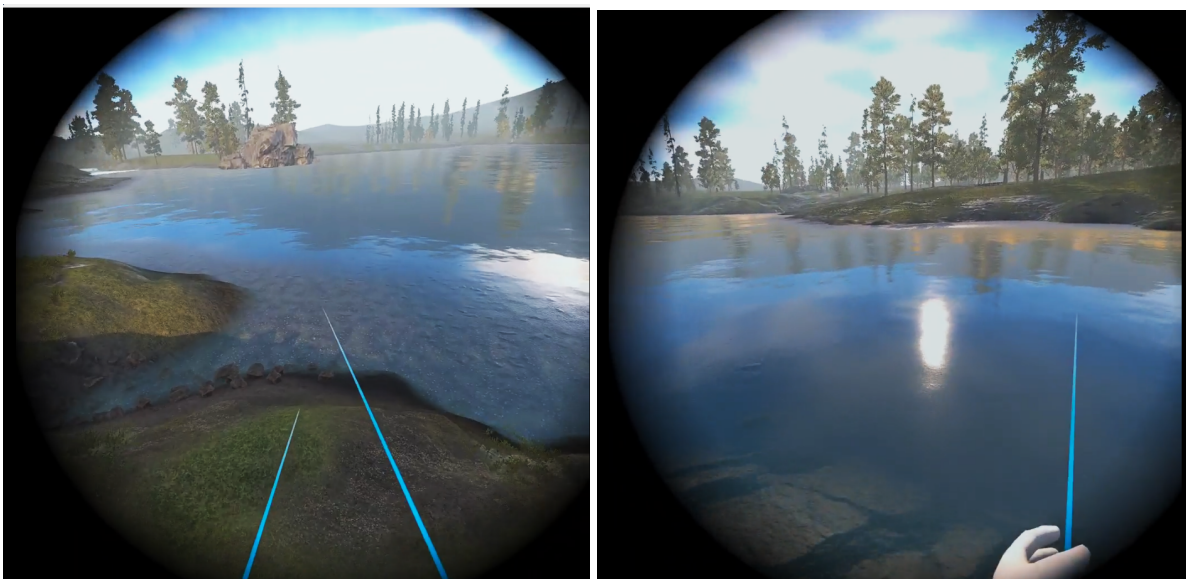


Figure 25 and 26. The tester exploring the rest of the nature scene.

4.2.7 User respondents after testing

Final testing and interviews were conducted at Visual Arena over the course of three days. During the "Immersive Experience For The Climate" event held at Visual Arena, the VR experience was showcased to individuals primarily involved in sustainability-related work in the city of Gothenburg. Only evaluation criteria were collected at this event, with no interviews being conducted. A total of 22 testers and 15 interviews were completed as part of the whole final testing process.

4.2.7.1 Interviews

The feedback and interviews from the testers of the VR experience centered on sustainability were overall positively received. The interviewees had varied backgrounds, ranging from different levels of knowledge in sustainability to varying degrees of experience with VR technology. Based on feedback from multiple interviews, the concept of using VR as a tool to engage for sustainability is believed to have big potential. Testers found it engaging and immersive with strong storytelling and clear messaging on sustainability, along with relatable examples of everyday life. The duration of the experience was considered appropriate, although it was suggested by some to add more visual elements and information scenarios for the less eventful parts of the experience. Certain occasional technical bugs with movement and audio were prevalent during testing, but in the majority of cases it was not noticeable or minor enough to not be distracting. Refer to section 9.4 in the appendices for the interview questions and below is a summary of the results from the interviews.

Only a few participants experienced minor motion sickness, though not enough to disturb the experience. All interviewees agreed that the VR experience had the potential to benefit society on multiple levels and could be appreciated by individuals of different age groups, both for those with and without previous VR experience. When asked who would be most suited for this kind of experience the most common responses were comments such as the following:

"Everyone, from politicians to researchers in this field, to children, the whole spectrum"
- *Anonymous tester*

"Everyone, both younger and older generations. I think it suits everyone"
- *Anonymous tester*

"In my opinion, I think all ages because it touches everyone"
- *Anonymous tester*

However, some believed that the experience might not be suitable for children, as they could be easily distracted by interactive objects and visuals, potentially detracting from the overall sustainability message. This was a sentiment not only said for children, but also for some of the participants themselves for whom the aspect of VR technology itself so fascinating it was difficult for them to focus on the story at times, which is echoed in the following statements from the interviewees:

"I wanted to experiment more than to pay attention to the journey. The journey itself was kind of boring compared to the new features I was figuring out"
- *Anonymous tester*

"At times I did feel a little distracted, and I had to repeat the voice in my head to kind of like know or parse out"
- *Anonymous tester*

"It's because it's a pretty calm experience and it still required some concentration, which I didn't have all the way through. And I think, it's just my opinion, that children might want a bit more interaction and more things happening and playing around"
- *Anonymous tester*

Interviewees found the VR experience to be engaging, immersive, and informative, with easy-to-understand narration. A majority of participants suggested adding more gameplay elements and interactivity when asked for what they think would make the experience better. However, as echoed in previous citations, it was also noted that the message sometimes went over their head due to being excited with the interactive elements of the story. A few participants appreciated the longer non-interactive moments, allowing them to reflect and focus:

"It was a nice feeling that it was quite slow pace and so. It was quite calming and you got into a meditative state."
- *Anonymous tester*

"A lot more relaxed [compared to other VR experiences]. Like just slow pace and, I felt like, you know, if this was fully optimized in a way and like, you know, just like more intricate, like if you were to advance it, I would go into this reality just to like, you know, let some steam off"
- *Anonymous tester*

It is a careful balance, which also was noted when the VR prototype was being tested by(T. Boonngamanong, personal communication, n.d.)Tarathorn Boonngamanong, one interviewee who is a

professional within the field of VR and storytelling who suggested adding more visuals directly correlating to the otherwise “boring” data and information being told. This is a way to both entertain and engage, as well as drawing focus to the story and information being told.

“Right now, a lot of data is being shown 2D right? And I think it is pretty new to see things in 3D data. You can feel it fully, which I think is a greater experience than just reading on a paper. [...] If you're talking about 10 000 phones, I want to see 10 000 phones. I don't want to see text, because text feels like ‘now I am in a 2D experience’, not in a VR experience anymore.”

- *T. Boonngamanong*

When asking the interviewees what they thought of the overall message of the VR experience, a common response was that “individuals can make a difference by implementing circular principles and making sustainable choices in their daily lives”. Some interviewees believed that the VR experience could be beneficial for education and raising awareness about sustainability issues in schools, specifically at high schools (gymnasium) and universities. Others suggested the experience to be shown to politicians, with some tweaks and improvements.

"I feel like this is definitely something that could be in, like in university. If they had that there, I would be on it for half an hour, it's really cool."

- *Anonymous tester*

“People like me, politicians. I think there are so many who need to see this.”

- *Anonymous tester*

Some interviewees wanted moments of togetherness or community to be added into the experience to reduce feelings of loneliness, increase interaction, and promote the idea that bigger changes can be made as a group. There was several suggestions from interviewees to incorporate a more “human-like” feeling, a person or other ways to make the narration more lively and emphatic, such as the following:

"For example, the fact that there is someone present [...], someone walking next to you or similar. That would be great, just to be able to keep up and feel more engaged with everything, everything that's in there really. Because that person motivates me to take things on and to understand things."

- *Anonymous tester*

"A narrator is always good [...] but maybe if there was that person in front of you, if that person was there, like a face or body, standing and talking. Well, then I think you get a bit more contact."

- *Anonymous tester*

"I believe more in, like, going into a room and accidentally turning on a TV, and there's a news voice telling you something. That would have caught my attention a bit more"

- *Anonymous tester*

The VR experience has the potential to be a powerful tool in promoting sustainable practices and driving behavior change. One key factor in its success is the engaging and immersive nature of the experience which is aided by the use of strong visuals and storytelling, see “Cognitive theories of learning, engagement and visualization” in theoretical background. Being fully immersed in a VR

environment removes many of the typical distractions, allowing testers to focus and feel present in the experience. This was also echoed by several participants, which can be seen in the following citations:

"These types of issues that are quite large and overwhelming and where people as individuals, I feel that VR, well, it takes my full focus when you enter a world like that. It's impossible to do anything else, but it kind of grabs my focus and it's something good when it's this type of issue."

- *Anonymous tester*

"It was designed very well because I don't 'see', I 'feel' myself in that environment"

- *Anonymous tester*

"I was like, this is it. This is my reality now. So that's like a really good aspect because it left time to, like when you get fully immersed in it, it leaves a lot of room to experience everything within that context.[...] So that was really, really nice because it put me in an environment where I could learn in a fun way"

- *Anonymous tester*

4.2.7.2 Evaluation criteria results

The evaluation criteria was being sent out to all testers as a survey via Google Forms, containing 10 questions, with an additional question asking if the participants had any further comments. The questions and their responses will be shown one by one. To see the full survey in its entirety, see appendix 9.5.

Our primary objective is to determine whether VR has been successful in serving as an engagement tool. As such, our initial question is regarding engagement. The responses to all evaluation questions could be rated on a scale of 1 to 6, with 1 indicating the most negative response and 6 indicating the most positive one. In total 22 testers evaluated the VR experience and the diagrams below summarizes the results.

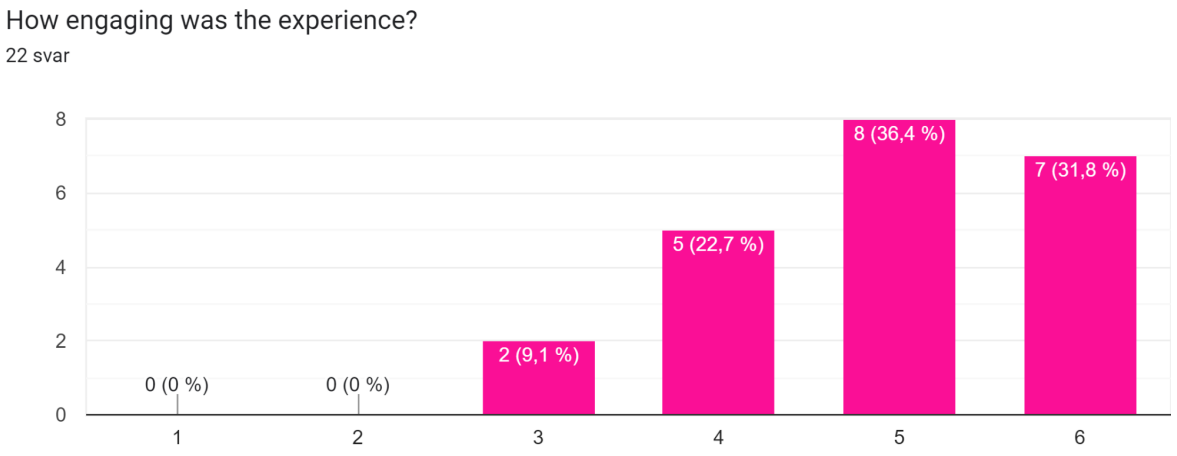


Diagram 1. The result of how engaging the experience was for the testers.

In Diagram 1, it is evident that 68,2% of respondents found the experience to be engaging, whereas 31,8% found it to be only average in terms of engagement. None of the testers experienced it to be not engaging at all.

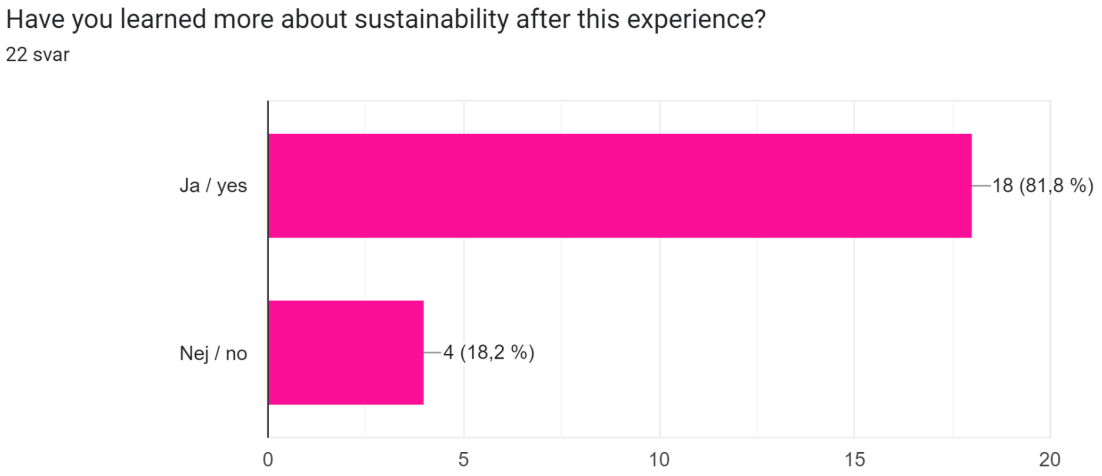


Diagram 2. The result of many had learned more about sustainability after the experience.

Diagram 2 above indicates that 81.8% of the participants who tested the VR experience learned more about sustainability, including the concepts of linear and circular economy. However, the remaining participants did not gain any new knowledge on the subject.

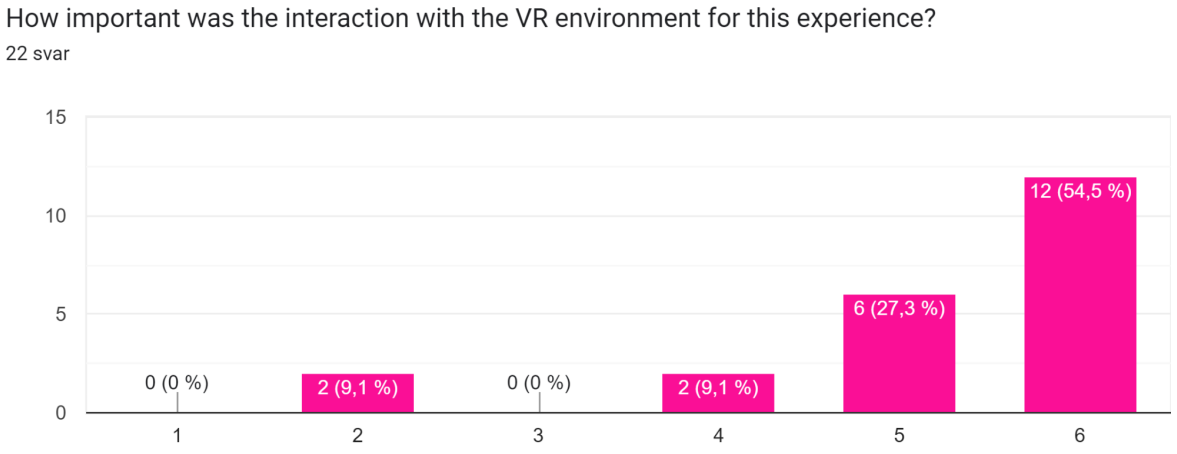


Diagram 3. The result of the importance of the VR environment's interaction for the testers during the experience.

The role of interaction in the VR experience is significant, as illustrated by the results in diagram 3. The majority of participants reported that it was highly important, with only 9.1% indicating otherwise. The remaining 9.1% and 27.3% were more neutral but still leaned towards the importance

of including the interaction in the VR experience. This sentiment was proven in the interviews, where participants expressed a desire for even more interaction to create engaging aspects in the experience.

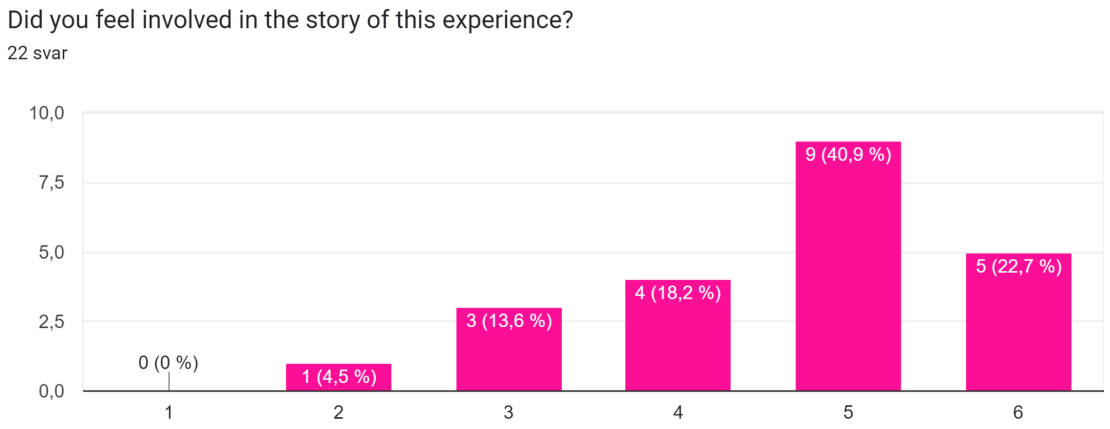


Diagram 4. The degree of feeling being involved in the experience.

A large percentage of the testers reported feeling involved in the experience. Specifically, 63.6% showed to feel involved, while 18.2% felt somewhat involved. Only one tester did not feel any involvement, and three testers felt neutral about their level of involvement. See diagram 3 above.

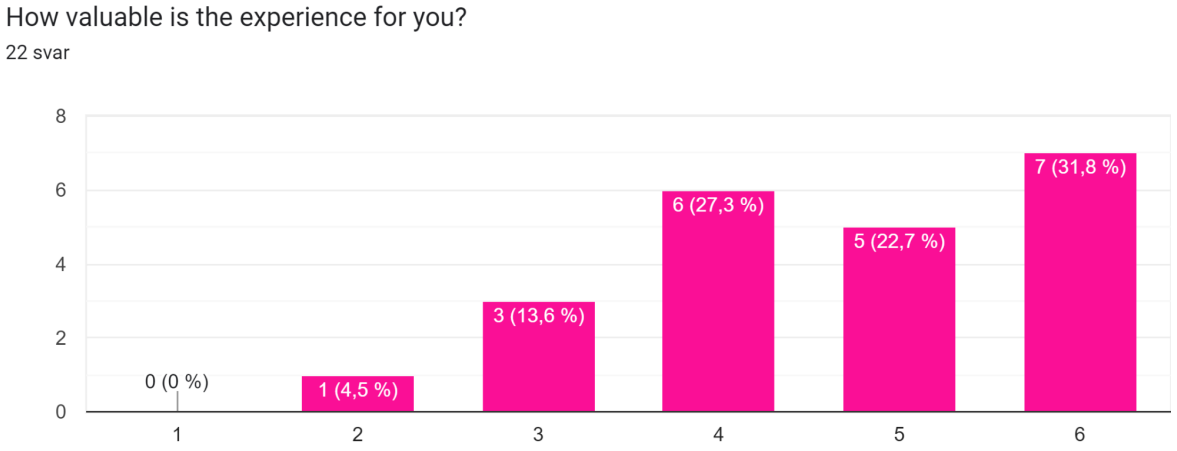


Diagram 5. The results of how important the experience was to the testers.

To assess the value of the experience for the testers, it was included as a question in the evaluation survey (as shown in diagram 4 above), using a scale from 1 (not valuable at all) to 6 (very valuable). The results indicated that everyone found the experience at least somewhat valuable, with four testers rating it as weakly valuable. Six testers rated it a 4, five rated it a 5, and the majority of testers (seven) gave it a rating of 6.

The fifth question in the evaluation criteria is: How do you think this experience was compared to your other VR experiences? Based on the answers, the majority of the participants had a positive

experience with the VR being used as an engagement tool. Many found the experience to be more interactive than other VR experiences they had tried before.

"More educational and less centered around entertainment. The experience is substantially more relaxed and slow paced opposed to my previous experiences."

"Great storytelling journey which spark a strong curiosity about sustainability"

However, some wished for even more visual and interactive elements to become more engaged. Those who had previous experience with VR commented that this experience was more meaningful and educational than previous experiences that were solely for gaming or entertainment purposes.

"More meaningful, as it concerns sustainability and calls for changed behavior patterns. Previous experiences have been games for entertainment only."

Some participants also wished the experience to be more challenging by setting challenges or questions in order to feel more engaged. To sum up the answers, the experience seemed to provide participants with more information about sustainability and triggered their curiosity on the topic.

"I think a lot was good, but it happened a little too little for my taste - just walking around in a VR environment and looking for things isn't really enough for me to get really engaged - needs to have a challenge, a goal or some competitive moment or something . There was a little too much navigation in VR (which is not that interesting in itself, I think) and a little too little challenge/stimulation in terms of content - a little too much instruction + information, instead of making the user ask themselves questions and wonder about as a driving force."

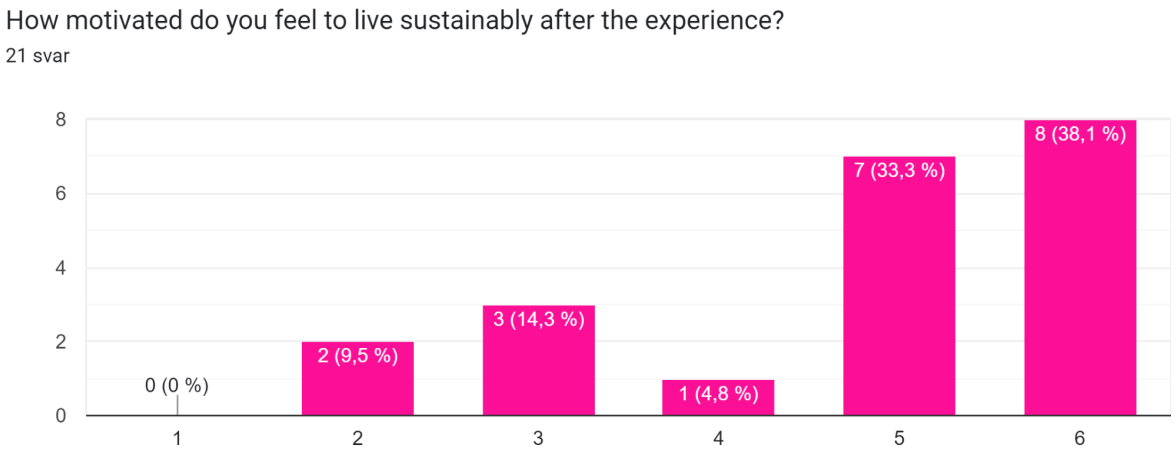


Diagram 6. The level of motivation to adopt a sustainable lifestyle, as influenced by the experience

The testers demonstrated a high level of motivation to incorporate sustainable practices into their lives after the experience. 15 of them strongly agreed with this statement, while four were somewhat in agreement. Only two testers did not feel motivated to live sustainably after the experience.

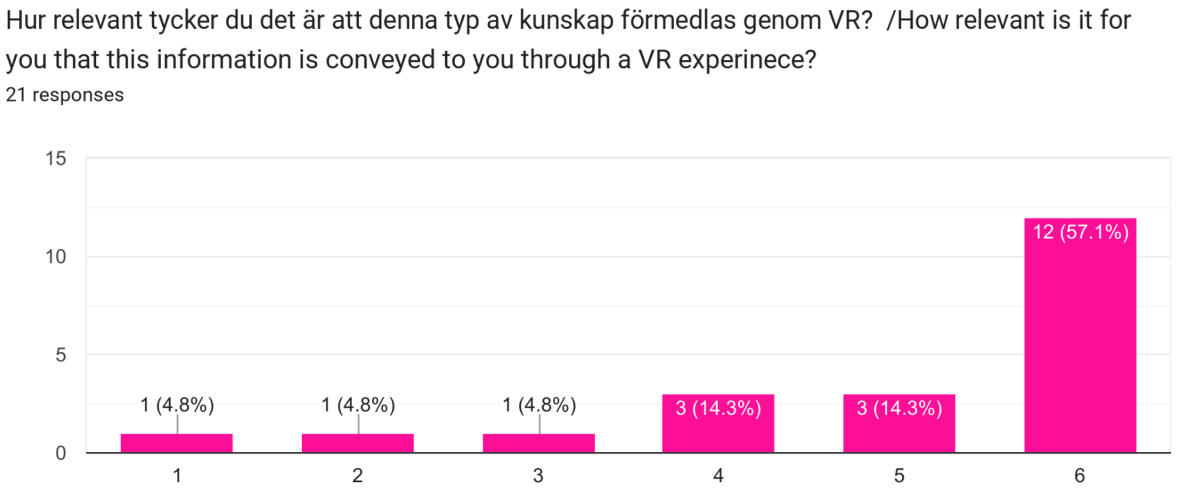


Diagram 7. The outcomes of the information conveyed through the VR experience.

According to the results presented in diagram 6, 57% of the testers found the information conveyed to them through the VR experience to be relevant. However, 14.4% did not find it relevant, and six testers felt that it was somewhat relevant.

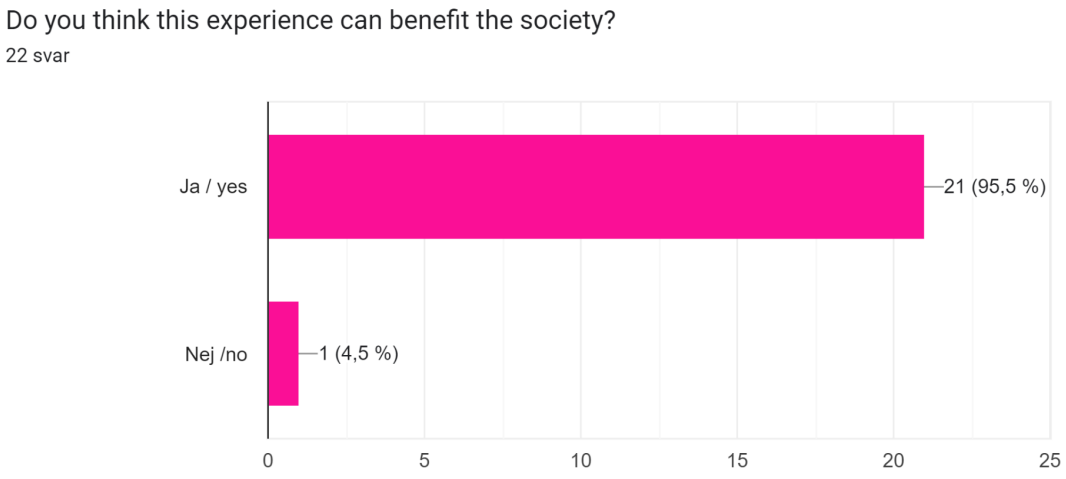


Diagram 8. the testers' opinions regarding whether the experience could be advantageous to society.

The testers responded positively to the VR experience, as shown in the results presented in diagram 7, 21 out of 22 testers believed that this experience would benefit society, with only one tester disagreeing.

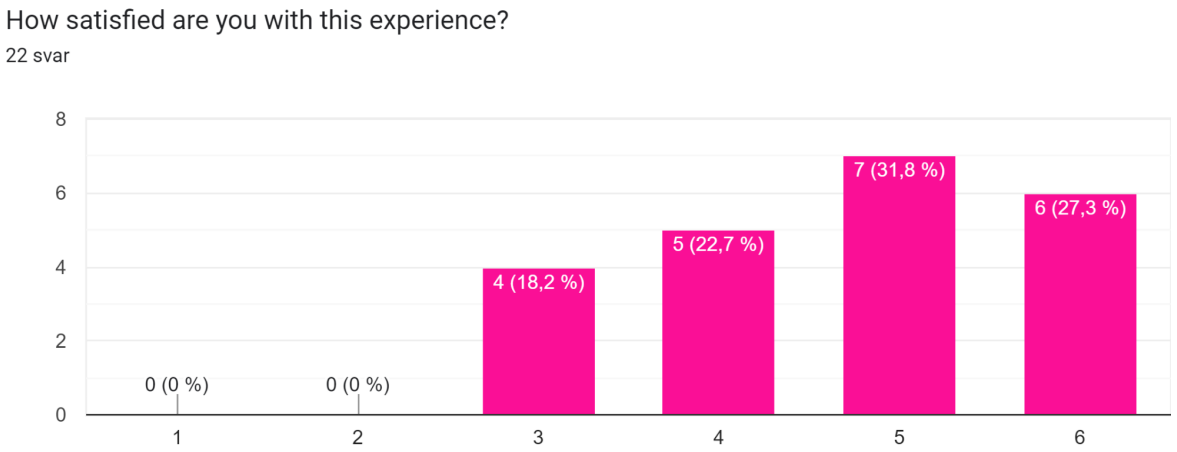


Diagram 9. Illustration of the satisfaction outcomes of the experience.

As indicated in diagram 8, the satisfaction score from the evaluation survey was generally positive. Six testers reported being very satisfied, while seven were satisfied and five were mildly satisfied. Four testers fell somewhere a bit lower than these levels of satisfaction. Importantly, no testers gave a rating of 1 or 2, indicating that everyone had at least some level of satisfaction with the experience.

The testers added comments at the end of evaluation criteria commending its well-designed environments and potential for immersive learning, and in addition to these strengths, they also noted areas for improvements. One tester found certain parts of the experience to be less engaging, with some moments feeling boring or confusing.

"The interaction was sometimes good, but at other times, particularly during extended periods of walking through a long tunnel or a white room, it became tedious. I understand the importance of avoiding overstimulation to focus on the conveyed content. However, there were instances during the experience where there were breaks or periods of silence, leaving me unsure of what to do other than simply walking through a dull corridor. If the experience were to incorporate a mixture of activities and learning opportunities that were more engaging, it would increase overall engagement. In scene 3, while looking at the drawing part, I was not aware that I could hold it up, and therefore spent the time looking down, which was a bit uncomfortable."

Moreover, other testers suggested that better synchronization of audio and movements could enhance the whole quality of the experience. Despite these critiques, the testers appreciated the creative and playful elements of the experience, which allowed for both curiosity and reflection. Many were impressed by the good rendering and quality of it which made it even more engaging to them. Many testers emphasize the importance and potential of using virtual reality for engagement and education since it gives them a sense of total presence and focus with no distractions, making it an effective tool for engaging users with topics they may avoid.

"VR creates a total presence and a full focus - perfect medium for these kinds of questions that people generally tend to avoid/postpone."

They also recognized the emotional impact of the experience and its potential to give space to reflect and think in order to encourage sustainability and circular thinking.

"I like the way the experience gives room for reflection in the meantime, while taking me to knowledge, which can be paused, and which makes me feel more engaged. I feel the potential and

power of how VR can help us develop and live more sustainably and understand more about circularity."

5 CONCLUSIONS

Based on the test results presented in this study, the main research question posed in Chapter 1.3, "Can VR help include and engage people in a way that supports their sustainability goals?" can with certain confidence be answered in the affirmative.

The extended research questions, see chapter 1.3, used to address the aforementioned main research question, yielded the following results, as determined by the conducted study:

- The majority of testers affirmed feeling more engaged and motivated to live more sustainably after having experienced the custom built VR prototype.
- The majority of testers reported feeling more knowledgeable about sustainability following the custom built VR prototype compared to previously.

The result can be affirmed with some certainty as the testers overall had a clear majority. However, as the test group is relatively small with a sample size of 22, the study and research would benefit from more testing in this area with a larger sample size to assert a result.

6 DISCUSSION

The discussion will explore the prototype and how it affected the results, the testing group, sustainability factors, ethical factors and possible underlying assumptions that potentially shaped the project's execution.

6.1 The prototype quality and its significance

As no prior VR application to promote sustainability in an accessible way was found, a custom built VR application was made as a tool in this project. The choice to make a custom built VR experience without prior knowledge in building VR applications and development likely led to the inclusion of substandard features in the prototype such as bugs, incomplete builds, and a limited grasp of game design principles. This likely contributes to some of the negative aspects of the result, such as feedback from testers indicating a lack of consideration for tester autonomy and occasional confusion caused by lengthy loading times between scenes and bugs. These are issues which could have been redeemed if there was more time put on optimization and game design. However, as the VR experience was developed purely as a prototype to explore the potential of using VR as a sustainability tool, this arguably does not matter significantly in this project as the outcome overall was positive. Despite the limitations, the prototype showcased the potential of VR as a tool for promoting sustainability, and could open up avenues for further exploration and refinement in future iterations.

6.2 Engagement improvements and further development

The thesis conclusion hinges on the custom built VR experience, and it is important to discuss how the choices that went into the making of the VR experience could have affected the result. The thesis is broadly asking whether VR could be used as an engagement tool, while this project made use of a single custom built VR experience to reach a conclusion. Although this project came to a positive result, the choice of investigating and building only one prototype was risky in that if the prototype was received negatively, the result would have been inconclusive. To gain a more comprehensive understanding of what strategies effectively engage individuals in sustainability efforts, it would be worthwhile to explore whether various VR experiences can yield similarly positive outcomes.

It is also worth noting that the VR experience in this project was built without previous knowledge in game design, VR and storytelling. Incorporating the feedback received from testers, some changes could have been made to the prototype if it were to be developed today. These modifications could potentially yield a better outcome, making the project more promising for further advancement:

- Fix the minor bugs and optimize the prototype to lessen loading time between scenes
- Develop and expand the experience by adding more interactive elements.
- Incorporate moments of togetherness and community and/or more humanlike features to prevent feelings of isolation and make the experience more empathic.
- Increase the presence of nature scenes for a more immersive experience.
- Enhance the visual elements to make the experience more engaging. Textures, visual cues, more objects.
- Provide more examples of sustainable and unsustainable practices to educate users.

- Shorten the tunnel scene or add more information told by the storyteller to prevent monotony and confusion.
- Use props and visualizations to better convey the data presented, including visualizing the numbers provided by the storyteller.
- Introduce a visible digital character for the narrator.
- Allow for choices and different paths, and include a contrast showing the consequences of not making sustainable choices.
- To help retain the information provided during the experience, add quizzes or tests. For example, to have a multi option question at the end of the tunnel that covers the information presented earlier.
- Create challenges or expand of interactivity in the last scene, nature.

To conclude, the project in itself worked well enough as a prototype to showcase the potential of VR as a tool for engagement for sustainability. Although the conclusion is clear, there are many areas of both the prototype itself and other aspects of VR which could be explored to expand this project, such as those listed above.

6.3 The testing and target group

All participants in the testing belonged to the target group, see chapter 1.5. However, as the target group is broad and the testing group relatively small it is difficult to pinpoint how effectively VR could be used as an engagement tool for specific sub-groups. For example, the VR prototype is in theory designed for both the 60 year old with no previous experience with VR, as well as the 24 year old with a lot of previous experience in VR. These two groups arguably have a very different perspective of VR, as the same prototype could be perceived as boring and slow for the experienced user, and overwhelming for the less experienced. This could possibly account for the conflicting feedback from testers, as some expressed gratitude for the instructions, while others felt they were overly restrictive and desired greater autonomy.

It was also noted that, although all testers were within the target group, it would have been beneficial to the project to get a greater range and sample size. All testers were between the age of 23 - 54, so it is yet to be seen whether the result is conclusive for the younger, respectively older, parts of the target group. It was also difficult to pinpoint patterns within certain subgroups, such as within a more narrow age range, with the sample size only being 22 people of varying age and degrees of experience. The project could have potentially benefited from a more narrow age group, to avoid conflicting interests and a more focused prototype. It is probable that this would have led to less contradicting statements from interviewees. However, it should be noted that although there was conflicting interest on certain aspects of the specific prototype, there was a consensus of the potential of using VR as an engagement tool for sustainability, and the prototype was in general received positively by the entire group. A few of the testers also noted the versatility of the prototype, suggesting it to be fitting for public spaces such as museums and society events.

6.4 Sustainability aspects

In today’s world, the impact of our work extends to various realms, including the environment. VR as a technology, with its immersive possibilities, holds promise not only for creating games and

experiences but also for environmental benefits. However, there is a sustainability aspect regarding the hardware that can affect the environment negatively.

The hardware components of VR, such as cables and VR headsets, utilize various materials similar to other electrical products, including plastics, metals, and electronic components. However, the manufacturing, extraction, processing, and disposal of these materials can have environmental implications. During usage, VR headsets consume electrical power, which can contribute to energy consumption and associated greenhouse gas emissions, depending on the energy sources employed. Moreover, the long-term durability and lifespan of VR headsets can impact their sustainability. Designing them to be easily upgradable or repairable can help reduce their overall environmental footprint. Although VR does consume power, which can have negative environmental effects, its overall advantages outweigh these concerns.

Virtual Reality has proven benefits and applications for encouraging sustainability. One notable advantage of VR is its capacity to eliminate the need for physical presence.Through the development of virtual-real experiences, scientists and technologists have made strides in reducing carbon footprint and minimizing environmental impact. Prototypes and simulations provide a glimpse into a future where widespread VR adoption can yield substantial long-term benefits (Sakhuja, 2022). Despite VR being a popular gaming technology, VR can indeed go hand-in-hand with sustainability. Although it may not be possible to reverse the damage already caused, the use of VR can help shape sustainable practices and contribute to a more sustainable future.

6.5 Ethical discussions

The custom VR experience that has been created may not be suitable for everyone, but it is important to recognize that the technology itself is not inherently designed to be universally suitable for everyone. There are some people with disabilities, such as those with visual impairment, who cannot use the technology. In addition, people with osteoarthritis in their hands, fingers or wrists may find using the controls to navigate painful. This raises issues of ethics and inclusiveness in the design.

It is particularly relevant to discuss some of the seven design principles within "The Principles of Universal Design" in this context (University at Buffalo, n.d.). One of these principles is equivalent use. This means that the design of products and experiences should be useful and accessible to all people, regardless of their abilities. In this case, we can conclude that the VR experience does not meet the requirement of equal use, as it cannot be used by people with certain disabilities. Another important principle is flexible use. This means that our design should be flexible and adaptable to the preferences and abilities of different users. In the case of people with osteoarthritis, it would be necessary to consider whether the VR experience is sufficiently flexible to enable use without causing pain or discomfort.

Although the prototype does not cover all ethical aspects given that VR has been used, other design principles have still been met. To create an ethically correct and inclusive design, it is crucial that the needs and limitations of different users are taken into account. The goal in this project has been to create an experience that is accessible and usable for a wider audience. The principle of simplicity and intuitiveness has also been taken into account. Simplicity and intuitiveness are important to create a positive user experience, regardless of the user's experience, level of knowledge or ability to concentrate. In this case, the VR experience has achieved this by making it as accessible as possible to

as many people as possible. The testers represented diverse sub-groups. For example, one individual was older and had no prior experience with virtual reality but possessed extensive knowledge of sustainability. In contrast, a younger participant had significant experience with VR games, felt comfortable using VR technology, but had limited understanding of sustainability. Despite their differences the results from the testing phase revealed the suitability of the VR experience for individuals with such contrasting backgrounds.

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8 3D ASSETS CREDIT

“The tunnel” by Klara Aune

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“Unity Terrain - URP Demo Scene” (https://assetstore.unity.com/packages/3d/environments/unity-terrain-urp-demo-scene-213197#publisher) by Unity Technologies is licensed under Asset Store Terms of Service and EULA as Extension Asset (https://unity.com/legal/as-terms).

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9 APPENDICES

9.1 Passion and purpose

Passion & Purpose - Individual Canvas

Step 1
"Divine Discontent"
A frustration about how some aspect of this topic could/should be done much better, a part of the problem that really troubles you personally.

Organizations and companies set sustainability targets which they have a difficulty reaching, partly due to having a difficulty communicating these targets to the employees and get the company members "on board" with the importance of sustainability.

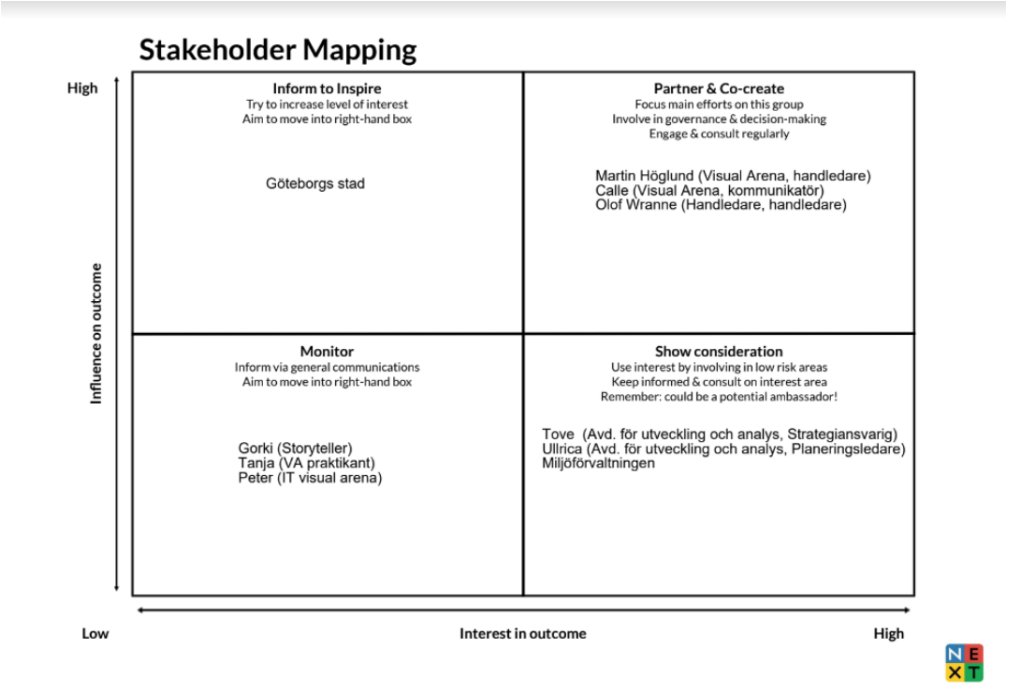
Step 2
"Golden Opportunity"
An exciting and fresh way of looking at the topic that you suspect other people don't see; an entrepreneurial possibility you sense in your gut.

The problems with communication opens up for opportunity to use new communications and visualisation tools to convey knowledge and attract attention to the subject.

An exciting way to communicate could be using VR/AR experiences, possibly making users empathize with the subject.

Step 3
Your slogan:
Sustain sustainability!

9.2 Stakeholder mapping



9.3 Script

VR & SUSTAINABILITY

USER INSTRUCTIONS (before they put the VR glasses on)

To navigate through this VR experience, you'll be using the controllers in your hands. To move forward, simply push the joystick buttons under your thumbs on both controllers. To rotate, use the joystick button under your thumb on the right controller.

Once you're ready to begin, follow the instructions that will be given during the VR journey.

SCENE 1 [ENGAGE]

TOTAL RUN TIME: 60 SECONDS

[The scene opens with the user standing in a dimly-lit tunnel, with a red line on the floor leading towards a bright light in the distance.]

> Narrator: Welcome to the VR & sustainability journey. As you can see, we have a ways to go before we reach the end of this tunnel. But, as they say, every line has an end. So why don't we follow this red line on the floor and see where it takes us?

[The narrator pauses, allowing the user to begin moving towards the light.]

> Narrator: Our society today is based on a linear economy, which means we take resources from the earth, use them to create products, and then discard those products when we're finished with them. But this approach is not sustainable in the long term. We're running out of resources, and the waste we create is damaging the environment.

[As the user approaches the light, a phone begins to vibrate.]

> Narrator: Ah, can you hear that? Take a closer look, see if you can locate where the sound is coming from…

[The phone stops vibrating]

Narrator: Can you see the phone on the ground? Did you know that mobile phones contain about 40 metals, many of which are rare? In fact, it's now cheaper to extract gold from a ton of old mobile phones than it is from a ton of gold ore. These devices contain a number of highly complex and valuable materials. However, only 17 of these metals can be recycled profitably, leaving the rest as waste.

[The user is in the middle of the tunnel, walks on its own pace]

[As the user approaches the end of the tunnel, a bright white door comes into view.]

Narrator: You've made it to the end of the tunnel. But our journey is far from over. Why not try entering that white opening to see what's beyond?

[The scene fades out.]

SCENE 2 [INVOLVE]

TOTAL RUN TIME: ? SECONDS

[The scene fades in, and suddenly the user finds themselves in a typical white kitchen, complete with items commonly found in such an environment: a fridge, a kettle, and coffee cups.]

Narrator: Take a look around the kitchen. Do you see anything that's familiar? Perhaps a cup of coffee, a kettle, or a fridge?

[The narrator pauses, letting the user take in the sights and sounds effects of the kitchen.]

Narrator: What if the coffee grounds we throw away everyday after making coffee could be used for something else?

[As the narrator speaks, the user notices the color of the coffee mugs starts changing from white to red/green]

Narrator: The coffee we drink actually accounts for less than one percent of the coffee plant and its waste. From the waste of 20 cups

of coffee, one can obtain one meter of water-repellent fabric, animal feed, floor mats, insulation material for refrigerators, and paint. Amazing right? Instead of contributing to an enormous amount of waste, coffee grounds can also be used to grow mushrooms. That's right - composting coffee grounds helps to add nitrogen to your compost pile, which in turn can be used to grow all sorts of things. And the best part? Anyone can do it.

[A brief pause to allow the user to process the information]

Narrator: Do you ever have lettuce in your fridge's crisper drawer that goes soggy before you can finish it? It's a common problem worldwide, leading to half-eaten lettuce being thrown away.

[As the narrator speaks, the user notices the color of the fridge starts changing from white to light blue]

Narrator: The crisper drawers aren't designed to keep things crisp. We need an airless environment to prevent natural degradation. And throwing away lettuce doesn't just waste its end-of-life impact, but also the resources used to grow it: land clearance, planting, fertilizers, nutrients, water, and sunlight. To tackle environmental problems, we need better designs for things like the crisper drawer. What if we could halve food waste worldwide by designing fridges differently?

[A brief pause to allow the user to process the information]

Narrator: Have you ever found yourself filling your kettle to the brim instead of just the amount you need for a cup of tea? It's a common occurrence that leads to unnecessary energy use from boiling excess water. This is especially noticeable in the land of tea drinkers, England. It's been calculated that the energy wasted from overfilling kettles in just one day is enough to light up all the streetlights in the entire country for a night.

[As the narrator speaks, the user notices the color of the kettle starts changing from white to blue]

[A brief pause follows to allow the user to process the information.]

Narrator: Let's get closer to the stairs - what lies beyond them? And when things age and decay, where do they end up? Step by step, things evolve and transform.

[The scene fades out, leaving the user feeling inspired and curious]

SCENE 3 [REFLECT]

TOTAL RUN TIME: ? SECONDS

[Fades into a beautiful landscape of lush green trees, rolling hills, and a sparkling river. The user is standing in a grown kitchen]

[The user can hear the sound of birds chirping, leaves rustling in the wind, and water flowing in the river.]

Narrator: Take a deep breath and enjoy the fresh air.

[brief paus]

Do you see the kitchen ahead? It may look familiar to you, although we can see it’s not quite the same anymore. Why don’t you take a closer look at the drawing on the kitchen table?

[Next couple paragraphs begin when the user is looking at the infographics]

As you can see, the coffee grounds from your morning brew belong to the biological cycle. When they're returned to the earth, they provide nourishment for plants and animals. But the phone, fridge, kettle, and other appliances in this kitchen are part of the technical cycle. These items have been designed and produced using finite resources, and they can't simply be thrown away when we're done using them.

That's where the circular economy comes in. This is a new way of thinking about our economy, where we keep resources in use for as long as possible, extracting the maximum value from them before recovering and regenerating them. This means designing products that can be easily repaired, reused, and recycled, and creating systems that enable this kind of circularity. The drawing illustrates the circular economy divided into the technical and biological cycles.

In your everyday life, there are small changes you can make that will help move us towards a circular economy.

As you look around this kitchen, think about the ways you can incorporate circular principles into your own life. Together, we can create a more sustainable future for ourselves and for the planet.

[sound of birds chirping, leaves rustling in the wind, and water flowing in the river.]

Narrator: As your journey comes to an end, take a moment to reflect on your experience. You are free to explore the surroundings at your leisure. Enjoy the views and interact with nature. Whenever you feel ready, take off the VR set to end the experience.

Goodbye for now and thank you for your time…

5

9.4 Interview questions

Tell us about yourself & What's your background in VR & sustainability?

Here are some additional general questions to add to the interview:

- What was your overall impression of the experience?
- How did the experience make you feel?
- Did you find the experience immersive? Why or why not?
- Were there any technical issues or glitches that affected your experience?
- Was the duration of the experience appropriate? Too short or too long?
- Do you this experience can be beneficial to Gothenburg city in any way?
- How does this experience compare to others you have had in the same genre?

Thematic questions:

- What do you think is the main message or theme of the experience?
- Did the experience evoke any specific thoughts or memories for you?
- How did the different scenes connect with each other?
- Was there a particular scene or moment that stood out to you? Why?
- Was there anything about the experience that surprised you?

Target audience questions:

- Who do you think would enjoy this experience the most?
- Is this experience suitable for all ages, or would it be better suited for a particular age group?
- Are there any specific interests that would make someone more likely to enjoy this experience?
- Is there someone who is NOT suitable for this experience?

Sound questions:

- How did you experience the sound effects?
- How did you experience the storyline in this experience?
- What was your impression of the story teller?
- Was it easy to follow along with the storyteller?
- Would you prefer information in the form of subtitles or text?

Motion sickness questions:

- Did you experience any motion sickness during the experience?
- Was the motion sickness severe enough to detract from your overall experience?
- Were there any particular scenes or moments that triggered motion sickness?

Other questions:

- In your opinion, what is one thing that could be added to enhance the experience, and why do you think it would be a valuable addition?
- One word to describe this. if someone asked u i heard you went to this experience…
- Any further comments?

9.5 Evaluation criteria

Evaluation criteria

Tack för deltagandet i våran studie! Vänligen svara på följande frågor.

Thank you for participating in our study! Please answer the following question.

* Anger obligatorisk fråga

1. Hur engagerande var upplevelsen? *
/ How engaging was the experience?

Markera endast en oval.

Inte alls engagerande /not at all engaging

1 ○
2 ○
3 ○
4 ○
5 ○
6 ○

Väldigt engagerande /very engaging

2. Känner du att du har lärt dig mer om hållbarhet efter upplevelsen?
/ Have you learned more about sustainability after this experience?

Markera alla som gäller.

☐ Ja / yes
☐ Nej / no

3. Hur viktigt var interaktionen med VR miljön för dig i denna upplevelsen?
/ How important was the interaction with the VR environment for this experience?

Markera endast en oval.

Inte alls / not at all important

1
2
3
4
5
6

Väldigt viktig / very important

4. Kände du sig involverad i denna upplevelse?
/ Did you feel involved in the story of this experience?

Markera endast en oval.

Inte alls involverad / not at all involved

1
2
3
4
5
6

Väldigt involverad/ very involved

5. Hur värdefull anser du upplevelsen är för dig? *
How valuable is the experience for you?

Markera endast en oval.

Inte alls värdefull / not at all valuable

1
2
3
4
5
6

Väldigt värdefull / very valuable

6. Hur tycker du denna upplevelse är jämfört med dina andra VR upplevelser?
/ How do you think this experience was compared to your other VR experiences?

7. Hur motiverad känner du dig att leva hållbart efter upplevelsen? / How motivated do you feel to live sustainably after the experience?

Markera endast en oval.

Inte alls motiverad / Not motivated at all

1 ◯
2 ◯
3 ◯
4 ◯
5 ◯
6 ◯

Väldigt motiverad / Very motivated

8. Hur relevant tycker du det är att denna typ av kunskap förmedlas genom VR? / How relevant is it for you that this information is conveyed to you through a VR experinece?

Markera endast en oval.

	Inte alls relevant / not at all relevant					Väldigt relevant / very relevant
	1	2	3	4	5	6

9. Tror du att denna upplevelse kan ha göra nytta i samhället? * / Do you think this experience can benefit the society?

Markera alla som gäller.

- [ ] Ja / yes
- [ ] Nej /no

10. Hur nöjd är du med upplevelsen?
/ How satisfied are you with this experience?

Markera endast en oval.

Inte alls nöjd / Not at all satisfied

1
2
3
4
5
6

Väldigt nöjd / Very satisfied

11. Övriga kommentarer?
/ Further comments?