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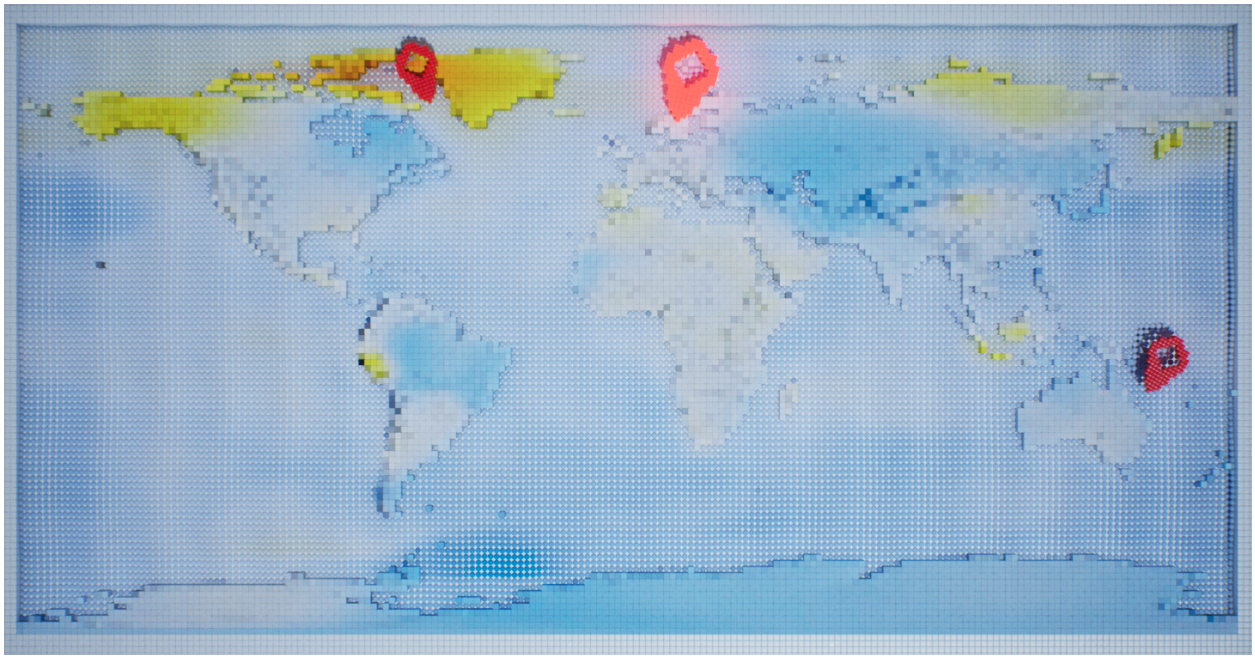

Bridging Storytelling and Visualization of Data in 3D

Exploring key Factors for Engaging and Emotionally Connecting Users with Complex Data Through Immersive Storytelling

Master's thesis in Computer science and engineering

Simon Truvé

Department of Computer Science and Engineering
CHALMERS UNIVERSITY OF TECHNOLOGY
UNIVERSITY OF GOTHENBURG
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Supervisor: Josef Wideström, Department of Computer Science and Engineering
Advisor: Kajsa Blomberg, Brickland
Examiner: Michael Heron, Department of Computer Science and Engineering

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Department of Computer Science and Engineering
Chalmers University of Technology and University of Gothenburg
SE-412 96 Gothenburg
Telephone +46 31 772 1000

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Abstract

This project aimed to explore key factors to integrate narrative storytelling and data visualization in 3D-environments to promote user engagement and improve emotional connection and understanding of complex data. The project has used the approach of research through design and included methods ranging from thematic analysis, storyboarding, immersive design prototyping, and experimental evaluation. The exploration was done by building a design space from previous research, exploring different solutions, and finally designing a high-fidelity interactive prototype. The final design was evaluated with users to observe and explore whether the prototype and the constructed design space include key factors that create engaging data stories. The findings from the evaluation have contributed to the discipline of data storytelling by showing that the design space is a suitable framework for creating engaging data storytelling in 3D-environments. Future research is needed to explore how different interaction tools and media technology can be leveraged to further increase engagement in data experiences and how to systematically extract interesting stories within data.

Keywords: Data storytelling, Data visualization, 3D-environments, Narrative visualization, Interaction design.

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Simon Truvé, Gothenburg, 2025-06-04

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Introduction

In the digital era we live in, data is found everywhere and is also invaluable to us. From scientific research to business management, data support much of how we shape and understand the world [1]. However, data in its raw form is often perceived as a collection of abstract numbers and figures that, while rich in information, are difficult for most people to interpret and relate to. This disconnect introduces the challenge of transforming data into something accessible, engaging, and meaningful.

To address this challenge, data visualization has become a powerful solution to this problem. Data visualization has in the 21st century emerged as a significant research field, with a big impact across many different disciplines and plenty of different activities. Data visualization enables the graphical and synthetic representation of data, promoting interpretation and drawing of conclusions. By converting complex datasets into visual formats such as charts, graphs, and infographics, visualization makes it easier to see patterns and trends. This is because visual representations of data are more comprehensible than data in the form of text due to the human brain processing graphical images easier than tables of text [1].

Yet, as the amount and complexity of data continue to grow, traditional data visualization methods may not suffice to fully engage an audience. This has led to the development of a concept called data storytelling. According to [2], news organizations such as the New York Times, Washington Post and The Guardian often include data graphics into their work to enhance their stories. [2] explain that data stories differ greatly from traditional storytelling, as stories in books and movies most often present a set of events in a controlled progression. Data stories can be presented in a linear format, but can also be interactive, leading to an emerging type of data storytelling that attempts to combine narratives with interactive visuals [2]. [2] also mentions that stories present information in a psychologically efficient format, which is also the goal when it comes to visualization design. This would make the combination of both disciplines interesting. According to [3], the main purpose of using visualizations is to provide insight on a specific topic, to make sense of it, and to help the audience form an opinion on it. [3] also mention a project called The Fallen of World War II by Neil Halloran [4]. This project presents the death of soldiers and civilians during the Second World War in an interactive and cinematic way that succeeds in telling a story about the terrible consequences of war through

data visualization and storytelling. The project is a good example of the potential of narrative visualization in the sense that it presents data in a way that is easy to comprehend but also incorporates storytelling elements that evoke strong emotions in the viewer, and thus increasing the engagement of the content by the audience.

One of the most exciting developments in this field is the use of 3D-visualization, a medium that leverages interactive and immersive technologies to bring data to life. [5] mention that storytelling in 3D-environments creates a strong immersion for an audience as they can interact with objects and characters in the environment. [5] claims that unlike traditional 2D representations, 3D-visualizations work as visual attractors and have the power to capture attention with stunning, dynamic graphics that allow users to explore and interact with data in entirely new ways. Using 3D-visualizations and interactive 3D-environments offers opportunities to create deeper connections with data by making it not just informative but also visually and experientially compelling.

Considering these developments, this project aims to contribute to the field of interaction design by exploring the possibilities of enhancing human-data interaction with 3D-visualization, interactivity and immersive storytelling. Ultimately trying to find new and engaging ways of presenting data to people.

1.1 Research question

The purpose of this project is to explore the use of data storytelling within the medium of interactive 3D-environments. To shape this exploration, the project is driven by the following research question:

What are key factors for integrating narrative storytelling and data visualization in 3D-environments to promote user engagement and enhance emotional connection and understanding of complex data?

The project focuses on understanding how narrative storytelling can be integrated into data visualization within 3D-environments, allowing users to engage with data on a deeper and more personal level. By treating these environments not merely as tools for visualization but also as platforms for storytelling, the project investigates how immersive design can transform complex datasets into meaningful, relatable experiences.

The project also aims to establish a foundation for a generalizable framework for translating data into interactive 3D-environments that can be adapted across a variety of disciplines and industries. Whether applied in education, healthcare, environmental science, or entertainment, these environments have the potential to bridge the gap between raw data and human perception. By creating opportunities for users to not only interpret data but also emotionally connect with it , this project aspires to demonstrate the value of narrative-driven 3D-visualization in bringing perspective, meaning, and human connection to otherwise complex information.

1.2 Approach

This project entails both a theoretical challenge and a design challenge. The theoretical challenge consists of answering the research question by exploring theory around the subject of narrative visualizations. The aim of the design challenge is to explore the potential of interactive 3D-environments as both a technique and a medium for data visualization. By utilizing immersive 3D technology, the project seeks to explore the possibilities of data visualization by creating immersive, interactive experiences. These experiences are designed to provide context and evoke emotional engagement with the data. This design challenge will additionally aid the process of answering the research question by providing empirical material.

1.3 Stakeholders

This project is made in collaboration with Brickland, which is a Gothenburg-based studio specializing in CGI, motion, and VFX, helping brands and agencies turn ideas into captivating visual experiences. With a focus on consistent and authentic product visualization and brand storytelling, Brickland has collaborated with clients such as Polestar, Oriflame, and IKEA [6].

While traditionally working with animation, images, and film, Brickland is now exploring how interaction and immersion can push the boundaries of visual storytelling. As brands seek clearer and more impactful ways to engage their audiences, they see an opportunity for a technological shift, moving beyond traditional websites, social media, and corporate presentations. By investigating interactive 3D-experiences, they aim to enhance understanding and help customers make more informed and responsible decisions when selecting products and services.

2

Background

This section aims to present examples of previous work within data storytelling and interactive data visualizations using 3D-environments as a medium. These examples will range from academic research to state-of-the-art examples with the purpose of shedding light on the research area and giving more context to the design challenge.

2.1 Previous research

Data visualization and data storytelling have been the subject of extensive research. Several studies have explored various aspects of data storytelling, ranging from how to approach design with data storytelling in mind to examining how the concept can be applied across different mediums and fields.

[2] have focused on investigating the design of narrative visualizations and identifying techniques to tell stories with data visualization. Through empirical analysis of online journalism, blogs, instructional videos, and visualization research, they formulate a design space for narrative visualization. [2] identify important dimensions of visual storytelling, explaining how graphical techniques and interactivity can promote different levels of structure and narrative flow. Based on their analysis, [2] present seven different genres of narrative visualization: Magazine style, Annotated chart, Partitioned poster, Flow chart, Comic strip, Slide show, and video. These genres can be combined with interactivity and additional information to create different balances of author-driven and reader-driven narrative experiences [2].

In the work of [5], they explain that the idea of any visualization system is to help and improve the understanding of the information that is being visualized. They also mention that this is done by promoting an engaging learning process. **thony** tells us that using interactive storytelling as a method to increase user engagement is widely implemented in other media such as games or theme parks, and their research has focused on exploring the possibilities of incorporating interactive storytelling in geographic visualization systems. From their research, [5] can derive four key requirements that support visual storytelling:

- Users are attracted by the visual representation to explore the data.

- Users are affected by the story and can identify with the topic and the scenery.
- Users can interact with the visualized data to gain more insight.
- Users return on a single or regular basis to refresh their learning process.

To meet these requirements, [5] highlights and breaks down many key factors in designing an interesting and engaging experience. One of these are storylines. If you view storylines in the context of data, they can follow a theme or a person that can vary between locations, over time, or between space and time [5]. [5] also mentions that these stories can follow highlights of the data such as extreme values, clusters, or other striking attributes. But they also highlight the importance of focusing on what makes a great storyline and how it can be presented.

[5] explains that a compelling story follows a tension curve, progressing through phases like exposition, incident, critical action, crisis, climax, resolution, and relaxation. Key elements include an engaging starting incident to draw attention, and an evolving plot that defies user expectations to increase emotional engagement. Emotional responses such as suspense, surprise, and curiosity enhance the experience. Suspense occurs when effects are delayed, surprise arises from unexpected outcomes, and curiosity is sparked when effects lack an apparent cause, often at the start of the story [5].

[5] tells us that the most well-known interactive stories are made by the video game industry. They explain that many games reject the traditional structures of storylines because the decisions of the players might lead to other outcomes. [5] also explains that something important for interactive storylines is that viewers should experience serendipity, which means that users detect something new and interesting by chance when they interact with and explore the experience. Serendipity supports the technique of surprise as an emotional response [5].

There are also more reasons to work on storytelling with 3D-visualizations according to [5]. Representations made in 3D can be much more visually pleasing and work as visual attractors for the viewers. 3D-representations can also serve as a dramatic element within a story. Interactive 3D-views enhance awareness and provide an immersive, on-site experience through visual perspective and spatial navigation. The depth and surface details not only enrich the visual impact, but also convey semantic meaning. When combined with continuous interactive navigation, this creates a deeply immersive connection between the user, the story, and its setting, illustrated in Figure 2.1 [5].

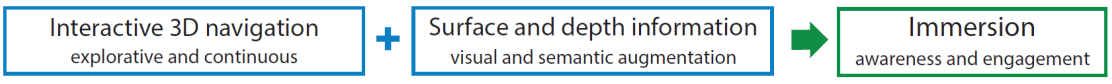


Figure 2.1: Immersion as a product of interactive navigation and 3D-information [5]

Another key factor brought up by [5] are narrative elements. These are plot, theme, setting, style, point of view, and character. The plot is the summary of the story, while the theme represents its central idea, often expressed in a single word like "love" or "crime" [5]. The setting includes time, place, and environment, which is extended to interaction tools in interactive stories. Style shapes how the story is told and influences its atmosphere, such as creating a specific mood through visuals. The point of view determines what information is revealed or hidden, often using a godlike perspective but allowing flexibility through data and character-driven views. Characters in visualizations can be used to offer the potential to guide, personalize and enhance storytelling, much like in movies and games [5].

The key factors referred to here, and in addition others outlined in [5], are important in increasing user engagement with the four key requirements derived by [5]. User attraction is important in increasing the attention of a story or a visual scene and can be increased by interesting visual content and guides. User affection is important to further increase the engagement of the viewer in the data. Affection can be raised by creating emotional responses with the user, but also by promoting personal involvement. Good interaction helps the user move further in the experience by allowing for interesting choices, and thus motivates them to explore more of the environment. And the final requirement for user engagement, return, is evidence of an overall well-designed experience [5]. According to [5], in the case of video games, most players do not finish the game and will not experience the final parts of a story, even if the experience is properly executed. However, the information learned at the end of an experience might be just as important as the information from the beginning. To increase user return, [5] propose that content updates, unique features, or achievement systems be included in the design.

In their paper, [7] explore the use of data stories that focus on presenting climate change in the Geneva area in Switzerland. [7] claim that storytelling stimulates the mechanisms of the human brain, facilitating the intake and understanding of information. They explain that stories have the ability to evoke emotions and that those who learn the stories will remember them and can carry them further. According to [7], data stories can be used to support decision making and persuade people to take action by presenting complex information that is easier to understand for a wider audience. They also claim that data stories consist of three important elements: data, visuals, and narrative, and that it is important to consider the balance between these. Telling a story involves several steps: understanding the context, choosing an effective visual, limiting cognitive overload, and focusing on something before telling a story [7]. According to [7], the balance between data, visual form, and narrative is intended to promote behavioral change by integrating narrative into data visualization, and that narrative should lead to a call for action.

To present the data stories, [7] used three different formats to present each data story. For one of the data stories, they designed a format aimed toward scientists, one towards the general public, and one for children. The visual form for children was visualized with a stop-motion animation using LEGO bricks to appeal to the

younger audience, see Figure 2.2. [7] claim that the only way for a data story to have a significant impact is to adapt the narrative and visual form to fit the intended target audience. They explain that tailoring the experience to the target group will make it easier for them to identify patterns that are relevant to their own personal lives and will thus increase engagement and emotional connection.

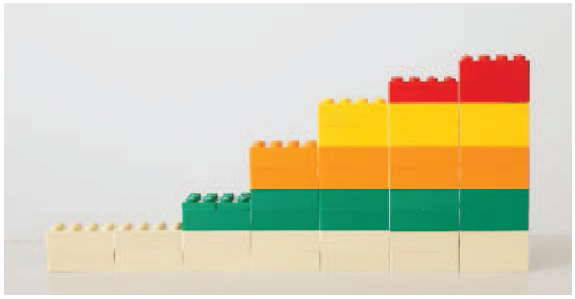
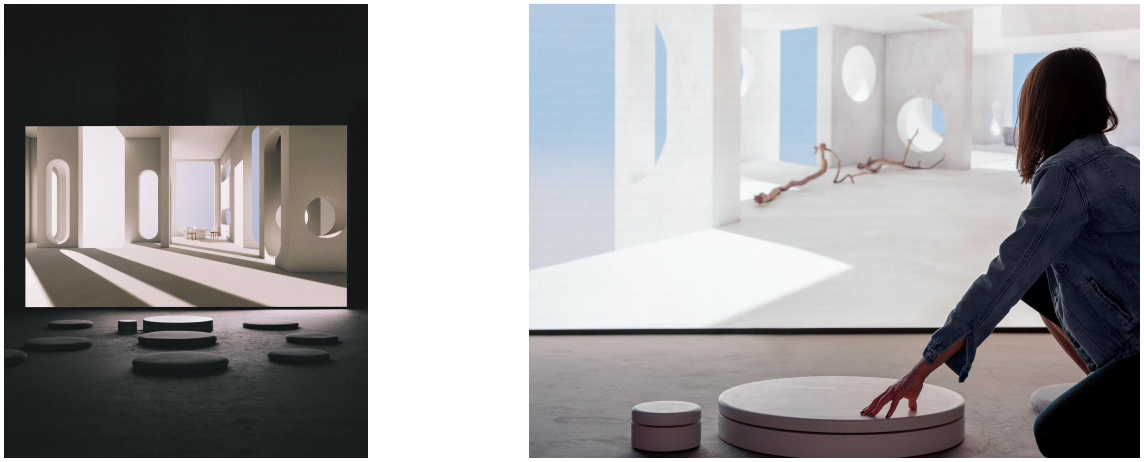


Figure 2.2: A visual representation of data designed for children [7]

2.2 State of the art

In 2023, Ezequiel Pini, who goes by the artist name "Six N. Five", designed an interactive experience installation for the exhibition "Digital Impact", on show from 28 April to 27 August 2023 in Disseny Hub, Barcelona [8]. This artistic project allows viewers to generate architectural spaces in a 3D-environment and allows them to explore these environments by changing the direction of the sunlight through the concrete structures, see Figure 2.3a.



(a) Exhibition installation

(b) The interface of the experience

Figure 2.3: Six N. Five Digital Impact installation [8]

[8] explains that the purpose of this project was to explore the intersection of disciplines such as architecture, art, photography, generative design, and programming, focusing on the shared concept of "beauty" and questioning whether it can be automated. The project is an example of an interactive 3D-environment made with Unreal Engine 5, where the experience is capable of procedurally generating unique,

and more importantly visually beautiful architectural spaces that feel realistic and livable [8]. The installation allows users to interact with these generated spaces by manually creating new designs and controlling the time of day using two custom-designed devices, as seen in Figure 2.3b [8]. This project showcases the possibilities of creating interactive 3D-environments that are also visually stunning, which could be used as a visual attractor for viewer engagement.

Universeum, which is located in Gothenburg, is the National Science Center of Sweden [9]. Universeum works with the world's most important experiences. They explore the world through science, technology, and mathematics. Their experiences aim to provide knowledge about everything from areas within IT, such as AI, to areas within biology, such as ecosystems. The purpose of these experiences is to put the knowledge in a larger context and help the visitor understand how the world works [9]. This knowledge comes from the desire to act for a sustainable future, which is one of the core values of Universeum. The mission of Universeum is to provide a resource and a platform for sustainable development [10]. Knowledge within science, technology, and mathematics and the ability to translate this knowledge into action are essential for individual development and participation in a world that is complex and driven by technology [10]. Skills such as critical thinking, problem solving, and the ability to create sustainable solutions are becoming more and more important to shape a responsible future [10].

(a) The Universeum building [11]

(b) The Vislab exhibition at Universeum [12]

Figure 2.4: The Universeum building and Vislab exhibition

Universeum has an exhibition on data visualization called Vislab, see Figure 2.4b [12]. This exhibition is about research data meeting visualization technology to facilitate a better understanding of the world and how everything is connected, and that a better understanding of the world will help contribute to a sustainable future. The Vislab exhibition has many different stations that use different visualization techniques, where you can explore different types of research data from areas such as space, climate, urban development, and more [12].

Some installation examples can be seen in Figure 2.5, with different structures of combining author-driven and reader-driven experiences [2].

Figures 2.5a and 2.5b show an installation where you can explore a dataset of the

different species of the African Savannah. The installation has three main tabs: one in which you can filter the species based on groups or relations, one where you can see the food chain of a selected amount of species, and one where you can see how climate change affects the different species in the food chain.

Figure 2.5c shows an experience similar to that of the African Savannah. However, this one is about the species of the Weddell Sea. This installation also uses 3D-techniques instead of 2D to visualize the relationships between species. The experience also uses 3D-animated transition between the different visual scenes.

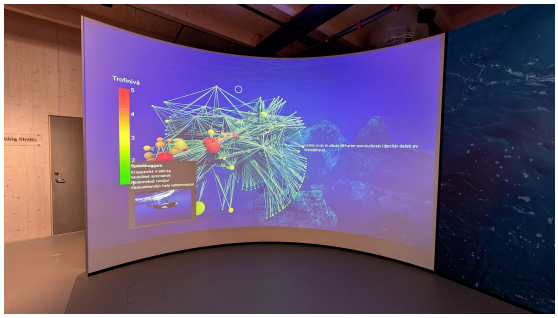
Figure 2.5d shows an interactive map of a part of the west coast of Sweden. The map allows you to navigate to different locations on the map, when a location is picked, the viewer is presented with the different species of Sea life that can be found in that specific location and some information about them. The map is 3D-modeled based on the topology to communicate both what is land, but also changes in depth of the sea.

Figure 2.5e shows an interesting example of an interaction technique. The interaction of the world globe is done on a touch screen, but in addition to the touch screen, the same visual elements are shown on a "Sphere" screen, simulating a physical world globe.

Figure 2.5f allows the viewers to explore a map of Sweden based on population. The installation allows the user to filter between different municipalities and see statistics such as average age, income, educational level, etc.

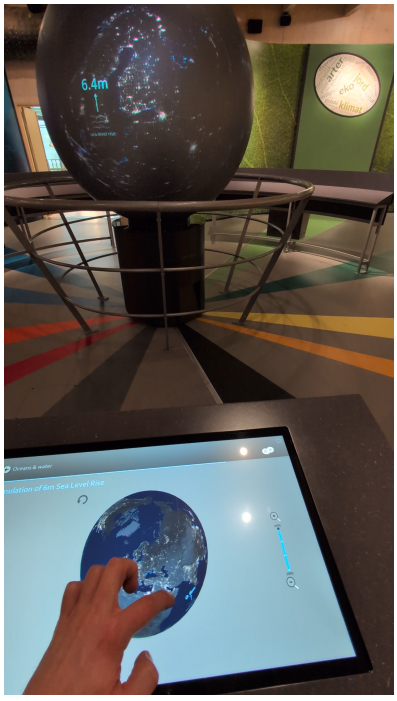
(a) Savannah - Different species

(b) Savannah - Impact of climate change

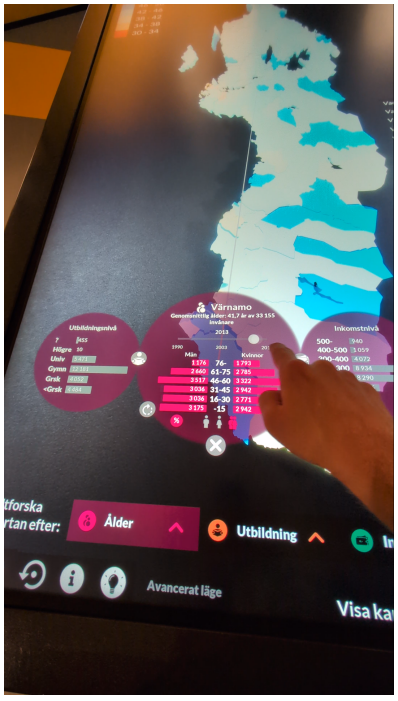


(c) The Weddell Sea

(d) Sea life on the West coast of Sweden



(e) A digital World Globe



(f) A population map of Sweden

Figure 2.5: Different Data visualization installations at Vislab

3

Theory

In this section, different kinds of theory are presented. The section is initiated with theory around design research, to give context to the very nature of this design project. This section also presents theories on data visualization, data storytelling, and narrative structure.

3.1 Research through design

In his work on what we can expect from research through design, [13] explains that designers have become more integrated into the research community of human-computer interaction. He claims that their resulting designs have been embodying the designers' judgments about good ways to address problems and possibilities within the area that the design is made for. These designs often take the shape of artifacts and systems, but also increasingly include methods, frameworks, and theories [13]. [13] claims that this agenda calls for the development of standards and theoretical foundation within design research.

To highlight the nature of design research, [13] mentions two scientific theories within the philosophy of science. One of them is [14]'s principle of falsifiability. [14] claims that scientific theories are primarily made of induction and are therefore more powerful than the phenomena that they agree with. He claims that it is easy to collect confirmations for every theory, but even if we have an endless amount of confirmations, it cannot prove a theory. [14] claims that the probability that a theory being correct is zero regardless of how many instances of positive data we can gather. Instead, he suggests that a single negative result of an experiment disproves a theory. According to [14], falsifiability is when you can paint up a scenario that would disprove a theory, and thus scientific theories are only scientific if they are falsifiable.

[13] explains that even if [14]'s idea of scientific theories need to be falsifiable has been influential, it has also been met with criticism. Another theory presented by [13] within the philosophy of science is that of [15]. His idea of scientific theories is very different from the one made by [14]: Instead of focusing scientific research on trying to disprove theories, he proposes scientific research as a way of generating new knowledge, new understandings, and new discoveries.

[13] argues that if the theory of [14] is accepted, then research through design is clearly not scientific. Within design research, theories are mostly too vague, and practice usually intends to verify them and not falsify them. [13] suggest that rather than seeing difficulties in verifying design theory, we should understand that design has two important characteristics.

[13] explains that design often addresses Wicked problems [16], which are complex problems that have no solution before any design research has been conducted. He also claims that design is an activity that involves many different decisions that exist within the special and specific circumstances of production and use. Design also changes the context of its own activities, and therefore theory under-specifies design theory. The result of this under-specification is that the theory that is created from design research is not falsifiable, whether they build on theory from others, of the world or other specific design examples [13]. [13] explains that design is generative because rather than making statements about what is, design instead makes statements of what might be and also statements about what is the "right thing". He further claims that designers do not focus on showing that design theory can create bad designs, rather the goal is to create theories that are sometimes right. Therefore [13] suggests that theory created from design research tends to under-specify practice and to be generative, and thus design research is provisional, contingent, and aspirational.

3.2 Wicked problems

[16] revisit the theory of Wicked problems, which was first established by [17] in their paper 'Dilemmas in a general theory of planning'. [16] explain that the first proposal of Wicked problems was presented in a seminar by Rittel in 1967 where he explained that there is a class of social system problems which are poorly formulated, where the information is confusing, where there are many stakeholders and decision-makers that have conflicting agendas, and where the consequences in the whole system are thoroughly confusing. This would then lead to the work of [17] being published in the journal Policy Sciences and the concept of these Wicked problems reaching a general audience in 1973 [16]. Wicked problems can be defined by ten propositions according to [16]:

1. There is no definitive formulation of a wicked problem.

2. Wicked problems have no stopping rule.

3. Solutions to wicked problems are not true-or-false, but good-or-bad.

4. There is no immediate and no ultimate test of a solution to a wicked problem.

5. Every solution to a wicked problem is a one-shot operation; because there is no opportunity to learn by trial and error, every attempt counts significantly.

6. Wicked problems do not have an enumerable (or exhaustively desirable) set of potential solutions, nor is there a well-described set of permissible operations that may be incorporated into the plan.

7. Every wicked problem is essentially unique.

8. Every wicked problem can be considered to be a symptom of another problem.

9. The existence of a discrepancy that represents a wicked problem can be explained in numerous ways. The choice of explanation determines the nature of the problems resolution.

10. The planner has no right to be wrong.

In this project, the research question is framed with the theory of wicked problems in mind. The knowledge gathered from taking on the design challenge and creating an artifact will give us insight into how to, or not how to, solve the wicked problem.

3.3 Abstraction in design

Abstraction is a topic that is highly relevant in many areas of design and can be defined in many different ways, depending on the discipline. However, abstraction often refers to simplifying complex systems to make them more understandable. One way of abstracting visual design is to reduce the clutter in the images. This is often used in photography to reduce the amount of unwanted details, making it easier for photographers to focus on the important subject of the image to create cleaner photos [18]. Abstraction is also often implemented in graphical design and artistic imagery, where you implement strategic simplification, exaggeration, and elimination of details to clarify the visual structure of an image. Abstraction is both a visual style and also a strategy for communicating information in an effective and understandable way. Abstraction allows the designer to highlight specific information and direct the audience to the most important aspects of an image [18]. Within data visualization, abstraction can be used to help select and group information to improve situational awareness and task performance. This also reduces cognitive workload and enhances the user's ability to interpret data [19].

In this project, design abstraction will be taken into consideration when designing visualizations to tailor the design workload to the time limit, but to also effectively communicate the desired message and information.

3.4 Data visualization

Data visualization has emerged as a very important field of research in the 21st century, where it has a great impact within many different disciplines and everyday activities [1]. The interest in data visualization dates back to the 1950's and

went from being scientific visualization to information visualization and then data visualization [20].

Based on psychology, the main motivation for the benefits of data visualization is that visual perception is better for taking in information than, for instance, audial perception. The basic purpose of data visualization is to make the information within data understandable to an audience in the most efficient way possible [20].

Sensation is the brain's response to specific properties of external stimuli. Human sensory activities rely on organs that convert physical energy into nerve signals, producing psychological experiences. Sensibility, which depends on stimulus strength and organ sensitivity, determines these experiences. Different organs have varying sensory thresholds; a lower threshold requires less physical energy to trigger sensation, leading to higher sensibility. With vision having the lowest threshold, it causes sensation more easily [20]. The eyes have the ability to feel light, but can also distinguish details and colors. Light waves have intensity, wavelength, and purity of three attributes that are brightness, hue, and saturation. Vision also has the ability to distinguish between space, time, and motion. Due to all these different attributes, vision has an excellent ability to obtain information [20]. Perception is the brains interpretation of sensory input, integrating information to understand the world. Visual perception plays a key role, supporting constancy, which consists of size, shape, and orientation, and spatial awareness. It also underlies perception of time and motion, which is crucial for self-awareness. Consciousness, shaped by brain function and perception, is highly dependent on vision. Language, both a medium and a creator of consciousness, depends on vision, making visual perception fundamental to human awareness [20].

According to [20], the world consists of matter and consciousness, with space and time as essential forms of existence. Since consciousness reflects matter, it inherently carries spatial and temporal features. Data, being abstract, are missing these features but always describe something tangible. Every data point has an owner, making data visualization more about context than the data itself. Visualizing data often relies on its spatial or temporal aspects, which is often considered a breakthrough in data visualization [20].

The expression of data visualization depends not only on the data type but also on the level of computer technology. Different data have different visual characteristics, meaning that the visual expression of a dataset should be considered. There are different ways of expressing data, with 2D, 3D and 4D. However, also utilizing camera roaming and animations can create a more vivid experience [20].

In the information society of today, which is characterized by explosive data generation, data visualization has become a vital tool. It helps people and organizations across many different fields extract valuable insights, identify hidden patterns, and communicate complex information with high clarity, making it possible to make informed decisions [1].

3.5 Data storytelling

Two design spaces are presented in the following sections, one is designed for data storytelling in a more general context, the other is designed for immersive data storytelling.

3.5.1 Design space - Data storytelling

[2] present a design space for narrative visualization. This design space consists of three divisions of features:

1. Genre
2. Visual narrative tactics
3. Narrative structure tactics

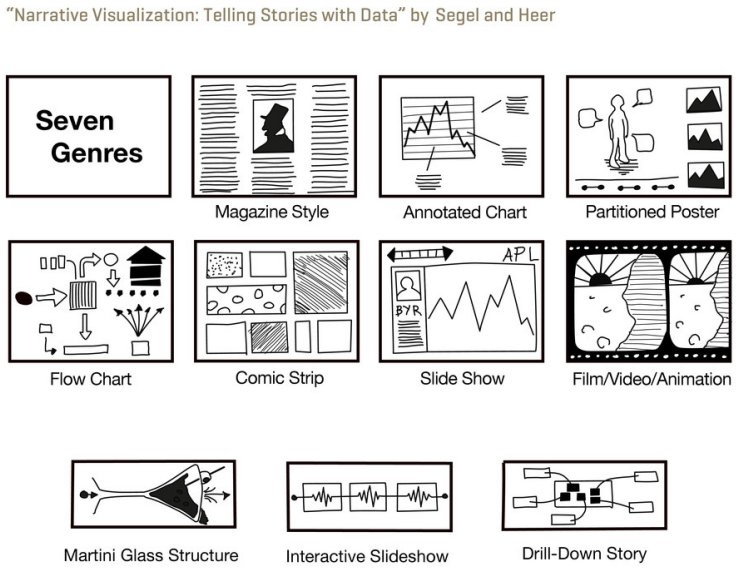


Figure 3.1: Genres and Narrative structures [2]

[2] present seven different genres in their first division, *Magazine style, Annotated Chart, Partitioned poster, Flow chart, Comic strip, Slide show* and *Film/Video/animation* as seen in Figure 3.1. [2] explain that these genres differ in terms of the number of frames, which are distinct visual scenes, and the ordering, defined by division three, of these visual scenes. [2] give the example that a single image embedded in a body of text, which would be *Magazine style*, is only one frame. Compare this to *Comic strip*, that can have multiple frames. A *Partitioned poster* can have many frames with a vaguely recommended order of how to read them, while a *comic strip* has a predetermined linear order. These styles are not exclusive and can be used to build more advanced genres [2]. These genres can be used to tell a story, but

different genres are more suitable for different types of stories. Choosing the right genre depends on factors such as the complexity of the data, the complexity of the story, the target audience, and the intended medium. These genres can be layered with interactivity and messaging, which is defined in division three, and the degree of interactivity and messaging also depends on the context of the data and the story [2].

The second division presented by [2], visual narrative tactics, are visual devices that help facilitate the narrative. This division is then divided into three different subdivisions: Visual structuring, highlighting, and transition guidance. Visual structuring consists of devices that help the viewer to locate themselves within the visualizations by helping them orient themselves early on in the experience, for instance, with an establishing shot, and helps the viewer to observe their progress, with a progress bar as an example. Highlighting are mechanisms that help the viewer bring attention to specific things in the visualization; this can be done with color, size, framing, audio, etc. Transition guidance refers to ways of moving within or between visual scenes depending on the genre without confusing the viewer [2].

The third division of the design space, Narrative structure tactics, refers to the tactics used by each visualization. This third division is also subdivided into three different subsections: Ordering, Interactivity, and Messaging [2]. Ordering refers to the path which is arranged for the viewer to go through. Sometimes the path is strictly decided and the viewer follows a linear path, other times there is no specific path at all and the viewer can freely explore different visual scenes, and sometimes you can have a combination of both where the viewer can pick from a smaller set of visual scenes to build their own path [2]. Interactivity refers to the different ways that the audience can explore and manipulate visual scenes. This can be done through filtering, selecting, searching, and so on. Messaging refers to the way that a visualization communicates details and observations to viewers. This can be done with short text fields such as labels, captions, summaries, etc. [2].

To finalize their design space, [2] explain that narrative visualizations can be put on a spectrum of author-driven and reader-driven approaches. A purely author-driven experience consists of a predetermined path through the experience where there is no room for interactivity for the viewer. This method works best when the main goal of the experience is storytelling or efficient communication. Reader-driven approaches, on the other hand, have no specific order of visual scenes and provide a very large amount of interactivity. This approach is best suited to facilitate diagnostics and pattern discovery [2]. However, [2] explain that in most cases visualizations use a combination of both approaches and also mention that this is an important attribute of narrative visualizations. [2] explain that there are countless ways of combining both author- and reader-driven approaches, but they present three common methods of striking this balance: *Martini Glass Structure, Interactive Slideshow* and *Drill-Down Story*, see Figure 3.1.

The *Martini Glass Structure* begins with an author-driven approach to introduce

the visualization. This is done to let the author set the intended narrative in the beginning, and after that, the experience opens up to interactivity for the viewer to explore the data [2].

Interactive Slideshow follows a rather standard slide-show format, but allows interaction in the middle of the narrative for each visual scene and allows the viewer to explore the slide before moving to the next. This structure is a good example of balancing author-driven and reader-driven approaches, compared to *The Martini Glass structure* [2]. [2] also mentions that this structure works really well with complex datasets and even if this structure allows for interaction mid-narrative, each individual visual scene can encompass the *The Martini Glass structure*.

The Drill-Down Story structure, presents the viewer with a general theme and then allows the viewer to explore freely among different visual scenes of the visualization. This is a structure that puts more emphasis on the reader-driven approach, as the viewer is allowed to experience the different scenes in any particular order [2]. However, [2] explain that even though this structure is mostly reader-driven, it requires a great deal of authoring to decide the types of interaction and stories in each instance and the details for each story.

3.5.2 Design space - Immersive data storytelling

In the work of [21], they mention that despite the potential of immersive storytelling, the subject is rather underexplored. They explain that there is a limited understanding towards the factors that make an effective data story and that there are no proper design spaces within the context of immersive technologies for data storytelling. [21] aims to create a preliminary design space for immersive data storytelling, with the aim of bridging the gap between immersive storytelling and narrative visualization. This design space was created from interviews with experts in different fields such as journalism and game development, and through the analysis of existing experiences [21]. The key findings are the following.

- *The soundscape.* Crucial in creating good immersion for the viewer. With just silence, the audience quickly gets bored.

- *The voice-over.* Can be really important to engage users in an immersive story. Sometimes work better than evocative shots.

- *Camera angle and positioning.* Different camera angles and positions can offer different perspectives in immersive storytelling.

- *Usage of space.* For effective immersive storytelling, it is important to create areas in the experience that allow the user to take in information. Overcrowding the space can result in the user not understanding the information.

- *Gamification.* By gamifying the experience you can increase engagement. The

two biggest components of gamifying any experience are rewards and progress in the story.

- *Diagetic methods for representing data.* Instead of traditional data charts, data in immersive experiences can take the form of physicalisations or visual metaphors within the environment.

- *Experience time.* Keep immersive data stories within 6-8 minutes.

- *Define viewer's role.* It is important to establish if the viewer is an observer or participant in the experience, as this will shape their interaction with the story.

- *Interaction.* Interactive elements within an experience foster engaging environments by providing the viewer with a sense of choice.

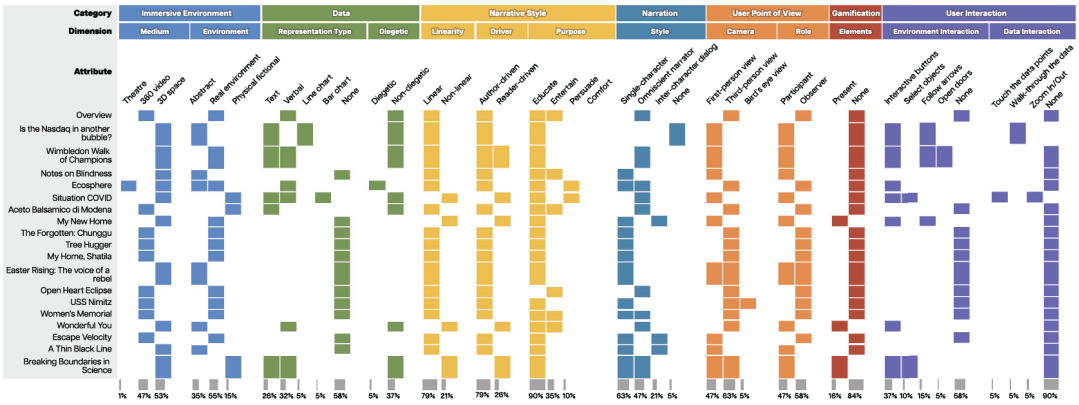


Figure 3.2: Immersive storytelling design space [21]

From the interview findings, combined with analysis of existing immersive data experiences, [21] present a design space with thirteen dimensions, which are divided into seven categories as seen in Figure 3.2.

Immersive environment consists of Immersive medium and Environment type. Immersive medium is the technology that is used, for instance, a 360 video or a 3D-space. Environment type can either be abstract, a real environment, or fictional locations that seem real [21]. [21] mention that the immersive environment should inherit parts of the physical environment to make the immersive environment more relatable to the viewer. However, the designer should remember that the immersive environment is not an exact replica of the physical one [21].

Data representation can be verbal, textual, or graphical. It can also be designed as diagetic or non-diagetic [21].

Narrative style is made up of the linearity, driver, and purpose dimensions. A linear story follows a predetermined sequence, which often means that the story is

author-driven. The less linearity, the more control over the story progression the viewer has, and the more reader-driven the story is. The purpose of the story is divided into educational, entertainment, persuade, and comfort [21].

Narration, as mentioned previously, can be very important to increase engagement in the experience. Narration can be defined by four different styles: single-character, Omniscient narrator, inter-character dialog, and None [21].

User point-of-view is a direct relation between the angle and the position of the camera and the role of the viewer. The design space presents three different camera views: First-person, Third-person, and Bird's-eye view, and two roles: Participant and observer [21].

Gamification elements can be utilized to help the viewer maintain engagement and curiosity while exploring the experience [21].

User interaction can be divided into Environment interaction and Data interaction. Interactive elements promote exploration, can help personalize the experience, and thus create a more engaging data story [21]. [21] mention that from their study, data interaction is not as utilized in immersive storytelling, and could be explored more, as interactivity is one of the main benefits of immersive storytelling compared to traditional storytelling.

3.6 Freytag's pyramid

Freytag's pyramid is a narrative structure developed by Gustav Freytag in the nineteenth century. It is a structure for telling stories that is followed by most stories, whether it is movies, theater, or other types of storytelling [22]. [22] explain that Freytag's pyramid consists of five phases that describe the different stages of a story:

1. *Exposition*
2. *Rising action*
3. *Climax*
4. *Falling action*
5. *Resolution*

In Figure 3.3, the structure can be seen in a diagram form. [22] claims that this structure of narrative building is most applicable to stories in the western part of the world, even if this type of heightening and lowering of tension is not exclusive to western stories.

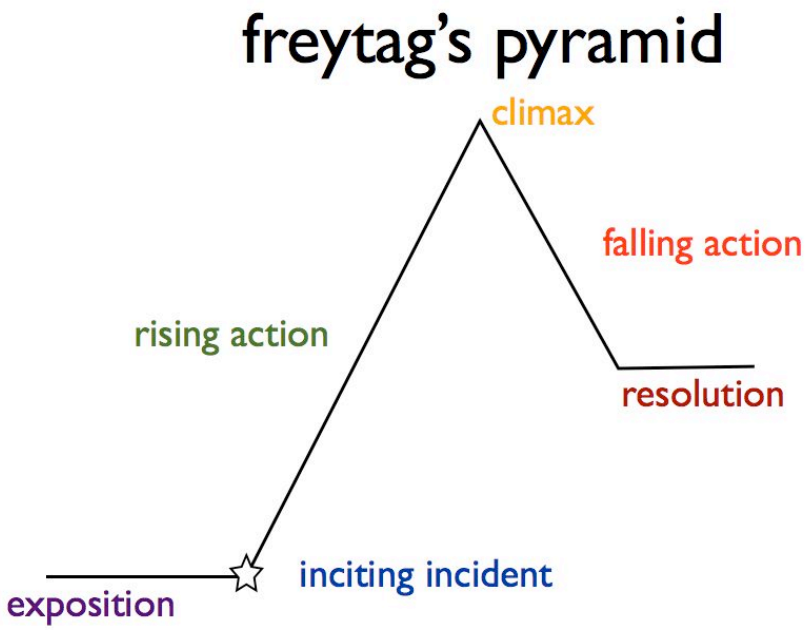


Figure 3.3: Freytag's Pyramid [22]

The story starts with *exposition*. This is the part of the story that introduces different elements, such as the setting and characters. In the exposition, the focus is on starting to build the world in which the conflict of the story takes place [22]. How long you choose to make your *exposition* depends on the complexity of the story, the extent of the world, or your preference. But, however long the *exposition* is, it should end with the inciting incident that starts the main conflict of the story [22].

The *rising action* of the story explores the conflict until its *climax*. This part often intensifies the story, and things get "worse". This section should also explore more than just the plot of the story. During this phase, the audience gets to learn more about the backstory of the characters, their motives, and details of the world. In the end, you should be able to look back at the *rising action* phase and find it clear how this section connects to the *climax* and its aftermath [22].

The *climax* can be considered the most important section, even if all sections are important when building a great story. In the *climax*, the conflict of the stories intensifies and reaches its peak, and we learn what will happen to the main characters [22]. [22] claims that many authors believe that the *climax* should be fast-paced and short. However, there is no strict rule on how to construct your *climax*. The *climax* is not only the turning point of the story, it is also an opportunity to display the themes and ideas of the story, giving the reader a chance to get an emotional

takeaway [22].

The *falling action* section is often the hardest part to construct. During this phase, the story explores the aftermath of the *climax*. But it is also important to tie up loose ends from the main conflict, explore other themes and concepts, and direct the story toward the *resolution*, while still not straying away from the *climax* and its aftermath. Although the intensity of the story is fading, the author still has to engage the user by expanding the world of the story, its mysteries, and other elements that make the story interesting [22].

The *resolution* is the end of the story and where the narrative ends. This section involves tying up loose ends of the *climax* and *falling action* [22]. The *resolution* can have more dramatic ends, such as the death of the main character, the villain escaping, etc. But it can also end with the main character learning from its mistakes and starting a new life. Despite how the story ends, it is important to provide the audience with something to think about [22].

3.6.1 Freytag's pyramid - Data stories

In the work of [23], they state that there has been plenty of research focusing on the theory of Freytag's pyramid on data stories, but that little systematic guidance exists for storytellers on how to properly apply it. To bridge this gap, [23] presents a design space that can guide storytellers on how to apply Freytag's pyramid in their projects.

[23] explain that there have been different interpretations of what narrative structures can be found within data stories and refinement of the original structures presented by Gustav Freytag has been made. [23] have constructed their design space around the different stages of Freytag's pyramid that they most frequently could observe in their study, and have simplified their design space by presenting three stages: *Setting*, *Rising-climax* and *resolution*. [23] argue that the *climax* stage is not a standalone point in the story but rather a result of the events that occur in the *rising action* stage, and therefor they merged *climax* and *rising action* into *Rising-climax*. The three stages are described as follows:

- *Setting*. Provides contextual information about the data story and makes sure to get the attention of the viewer.
- *Rising-climax*. Builds the tension of the story and provides facts that support the story leading to the *climax*, which present main insights of the story.
- *resolution*. Gives conclusions and messages for the viewer to leave with.

In their design space, [23] describe these narrative stages based on three dimensions: narrative pattern, data flow, and visual communication, where the data flow and visual communication are centered around the narrative pattern. Narrative patterns

are narrative tools that serve a specific purpose. In data stories, an example would be to show contrast between data facts. Data flow is defined as strategies for selecting and organizing data in order to apply narrative patterns. Visual communication describes how narrative patterns are visually presented to the audience, using visual design techniques to enhance the presentation of narrative patterns [23].

In the *Setting* phase, [23] identify six narrative patterns:

- *Introducing visualizations.* This pattern informs the audience of how to read the data visualizations in the story. The corresponding data flow of this pattern is *Introducing data attributes* and visual communication is *Building up the visualization.*

- *Static hook.* Activates attention by showcasing significant or unexpected data. Data flow involves selecting *abnormal or significant data facts* to emphasize the importance of the story. For visual communication, designers may, for instance, use *counting numbers*, a number that counts up to the final value instead of giving it directly.

- *Preview.* Foreshadows key events to set audience expectations. The data flow is *changes over time*, summarizing overall trends before chronologically describing events. For visual communication, designers use *fast forwarding the visualization animation* to quickly show the progression of data.

- *Raising a question.* This pattern asks a question directly to the audience to evoke interest and curiosity for the exploration of the answer. The data flow is *questions surrounding the climax fact*, where the question is answered at the *climax* stage. Visual communication is *Big text*, using big text across the screen to really emphasize the question.

- *Introducing backgrounds.* This narrative structure provides the audience with contextual information about the story. The data flow is *context of data*, which shows how the data were collected and from whom, if applicable. Visual communication is to use *related icons/cartoons/archive footage.*

- *Presenting concrete characters.* Allows the story to begin with a personal view to enhance the engagement from the viewers by providing characters that the they easier can relate to. The data flow is the *individuals behind the data.* Visual communication is *cut-out people* and *cartoon*, that give the audience a face of the characters.

In the *Rising-climax* phase, [23] could identify four narrative patterns:

- *Showing contrast.* Showcases data facts that are very different, which can create a turn in the plot that leads to the *climax.* Data flows are, for example, *contrasting in different measures and subspaces.* The first is different numbers

within the same category of data, and the second is differences in numbers across categories of data. An example of visual communication is *juxtaposing difference*.

- *Showing accumulative significance*. Increases the intensity of the story by presenting similar data facts repeatedly. This is often done with data flow *adding up in different measures* or *adding up in different subspaces*. There are different visual communication techniques for this narrative pattern, but an example is *staging of visual cues*.

- *showing the decisive moment*. This pattern starts the *climax* by presenting the audience with an important moment in the story. The data flow is *showing changes over time* and can be done with the visual communication of *speed up*, among others.

- *Showing ranking*. Sorting things according to a criteria and presenting them one by one to establish a sense of suspense. *Counting down values* is the data flow and can be done with *close-up tracking*.

In the final section, the ***resolution*** phase, [23] identifies four different narrative patterns:

- *Recap*. Helps viewers to remember the main message of the story. The data flow is *facts to be emphasized*, which recalls data that are essential to the story. An example of visual communication is *Replaying the visualization animation*.

- *Predicting the future*. Provides a glimpse into future data trends. The data flow is *from present to future*, which include data facts of the predicted data. Visual communication is done with *adding new data points*, which makes it possible to view the predicted data in relation to the historical data.

- *Echoing the beginning*. Re-visits the content that was presented in the beginning of the story. Data flow is *facts in the beginning*, which allow data to reappear with visual communication being *reusing elements*.

- *Next steps*. Provide solutions to the presented problem and motivate the audience to take action in order to solve the problem. Data flow is not defined for this narrative pattern, as this requires designers to have knowledge beyond the data to give recommendations [23]. An example of visual communication is *listing the solutions*.

[23] explains that this design space was based on the analysis of data videos. They also mention that Freytag's pyramid has been used for games, making this design space relevant for this project. To see the full design space with all dimensions, see Appendix A.

In this project, the design spaces of [2], [21] and [23] will be utilized as a foundation and framework for the design process, by exploring how these theories can assist the process of designing narrative visualizations in the medium of interactive 3D-environments.

4

Methods

This section will PRESENT the methodology of this project. There are many ways of working with the design process. This project will implement the Double Diamond design framework in the process [24]. This section will also highlight the processes of literature review, ideation, prototyping, and evaluation.

4.1 Double Diamond Model

The double diamond framework structures the design process in divergent and convergent sections that consists of four phases: Discover, Define, Develop, and Deliver, see Figure 4.1 [24].

The first phase is the divergent Discover phase where the nature of the problem is examined. This involves the process of understanding the problem rather than assuming it through research. The second phase is the convergent Define phase, which involves using the gathered information from the research to help narrow down the problem and understand the most important aspects of the problem. The Develop phase is the third divergent phase in which you explore different solutions to the problem. This involves exploring ideas and prototypes. The fourth and final phases, the Deliver phase, involve testing out the different answers to the problem, that is, the different design ideas, removing those that do not work, and iterating and improving those that will [24].

How these phases will be utilized is presented in the following subsections:

4.1.1 Discover

In the Discover phase of the Double Diamond framework, the project will conduct a comprehensive literature study to gain a deeper understanding of the research area. This includes reviewing academic papers, industry reports, and other credible sources to identify key concepts, challenges, and existing solutions. In addition, the project will analyze state-of-the-art developments within the field to understand the latest advances and emerging trends.

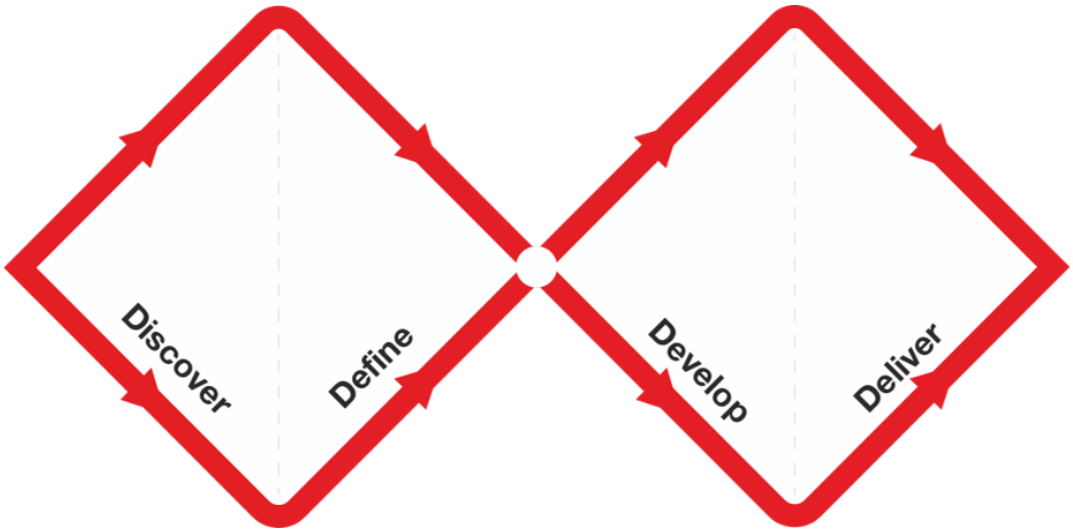


Figure 4.1: The Double Diamond framework by Design Council [24]

4.1.2 Define

The define phase will entail converging the problem. From the knowledge gained in the Discover phase, from both the literature review and the state-of-the-art exploration, this phase will focus on extracting key insights about how to approach the problem. This will involve analyzing design spaces within the area and extracting the components of them that will be used as a foundation for the project's development phase. The goal is to produce a set of design implications as a guide for ideation and prototyping.

4.1.3 Develop

At this phase, the project is expected to have a set of design implications and guidelines on how to approach the design work of an interactive 3D-environment. From this foundation, different solutions will be explored through ideation, diverging the problem once again. From this exploration of ideas, some will take form with different prototypes with varying degrees of fidelity in order to shift the focus from the problem into the solution. With the limited resources of this project, not all solutions will be taken further into the process and become prototypes of higher fidelity. The aim is to explore and evaluate the different ideas and refine them into one that can be realized into a higher fidelity prototype for evaluation.

4.1.4 Deliver

From the previous phase, one idea will be used for high-fidelity prototyping, converging the project once again. This prototype will be used for testing and evaluation to get feedback on whether the solution is good or bad. The knowledge from this phase will be used not only to evaluate the solution, but also to attempt to analyze whether the design implications extracted are suitable for design work within immersive data stories. To finalize the project, the goal is to discuss whether the design process and

design implications can be implemented as a framework for further research and design work.

4.2 Literature review

To establish a foundation for the design work, the project will conduct literature reviews and state-of-the-art research to develop a theoretical basis for the design process. Thematic analysis will be used as a method to compile and synthesize various frameworks and theories.

4.2.1 Thematic analysis

Thematic analysis is a method of identifying, analyzing and reporting patterns within data. It is a method that reduces data in a very flexible way and is commonly used for many different research questions and topics. When applied to a literature review, it helps synthesize existing research by identifying key themes, trends, and gaps across multiple sources [25]. According to Castleberry and Nolen [25], thematic analysis can be described in five steps:

1. Compiling
2. Disassembling
3. Reassembling
4. Interpreting
5. Concluding

Compiling the data into a useful form is the first step in finding meaningful answers to your question. In this step, the researchers immerse themselves in the data and gain a comprehensive understanding of its entirety, allowing for a deeper interpretation of the phrasing and meaning of terms within their broader context. Once the data is consistently structured and organized, the next step is to analyze and break them down into their key components.

After compiling and organizing the data, it is separated. The disassembling of the data involves taking it apart and creating different groupings. This is done through coding, a process in which raw data is converted step by step to useful data by identifying themes, concepts, or ideas that have some type of connection with each other, i.e. identifying differences and similarities in the data [25].

During the reassembly phase, the codes, or categories assigned to each concept, are then analyzed in relation to one another to form overarching themes. A theme captures a meaningful aspect of the data in connection with the research question and reflects a recurring pattern or significance within the dataset. The analytical

thinking of the researcher becomes important in this phase. They start by gathering all relevant data under each potential theme and continuously refine them to ensure they accurately represent the coded extracts and the dataset as a whole. It is essential to faithfully convey the story within the data rather than shaping it to fit a preconceived theory or overextending its interpretation [25].

In the interpreting stage, the research process involves drawing analytical conclusions from the data as codes and then themes. Despite this being step four, interpretation should always be performed continuously during the first three steps of analysis [25].

Concluding is the final step. The raw data have been transformed into codes, themes, and thematic maps. By identifying these themes, we have interpreted the data. The conclusions we can draw from this are responses to our research question. The purpose of thematic analysis is to provide an answer to a research question [25].

A thematic analysis is useful for identifying key themes within larger amounts of information, and will thus be utilized in this project to extract key factors for designing narrative visualizations within interactive 3D-environments.

4.3 Ideation

Design ideation is one of the most important parts of the design process. Okudan, Ogot, and Shirwaiker [26] explains that creativity in design engineering is mainly based on:

1. Desire and fulfillment.

2. Knowledge of and principles, available or already possessed by the designer.

3. Willingness to accept criticism and ideas from others

4. knowledge of the design and problem solving process.

There are many ways of working with the process of ideation; for instance, Okudan, Ogot, and Shirwaiker [26] presents a more structured way of working with ideation that they call TRIZ. But they mention the most traditional approach of working with ideation is to use methods that make the designer look inward for inspiration. Gonçalves and Cash [27] states that ideation broadly describes a set of activities that relates to the creation and development of goal-directed ideas. In the context of ideation, Gonçalves and Cash [27] also raises important factors. One is that designers can get fixated and grow attached to early ideas in the process. Another is the balance between generating many ideas and generating original ideas. According to Gonçalves and Cash [27], it is widely accepted that by generating a large amount of ideas, there is a higher probability of coming up with a creative solution. However, there is also evidence that fewer ideas correlate positively with a higher originality of the ideas.

In his work on spatial models for artistic creativity, Dahlstedt [28] mentions that in the context of art, creativity is essential. He also explains that artistic expression is highly affected by the tools chosen by the artist. Tools embody complex behaviors and enable new ways of thinking that would otherwise not be possible. With more advanced tools, we also have to consider the indirect contribution that the creator of the tool makes to the ideas [28]. Another factor about the tools mentioned by Dahlstedt [28] is that a tool could lead users to create similar results, but also that if the tool is complex enough, it should provide variation possibilities controlled by the user if he or she invests time in their work. Dahlstedt [28] also explains that it is very rare that we as artists use just one tool to create artwork, but a whole toolbox.

This project will utilize the more traditional approach to ideation, using a set of activities as tools to explore different solutions to a problem. The toolbox will involve different ideation methods, but also different practical methods of visualizing ideas, such as sketching, storyboards, or creating fast prototypes in 3D-softwares.

4.3.1 Benchmarking

Benchmarking is the process of measuring products, services, and processes between different companies and organizations that are considered the leaders within their respective industries to gather information on best practices [29].

During the exploratory part of the ideation process. The project used benchmarking as a method to study how other companies have utilized 3D- data visualization in their communication and storytelling practices. This involved analyzing different design examples to understand how different data subjects were visualized and how interactive elements were implemented in the experiences. The purpose of this benchmark was to gather inspiration, identify best practices, and aid in the development of this project's design work by providing the ideation phase with relevant data subjects.

4.3.2 Crazy 8's

Crazy 8's is a fast sketching exercise that challenges the designers to sketch eight different ideas in eight minutes. The goal of this exercise is to help you look beyond your fixation on your first idea. It is important to remember that the ideas created with this method do not have to be great. The purpose of this exercise is to allow designers to give space to their creative impulses and allow crazy ideas [30].

This method is appropriate because of its flexibility and the ability to generate many different ideas. Compared to ordinary brainstorming, which works best when ideas can be discussed with others, Crazy 8 helps the creation of many different ideas by one person. Hence, this method will be utilized at the beginning of the ideation phase to explore different solutions and broaden the perspective of design possibilities.

4.4 Prototyping

Prototypes are working models created to develop and test design ideas, allowing designers, clients, and users to evaluate various aspects, such as content, aesthetics, and interaction techniques. By providing a tangible representation of a concept, prototypes help identify potential issues early in the design process. Through user testing, designers and usability professionals can gather valuable data on user mistakes and feedback, enabling them to detect usability problems before significant resources are committed to flawed designs. This early stage evaluation ensures a more efficient and user-centered design process, ultimately leading to a more effective final product [31].

Fidelity in prototyping refers to the degree to which a prototype resembles the final product. High-fidelity prototypes closely match the final design in appearance, interaction, and detail, while low-fidelity prototypes, such as sketches, differ significantly in these aspects. Low-fidelity prototypes are quick to create, allowing designers to iterate rapidly between usability tests or even during usability tests. These simplified representations help focus on high-level interaction design and information architecture rather than fine details. In contrast, high-fidelity prototypes are often built using the same methods as the final product, making them more realistic, but also more expensive and time consuming to produce. Although high-fidelity prototypes effectively demonstrate interaction techniques and design possibilities, they can also make designers reluctant to explore alternative solutions, potentially limiting innovation. The choice between low- and high-fidelity prototyping depends on the design stage and the specific goals of the testing process [31].

The choice of prototyping medium significantly affects the realism and flexibility of the design process. Low-fidelity prototypes, such as paper prototypes, often rely on a human to simulate interactions, allowing for quick adjustments and exploration of ideas while sacrificing some realism. Paper prototypes are particularly useful in participatory design, as they are accessible to everyone and enable spontaneous modifications. On the other hand, computer-based prototyping offers advantages in terms of precision and interactivity but comes with its own challenges. Some digital prototyping methods require designers to define interaction flows before testing, which can restrict flexibility. Additionally, high-fidelity computer prototyping tools may require more implementation details than necessary, disrupting creativity. However, sketch-based low-fidelity digital tools offer a compromise, enabling rapid prototyping with less expertise while potentially limiting the variety of interaction techniques available [32] . Ultimately, the choice between paper and digital prototyping depends on the projects needs and the stage of the design process [31].

4.4.1 Prototypes as filters

According to Lim, Stolterman, and Tenenberg [33], a key strength of a prototype lies in its incompleteness. Unlike a final product, a prototype is intentionally unfinished, allowing designers to examine the main qualities of the idea without fully committing

to a complete design. What a prototype excludes is equally important as what it includes, as this selective representation enables focused exploration and refinement [33].

This characteristic of incompleteness is why prototypes can be seen as *filters*. Rather than serving as definitive representations, they help designers isolate and evaluate specific aspects of an idea. This differs from the scientific notion of filtering, where variables are eliminated to eliminate noise; in design, prototypes act as tools for discovery, guiding creative exploration rather than simply testing solutions [33].

Lim, Stolterman, and Tenenberg [33] claims that prototyping is not about proving that a solution works, but rather about revealing potential problems and exploring new directions for design work. A well-crafted prototype highlights particular design aspects while leaving others undefined, encouraging iterative development. Its primary role is generative and evaluative discovery, helping designers refine ideas before committing to a final version, which aligns with the ideas of research through design Gaver [13].

The art of prototyping, therefore, lies in designing an incomplete model that effectively filters the desired qualities. The most efficient prototype is not the most detailed one, but rather the simplest one that still captures the most important characteristics needed for a meaningful evaluation. By mastering this skill, designers can strategically use prototypes to shape and refine their ideas.

4.4.2 Storyboards

Storyboard is a method of mapping each step of the experience you are designing and is a good tool to clarify the different aspects of the concept, in part to effectively communicate the concept, but also to find aspects that need further refinement [34]. Storyboards are often used as an iterative design tool to document ideas and create an atmosphere by mapping out the experience with visual scenes using images. Storyboarding can also be used as a tool for interaction design by showing the transition between different scenes in the experience [5].

Storyboarding was used in this project as a means of creating low-fidelity prototypes for different data stories, but also when developing the different scenarios of the final prototype.

4.4.3 Moodboards

A moodboard is a collage of images, patterns, or text that has the purpose of conveying a certain feeling when you look at it. Moodboards are used in a wide range of applications, including interaction design. A mood board is typically used to define the visual identity of a product in the early stages of development, but can also be used as a method to generate ideas and convey the tone of a product [35].

For this project, moodboards were used as a means of defining an initial idea of

the visual identity for the final prototype. By exploring and combining different references, the moodboards helped create visual references for each visualization to work with during development of the final prototype.

4.4.4 Scenarios

User scenarios are rich descriptions of situations that are relevant to the design of a solution. In interaction design, user scenarios can be utilized to put user interactions in context and thus help designers understand the practical needs and behaviors of users by being generally evocative [36].

In this project, scenarios were used for the different data stories as a means of creating dramatized descriptions of the different visualizations. This helped putting the desired emotions into context and create a picture of how the visualizations would evoke these emotions through visual and auditory changes in the experience.

4.4.5 Immersive design prototyping

For high-fidelity prototyping, an immersive and interactive prototype was created using game engine technology. The game engine used in this project was Unreal Engine 5. This game engine is one of the most advanced real-time 3D creation tools that can be used for a wide range of use scenarios such as video games, animation, CGI, architecture, product showcase, and many more [37].

4.5 Evaluation

This project revolves around both a research question and a design challenge. The purpose of the design challenge is to generate empirical data that contribute to answering the research question. To achieve this, the artifact will be designed on the basis of a framework developed from the literature review.

The evaluation process will assess whether the artifact is engaging and fosters emotional connections to the experience. Ultimately, the goal of this evaluation is to determine how effectively the artifact achieves this, thereby providing insight into the validity and quality of the created framework and thus attempting to answer the question:

What are key factors for integrating narrative storytelling and data visualization in 3D-environments to promote user engagement and enhance emotional connection and understanding of complex data?

In their work, Müller, Wurth, Schäffer, *et al.* [38] creates a framework for choosing a suitable evaluation method for information systems, as they claim that it is important to use evaluation methods that are suitable for the artifact. In the context of their research of information systems, they present different criteria that can be

evaluated, and different methods that are suitable for evaluating an artifact based on the desired criteria [38].

With this being said, it is essential for this project to use a evaluation method that suits the nature of the artifact and the criteria being evaluated. This will increase the chances of generating a higher validity answer to the research question.

4.5.1 Experimental evaluation

In experimental research approaches, researchers can observe behavior in an environment they control [39]. There are mainly two different ways to construct experimental studies. In an "within-subject" study, every test subject is exposed to every treatment that is being tested. In an "between-subjects" study, the test subjects are only exposed to one of the treatments being tested [39]. In this project, the "Within-subjects" approach was used for design evaluations, as every test subject received the same task and was asked the same questions.

The projects used an unstructured approach to evaluate the final prototype. The tests used controlled observations, where behavior is studied in a controlled and structured environment [40]. The test also combined observations with semi-structured interviews, in which interviewees were asked predetermined questions, but with the possibility of elaborating and explaining ideas through open-ended questions [41].

5

Planning

This section aims to give a brief description of the planning of the project work in addition to the expected outcomes and eventual risks related to the project.

5.1 Time plan

The first part of this project focuses on exploring previous academic work, but also state-of-the-art examples to build a theoretical foundation for the design work. This exploration entails the first four weeks of the project, combined with the overall planning of the project.

The design work will be done for 12 weeks and will begin with building the theoretical foundation and extracting design implications for the ideation phase, which will begin in tandem with the phase of building the design implications. During the ideation phase, the prototyping phase will also begin simultaneously, as rapid prototyping will be present when exploring different ideas.

The prototyping stage involves a large part of the project. The ideal scenario would be to create two to three high-fidelity interactive prototypes for evaluation. However, with time limitations, the prototyping stage aims to explore different types of data with lower-fidelity prototypes and to focus on designing one high-fidelity prototype. The goal of this prototype is to be interactive, so it can be tested and evaluated with users, which moves us to the evaluation stage. The evaluation aims to explore whether the design fosters engagement and emotional connection with the experience. The evaluation results will be used in the final stage to analyze the design approach and discuss whether it can be used as a design space for further work.

The last four weeks will focus on writing the report and finalizing the thesis. GANTT-sheet can be seen in Figure 5.1.

5.2 Expected outcomes

The expected outcomes of this masters thesis revolve around exploring data storytelling and narrative data visualization within interactive 3D-environments. The

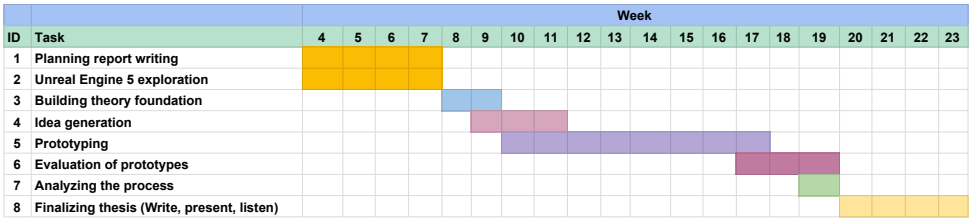


Figure 5.1: GANTT-sheet for the project

project will end with a high-fidelity prototype that serves as a proof-of-concept for the proposed design approach. Through the evaluation of this prototype, the study will assess the effectiveness of the approach and its potential for further development. Ultimately, the thesis aims to establish a foundation for a design space that enables designers to work with data visualization and storytelling in interactive 3D-environments, fostering engagement and an emotional connection to data.

5.3 Eventual risks

The theme of this project is inspired by an industry interest in exploring interesting ways of conveying data, but also by my passion for 3D-experiences.

This project can be considered an independent Masters thesis conducted at Chalmers, with the interest and support of the company Brickland. The companys involvement is based on curiosity about the subject, offering primarily supervision and an industry perspective.

Given the independent nature of the project and the absence of required deliverables to Brickland, it will continue even if the companys support is withdrawn due to unforeseen circumstances. This ensures that the project's continuation is not dependent on the collaboration with Brickland, minimizing the risk of cancellation during its course.

6

Process

This section will outline the project's execution, detailing the various phases involved. It will describe the process, explain how each phase was implemented, and highlight the methods used to achieve the project's objectives.

6.1 Building a design space

The first step in extracting the key elements of narrative visualization for interactive 3D-environments was to create a design space grounded in theory. This task was completed by conducting a thematic analysis extracting key insights from three different design spaces within data storytelling. The first design space analyzed is the work of [2], which is a foundational design space within narrative visualizations. To further develop into the context of this master thesis, the second design space analyzed is the work of [21], which builds on the design space of [2]. This design space presents key elements for creating data stories within immersive mediums, such as interactive 3D-environments. The third design space is that of [23], which addresses how you can work with data stories using Freytag's pyramid of narrative structure created by Gustav Freytag [22].

After familiarizing with the data, key insights were extracted and coded from each design space. The codes were rearranged into different themes based on similar attributes in the design spaces. To scale down these themes, three iterations of interpretation and reassembling were done and finally concluded into a design space with nine categories, each containing different dimensions; see Appendix B.

6.2 Ideation

The stage of ideation consisted of two tasks: selecting interesting data to work with and exploring different solutions to the problem.

6.2.1 Selecting data

Brickland is a company that provides the service of creating visual experiences in 3D for their clients, and in many cases these experiences are designed to act as an

advertisement for the client's brand, but also to help customer make informed and responsible decisions when selecting products and services. Brickland has expressed an interest in diverging their knowledge and is looking for new ways of designing immersive visual experiences, hence the collaboration in this project. To gain an understanding of how you can work with data in the context of their services, the project proceeded with a benchmark of state-of-the-art experiences. This was done by looking at Brickland, but also other different studios that provide similar services as Brickland, and exploring their projects to see what themes of data they have worked with and how they have designed the experiences for their clients. With these references, interesting themes of data and approaches of working with them could be moved further into the next stage, solution ideation.

6.2.2 Creating solutions

Based on the different data themes extracted from the benchmark. The next step of the process was to ideate and explore different concepts with the design spaces as a guide for shaping the experience. The ideation involved building up an interesting story about a subject, which meant that for every theme, I needed to explore the subject and relevant data to get a grasp and a baseline understanding of what types of narrative could be told. When an interesting narrative had been found, I used many iterations of the Crazy 8's method, to explore different ways of visually presenting the narrative and ways of interacting with the data in a 3D-environment. The different ideas were iteratively polished and all the details were defined in regards to the nine categories of the design space.

6.3 Prototyping

The prototyping process involved two different stages. The initial step involved creating simple storyboards for all the ideas created in the previous ideation stage. The second stage involved working further with one of the concepts and further exploring ways of practically developing the experience in 3D.

6.3.1 Storyboarding

To highlight the possibilities and potential of the created design space, different ideas were shaped into more comprehensible prototypes based on the different aspects of the design space. This was done by creating shorter storyboards for each concept by breaking down the experience in a shorter presentation pitch combined with a simple visual storyboard. Visual storyboards were created using AI-generated images from Adobe Firefly [42] and combined into a storyboard, using arrows and short text descriptions to visualize the progression of the story in Adobe Illustrator [43].

6.3.2 High-fidelity prototyping

To further explore the potential of using 3D-environments to present data, a higher-fidelity prototype was designed from one of the initial design ideas. One of these

concepts was further improved, and a plan was constructed of how this story would be told through a digital experience by creating storyboards, moodboards and scenarios. The presentation of the story was built up in Unreal Engine 5, and the final prototype is a fully interactive experience that highlights how you can present a data story in 3D, but also how you can use data in connection to visualizations within a 3D-environment.

6.4 Evaluation

How the process of evaluation a semi-structured interview and observation. The tests were performed in pairs of two and the process involved four tests in total. During the tests, users were allowed to freely explore the experience together, when they had viewed every visual scene once, or when they felt satisfied, the test was finished with a shorter interview. The tests involved eight different people around the age of 25. All test subjects were students within the interaction design Master's program.

The tests started with a brief introduction about the task. As the experience is meant to be experienced as an installation, users were asked to imagine themselves walking in a museum and encountering this experience with the World map visual scene active, see Figure 7.10a. This was to provide information on the context in which the design is meant to be experienced. Then the users were told to explore the installation freely together and discuss the different scenes between each other. These discussions would be the main focal point for the observations.

During the test, the evaluation involved observing interaction, understanding of the user interface and visualizations, and engagement. This was done using a simple checklist, where if something was observed, it was ticked off, in combination of taking notes if needed. Interactions were observed on the basis of whether they used the different user interface elements and whether they used them directly or after some time. Understanding and engagement were observed on the basis of discussions between users during their walkthrough and if they collaborated to navigate the experience. The points looked for were the following:

- Discussions of what users are seeing.
- Discussions of how to navigate the experience.
- Discussions of what is happening in the visual scenes.
- Discussions about the underlying theme of the whole experience.
- Are users collaborating?

The observation points were the same for every visual scene, with some variations. For the world map scenario, the understanding of the map pins was observed. For

the different environment scenarios, it was observed whether users discussed and understood the message "*Point of no return*". For the marine heat waves scenario, it was observed whether users explicitly noticed the bleaching of particles.

When users were finished exploring, the tests ended with some final questions, with the purpose of understanding whether the users found the interface intuitive, how they interpreted the visuals, and how they interpreted the general theme of the whole experience. The questions were also a good way to gather knowledge about engagement if there were few discussions during the exploration. The questions were the following:

- What did you see during this experience?
- Did you understand how to navigate the experience and what helped you understand that?
- Could you understand what happens during each visual scene and how could you draw that conclusion? (Asked for every visual scene)
- Could you understand what the underlying theme of the experience is?

For the complete observation checklist and interview questions, see Appendix C.

7

Result

This section will present the findings collected from the various phases of the project, providing details of the results and insights obtained throughout the process.

7.1 Building a design space

Presented following is the design framework created from the theory and design spaces of [2], [21] and [23], which can be seen in Figure 7.1.

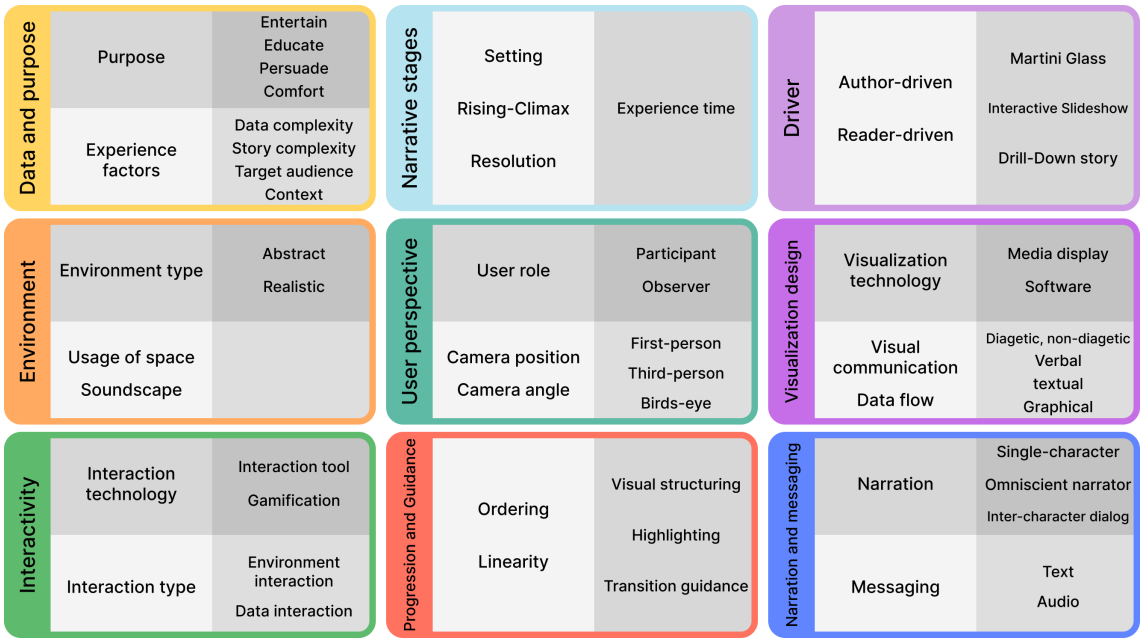


Figure 7.1: The final design space

As the theme of this project is to design narrative visualizations in interactive 3D-environments, the immersive medium from [21], and visualization genre from [2] would already be determined as interactive 3D-environment for our design space. But in the context of this medium, instead of different immersive mediums or visual genres, you can have different environment types [21]. This has resulted in the category **Environment** in the design framework.

Environment. The environment category is divided into three dimensions: *Environment type*, *Usage of space* and *Soundscape*. The *Environment type* itself can be divided into abstract environments or real environments. Abstract environments are environments that do not have to be a representation of real life, they can consist of abstract shapes and platforms floating around in space. Real environments are environments that are representations of our world. This can be real-life environments recreated in 3D or fictional environments that could be practically real [21]. If it suits your purpose, the environment could be a mix between the two types. With *Usage of space* the designer has to carefully design the environment to allow efficient interpretation of the information by the user. If you overcrowd the space, you leave no room for the user to breathe and process information [21]. When designing the environment, it is important to consider not only visuals, but also sound. Therefore, it is important for the designer to consider the *Soundscape*. This is a crucial aspect as sound helps to attract the attention of viewers, immerses them, and ultimately enhances the environment and experience [21].

[2] mention that the choice of visual genre in their design space depends on different factors such as data complexity, story complexity, and the target audience. Similar can be said for the choice of environment type. This has resulted in the category **Data and purpose**.

Data and purpose. This category highlights important factors for why and how you design an experience. [21] highlights the dimension *Purpose*. This can range from entertainment, education, persuasion, and comfort. In the initial stages of the design process, it is important to understand the data that you have and what your intentions are to design an experience, as the goal of your design will factor into other decisions. This category also includes the dimension *Experience factors*, which refer to data complexity, story complexity, and context, which was highlighted during the design process as an important factor to consider. The context refers to where the experience will take place, is it at home on a computer, anywhere on the phone, or at a physical installation. These *Experience factors* will affect the choices you make while working with all the other categories of the design space.

Driver. [2] mention that a data story can be *Author-driven*, *Reader-driven* or a balance between both. The progression of an *Author-driven* experience is predetermined by the author, and the user follows a linear path, whereas a *Reader-driven* experience gives more agency to the user in controlling the progression of the story. [2] mention that a *Author-driven* approach is effective when you want to put more focus on presenting a story, as you can design how and when the narrative is presented. A *Reader-driven* approach is suitable when you want to promote diagnostics and pattern recognition [2]. The category also includes the different approaches of balancing *Author-driven* and *Reader-driven* structures presented by [2]. These are Martini Glass structure, Interactive slideshow and Drill-down story.

User perspective. This category is divided into the dimensions *User role* and *Camera position and angle*. [21] explains that it is important to define the role of

the viewer early on in the story, as this will shape how the viewer interacts with the experience. *User role* is connected to *Camera position and angle*. For instance, if you want to provide the perspective of being an observer of an experience, using a third-person view should be considered. In the same way, a first-person view can immerse the viewer more efficiently if their role is defined as a participant of an experience.

Narrative stages. This category highlights the structure of building an engaging story presented by [23], which is an adaptation of the well-known narrative structure created by Gustav Freytag [22]. The structure is divided into three stages: *Setting*, *Rising-climax* and *Resolution*. *Setting* provides contextual information about the story and grabs the viewer's attention. This includes presenting the **Environment** and setting the *User role* from the category of **User perspective**. *Rising-climax* builds the tension of the story and provides facts that support the story leading to the climax, which presents the main insights of the story. The *Resolution* gives conclusions and messages for the viewer to take away from the experience. An important factor mentioned in [21], is to consider the experience time. It is important to limit the time of the experience so that viewers will stay around for the entire duration of the experience. This time will vary depending on the context in which the story is experienced and the target audience.

Visualization design. To facilitate the story, narrative, and present the data within the different **Narrative stages**, we have to design the visuals. [23] explains that the different **Narrative stages** can be built using different *Narrative patterns*. These patterns are facilitated by *Data flow* and *Visual communication*, which defines how the data is structured and then visually presented. *Visual communication* can be done in different ways, [21] explain that it can be verbal, textual and graphical, but also that it can be diagetic and non-diagetic. Diagetic methods of presenting data should be considered when working with interactive 3D-environments, as you can visualize data with metaphorical means such as physicalisations and visual metaphors within the environment, to act as visual attractors and increase the engagement with the viewer [21]. During the design process, it also became clear that it is important to consider what *Visualization technology* you want to use to present the story and the data. This involves considering what the experience is viewed on, such as a flat digital screen, Virtual Reality, Augmented Reality or other methods such as multi-screen installations, sphere displays etc. Technology also relates to the software used to design the experience. In many cases game engines are suitable as they are very versatile. But if you are working with a more artistic approach and you want to design a physical installation, a software for real-time interactive media content, such as TouchDesigner [44], can be suitable.

Progression and Guidance. [2] explains *Ordering*, which refers to the ways in which to arrange the path that the viewer will go through the experience. Depending on the **Driver** approach, this path will have different levels of *Linearity*. A strictly *Author-driven* approach will have a very linear progression, where the viewer is guided through the experience on a predetermined path [2], [21]. To help facilitate

and guide the viewer through the story and present the narrative, you can use visual narrative tactics [2]. These are visual structuring, highlighting, and transition guidance. Visual structuring are visual tools that help the viewer to know their position within the visual scenes, or in this case, the environment. Highlighting refers to visual tools that help grab the viewer's attention to a specific part of the environment. Transition guidance refers to ways of moving between different visual scenes without disorienting the user.

Narration and messaging. [21] explains that *Narration* can play an important role in engaging viewers in an immersive story and can even be more powerful than visuals in some cases. Narration can work in tandem with the data representation mentioned in **Visualization design**, where narration can assist to push the narrative when visually presenting the data. [21] mention three different types of *Narration*: single-character, omniscient narrator or inter-character dialog. In addition to aiding in the presentation of the narrative, Narration can add additional information about the data representation similar to *Messaging* presented by [2]. *Messaging* refers to additional information about visualizations that can either be textual or audial.

Interactivity. This category highlights the importance of interactivity in immersive storytelling. Interaction allows for exploration and makes the experience more personalized as the user feels like they have more agency over the experience, thus increasing engagement [21], [2]. Interaction within immersive data stories can be divided into two different *Interaction types*: Environment interaction and data interaction [21]. If you are implementing diagetic methods of visualizing data, i.e. using physicalisations or metaphorical representations within the environment, data interaction and environment interaction would connect into each other. It also became clear that it is important to consider *Interaction technology* for the experience. Different interaction tools such as a controller, keyboard and mouse, VR-headset, touchscreen, etc. will allow for different opportunities in the design and shape the experience in different ways for the audience. To further increase the engagement of an experience, you can add elements of gamification in the experience, where the interaction of the viewer could result in a deeper entry into the story or other type of rewards [21].

The design space has nine categories. To complement this design space we can take use of the design space of [23], as it provides excellent examples of different *Narrative patterns* for the different **Narrative stages**, see Appendix A. This is done by extending the category **Visualization design**, and give examples of *Narrative patterns*, *Data flow* and *Visual communication* for each narrative stage.

7.2 Benchmarking

In order to work and test the design space, the project needed interesting data to design experiences for. To find data themes and approaches suitable for the services that Brickland provide to their clients, a benchmark was executed of different

companies within the industry. All the projects mentioned are not strictly interactive experiences, and also not visual experiences that present data. However, the mentioned projects focus on presenting information within a story that engages an audience and gives them knowledge about a brand, concept, event, or situation, rather than information about a specific product. Some examples may have a specific product in focus, but also present the context in which this product is found.

The first example presented is a project created by Brickland themselves in collaboration with the electric car manufacturer Polestar. The goal of this project was to create visualizations for the materials used in their vehicles to engage in the communication of how they use blockchain technology to source high-risk materials [45]. The content created for this project was designed to engage an audience in learning about how Polestar works toward sustainable sourcing of materials, but also transparency about how and where these materials have been produced [46]. Polestar themselves mention that the electric car industry requires the use of high-risk materials such as lithium, nickel, and cobalt, where the extraction has major risks of being associated with child and forced labor, corruption, etc. Other types of materials used are the so-called conflict materials, or 3TG materials, which are tin, tantalum, tungsten, and gold. In politically unstable areas, the trade of these minerals can be used to fund armed groups that fuel forced labor, corruption, and other human rights abuses [47]. This highlights an area very suitable for narrative visualizations where many different perspectives and stories can be presented backed with data, both from a company as Polestar that wants to highlight their responsible sourcing, but also from human rights organizations.

Another interesting project analyzed was by AKQA, where they collaborated with Volvo Cars to create an informational video about their self-driving cars and the company's ambitious goal of no fatal accidents in their new cars [48]. The purpose of the campaign was to inform the audience about how Volvo works for safety in their cars and how they want to design for the safety of drivers. They mention that there are many reasons for car accidents, such as intoxication, speeding, but also accidents that occur when we least expect it. With Volvo's aim for safety, they want to assist humans, and avoid accidents with self-driving cars. This informational video is not an example of data visualization, but data could be implemented to enhance the story. This highlights the theme of traffic accidents and the devastating effects this can have on people's lives. An experience could be designed to highlight how dangerous it is to drive cars, but also include the key takeaway of self-driving cars being the solution to this problem.

Beautysphere is another project by AKQA in collaboration with P&G Beauty. The result is an immersive experience with the purpose of educating people on the topic of sustainable beauty [49]. The experience is made up by an interactive 3D-environment of a garden containing different plants used for beauty products. By exploring the space and collecting the different plants, you become better educated on the issues that responsible beauty advocates for, such as quality, sustainability, transparency, equality, and inclusion [49]. This highlights the theme of using Earth's

resources to produce everyday luxury products and the effects this has on our ecosystems, the areas where these plants are extracted from, and the people and animals that live in these areas. Beauty products could be the focus for this theme, but also the result of other products made from plants, such as coffee.

The Mill have created an immersive and interactive installation that uses research data to tell the story of how different tools and methods of scientific invention have helped reduce malaria in the last 60 years [50]. This is a good example of narrative visualization, where you see data visualizations designed in a very visually attracting way, and where these visualizations are used to tell the story of the fight against malaria. Creating experiences that tell the story about global diseases is a very interesting topic. As this is a problem that affects many people, you can tell very engaging and emotionally loaded stories while also educating people about the data behind the problem. A project could mainly be presented by an organization, as in this example of malaria, but also a company that provides a solution to the problem.

Futuredeluxe has created a visual time capsule om the distribution of the Covid-19 vaccine during the pandemic, which further relates to the theme of global diseases [51]. In this experience, they highlight, based on data, the remarkable stories of how the vaccine was distributed to every corner of the world [51]. The Covid pandemic is an excellent theme, where you can tell many different stories with data. In this example by Futuredeluxe, the theme is humanities ability to solve a problem on such a large scale.

Futuredeluxe has a great example of an interactive installation called Your system is a Garden, Too. This is a digital art installation part of the Digital Impact installation in Barcelona, the same exhibition where the work of [8] is situated. This installation consists of an ecosystem that changes based on interaction. However, the installation is designed as anti-interaction, where the ecosystem grows as humans remain still and will retreat if it senses movement [52]. This is also not an example of data visualization, but it can be used as inspiration to create narrative visualizations. Similarly to the theme of beauty products, an idea could be to create an experience about the human impact on the earth's ecosystems and what it means for people.

These projects were the main source of theme inspiration for the ideation phase, where some concepts would focus on a specific perspective within the theme, or be a different take on the same perspective. The different themes that were chosen in the end were:

- The increase in extreme weather due to global warming and its effect on ecosystems, humans, and the world.

- The distribution of the Covid vaccine across the world and the amazing adventures included in this great challenge.

- The life and timeline of the Covid pandemic in Sweden.
- The annual fatal traffic accidents in Sweden and the zero-vision, a goal of having zero fatal traffic accidents.

7.3 Design solutions

Following are four different concepts presented. These concepts were created based on the themes extracted from the benchmarking process and designed with the nine categories of the design space in mind. The different concepts are examples of how you can design data stories within interactive 3D-environments, and they are presented with a description of the experience combined with a visual storyboard.

7.3.1 Our World at 2°C

This experience raises the topic of what will happen to the world when we reach 2 degrees Celsius, by focusing on extreme weather and how they will be more frequent, intense and longer. The experience has an exploratory approach where the user is greeted with an interactive 3D-globe of the world, and the question: What will happen at 2 degrees celsius?. This globe has different pins across its surface that represent different locations in the world. The user can explore the globe and choose from the different locations. When a location is chosen, the user will be transitioned into this location and taken through it from a first-person perspective with an author-driven approach, to immerse them in the real environment. The locations in the experience are different parts of the world that will be heavily affected by different extreme weather conditions.

An example of a location would be the Amazon rain forest. The person will travel through this environment in a car and be presented with data surrounding this part of the world by the radio in the car. This information will refer to how many different species live in the forest, how many people live here and near the area, and how important the Amazon rain forest is to the Earth. As the user is taken through the environment, they will eventually see it change, and when a certain line is crossed, they are fully immersed in an intense wildfire. As they travel through the wildfire with their car, the radio will present facts about how wildfires will increase and how this will affect species, humans, and ultimately the world in different ways. Each environment experience will eventually fade out and the user is met with an encouraging question and a subtle call for action: What will you do?.

This experience is a set of many different shorter scenarios with the intention of immersing the user into the environment that will be affected by climate change and hopefully engage them in understanding the dangerous future that lies in front of us.

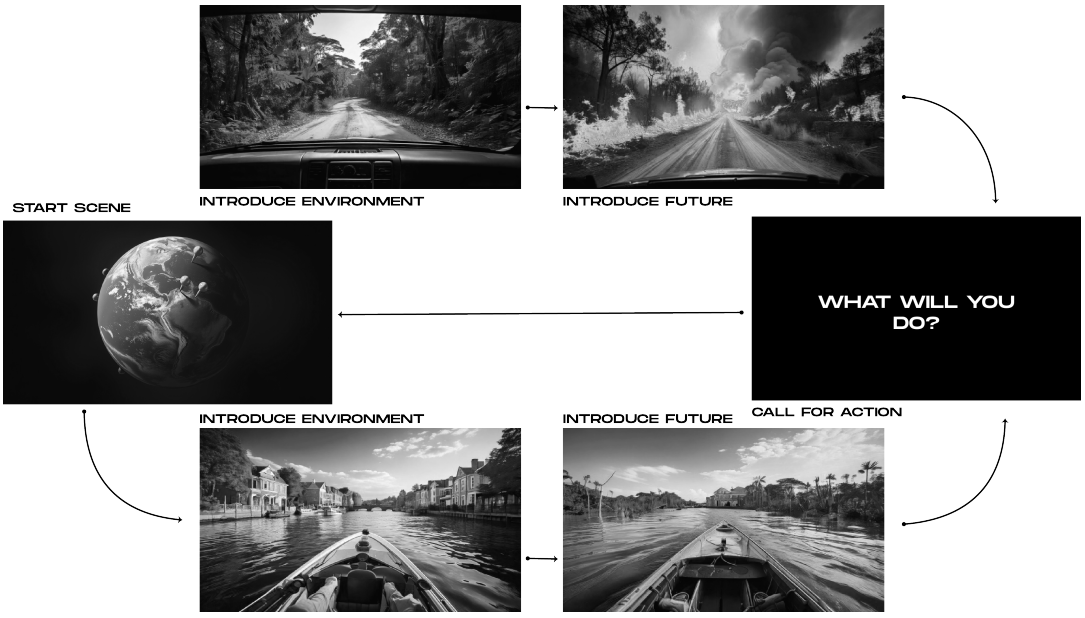


Figure 7.2: Storyboard for *Our World at 2°C*

7.3.2 The Vaccine Adventures

This experience highlights the amazing travels of the Covid vaccine to many different parts of the world and tells the story of the amazing work humans did to ensure that everyone received the vaccine, by highlighting the distribution of the vaccine to the most extreme places in the world. The experience starts with a flat map of the world. The map is highlighted based on which areas of the world the covid vaccine has been distributed. Some places do not have the same highlighting, and these are the rural areas that still need the vaccine. The user's role is established as a participant, and they are tasked with delivering the vaccine to these locations. This part of the experience takes on a more reader-driven approach, where the user can interact with the map and choose their next adventure, and when they explore the map, they can see information such as the country and region of the next adventure.

When an adventure has been chosen, the user will transition to a new scene. This scene will add more data about the transportation route, with which the user can interact. With data such as the distance and route displayed on a map, the method of transportation, the amount of vaccine that is possible to bring in one go, and the transportation time, the user is presented with the great task of distributing the vaccine to these areas. When the user is ready for the adventure, they are immersed in the environments by being presented with shorter animations in a first-person perspective from the route, highlighting the difficult terrain. After this more author-driven sequence, the user has delivered the vaccine and is brought back to the world map. By utilizing an element of gamification, the distribution highlight is increased on the map and the user can see the progress from their contribution. In order to reach the goal, the user can choose to take on more adventures in the not yet distributed areas of the map.

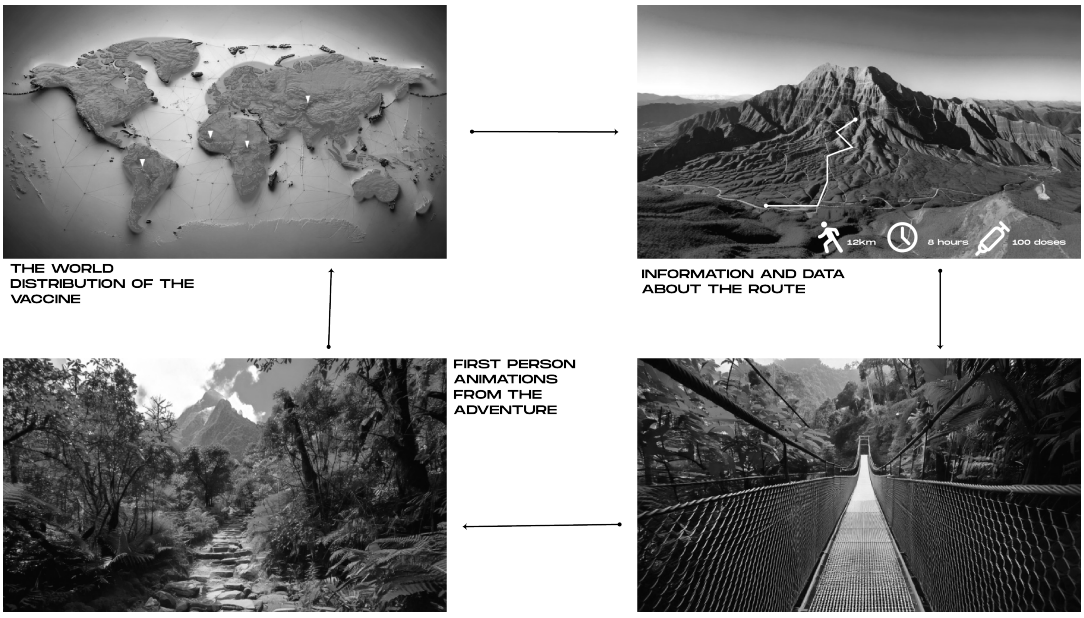


Figure 7.3: Storyboard for *The Vaccine Adventures*

7.3.3 The Life of Covid in Sweden

This experience tells the story of the Covid pandemic in Sweden. It aims to go through the timeline from the very first case of Covid in Sweden, to when the emergency situation was called off by presenting important numbers but also giving contextual imagery to enhance the storytelling aspect and immerse the people into the different important happenings in the timeline.

The experience is designed with an initial interactive 3D-map of Sweden, where the user is allowed to explore data freely. The data will be the numbers of the pandemic divided by the different regions of Sweden. The numbers refer to the number of confirmed cases, the number of people needing medical help, the number of deaths, and the rate of vaccinated people within each region. By using topology, the user gets a visual representation, combined with textual messaging, of how the spread of Covid has been within the different regions of Sweden.

At any time, the user can choose to experience the story of Covid by starting it on the interface. This will change the structure from reader-driven to author-driven, and a more linear progression of the data story will start. The story will be told through the map and key happenings that can be pin-pointed to specific locations will be highlighted on the map. As the narrative is presented, the relevant data will be presented visually, on the map, if applicable, and through narration. The story will go through key happenings in the timeline starting with the first case, moving along to the first death, when the vaccine came, and ending with when the situation of emergency was called off. The information presented will also include the effect that the pandemic had on the healthcare system, healthcare workers, and society as a whole to some extent. For the most important happenings of the story, the user will be immersed in a contextual environment through pop-up windows to attempt

to increase engagement and evoke emotions. This could be a first-person view of a hospital room, with a deceased person lying covered on a hospital bed, to highlight the first fatal case. The map will always be present, as the screen does not fully change when the user is presented with the contextual environments. When the story has ended, the experience goes back to the interactive map, the starting scene, allowing the user to explore the data freely once again.

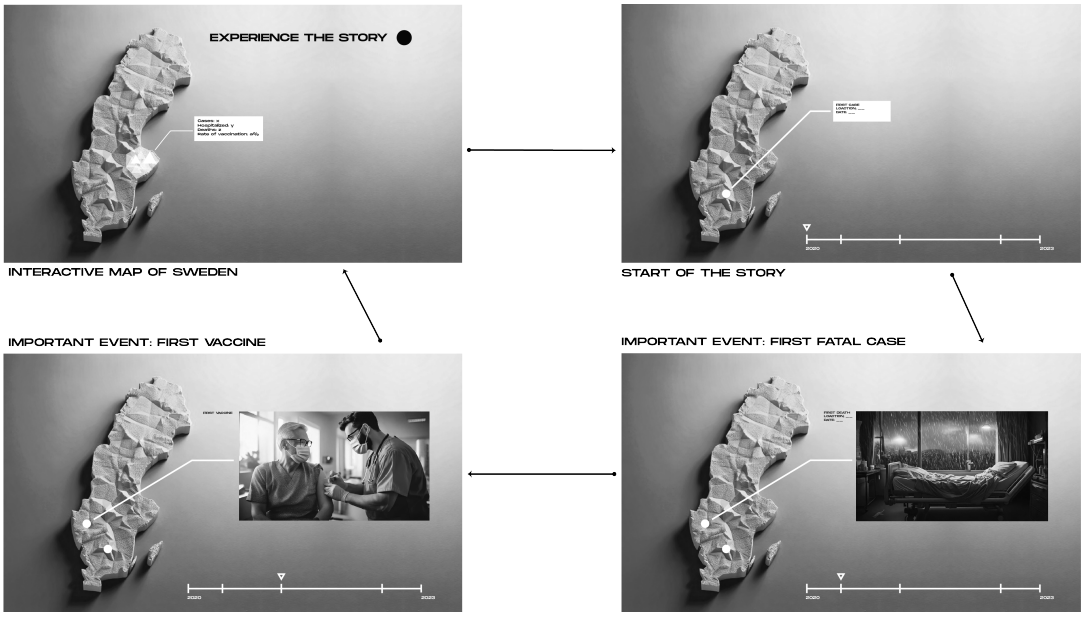


Figure 7.4: Storyboard for *The Life of Covid in Sweden*

7.3.4 The Unwanted Call

This experience aims to tell the story of traffic safety in Sweden and persuade people to consider traffic safety, by presenting data on the annual cases of fatal accidents in traffic. The experience is meant to be a physical installation and starts off with a pre-recorded phone call where a first responder is calling someone and delivering the news that a relative has passed away in a car accident. The purpose of this is to draw the viewer in to the experience with this dramatic start. The data story then starts by presenting the number of phone calls received in the beginning of 2025. This establishes the phone, and more importantly the phone call, as the personal connection to the viewer. These phone calls had the purpose of delivering the news that someone has died in a car accident, giving the first data fact. With this first data fact, the viewer is introduced to the data visualizations, which are designed to be abstract to visually attract the viewer.

The story continues in this abstract environment, where the narrator presents the facts in a linear and author-driven way. The viewer is presented with the numbers of previous years, from fatal cases, injuries, division between genders, vehicle type, etc. After the data is presented, there is a pause in the story for the viewer to interact with the data if they desire, opening up to reader-driven approaches. When they feel satisfied with their exploration, they can proceed with the story, returning to

an author-driven approach. The story nears its climax by presenting the zero-vision, that Sweden should reach zero fatal traffic accidents. Previously reached stage goals for this vision are presented, where the numbers have decreased since the initiation of this vision. The user is once again allowed to interact with the data freely and to see the progression over the years.

Finally, the story reaches its climax by presenting the current goal, which is to further decrease the number of deaths, but also state that the decrease that we have seen during the years have stagnated. The number of current deaths in the year is presented. The narrative that all these fatal incidents have given the same amount of phone calls, and the experience brings the viewer back to reality, by mentioning that the next call might be received by themselves. To bring back the viewer to reality, after experiencing the abstract visualizations, after the narrative that the next call might reach them has been presented, a physical phone rings, indicating that this might happen to anyone.

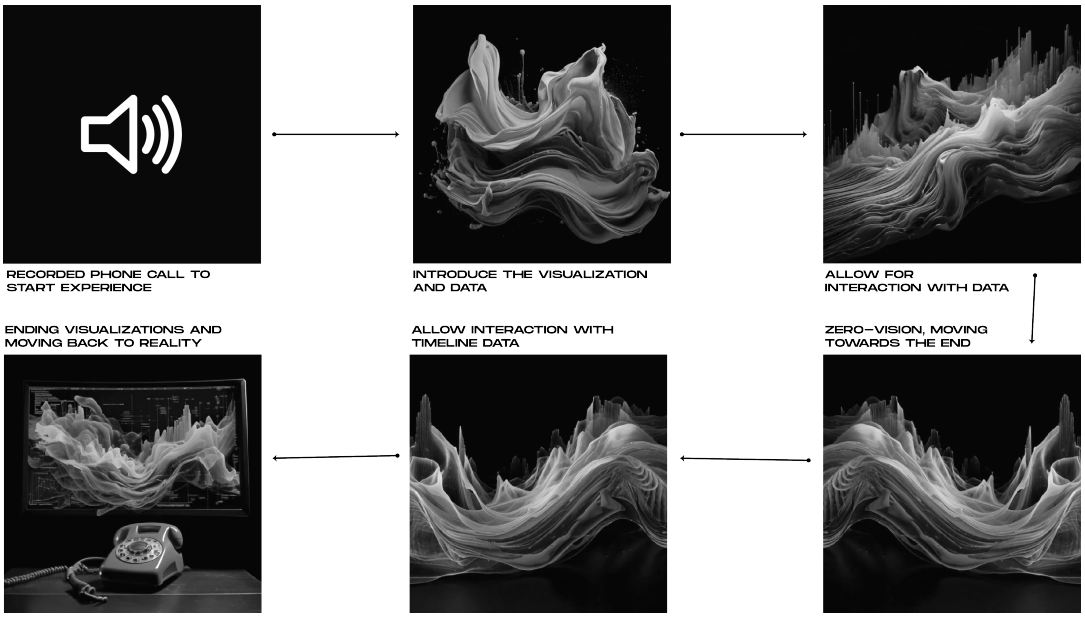


Figure 7.5: Storyboard for *The Unwanted Call*

7.4 Interactive prototype

The concept *Our World at 2°C* was chosen as the story to bring to further development. The topic of global warming and the effects it has on the earth is a relevant topic that also has a lot of accessible data to use as material for visualizations. The initial pitch for this concept involved a representation of Earth in the shape of an interactive globe, and different scenarios that the user could experience that would present the effects that global warming has on the Earth. These scenarios were initially meant to be presented with a more realistic environment type, with the idea of immersing the viewer into the context of where these effects take place. However, for the final prototype, the design of the visualizations would take a more abstract approach. The reason for this was partly to fit the design work into the time scope of

the project, with the possibility of focusing on effective communication with simpler elements and thus benefiting from the principles of abstraction in design. In conclusion, the visual approach for the experience would be using primitive objects such as spheres and cubes to represent world environments, to create an environment type that is a blend between abstract and realistic.

7.4.1 Planning the experience

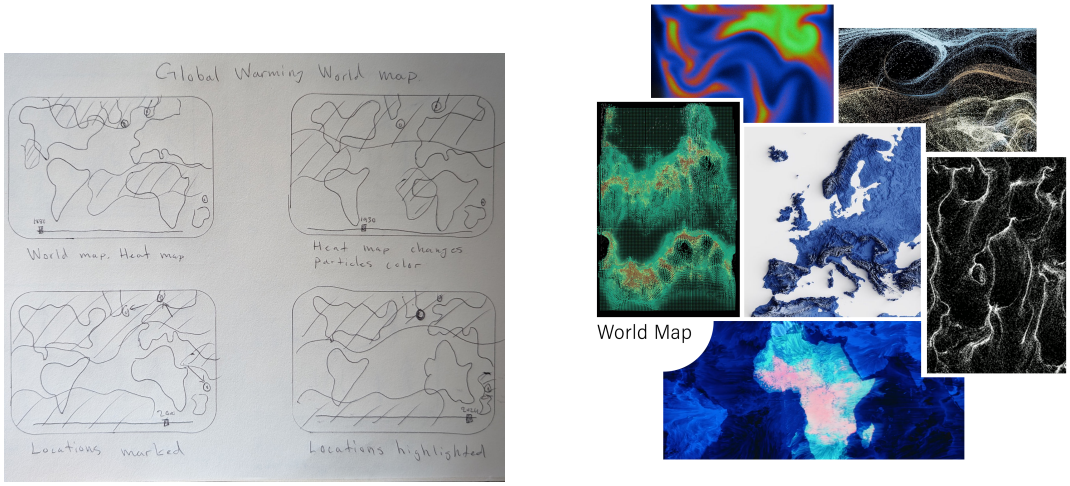
The process of creating the final prototype began with the creation of a plan for the entire experience using the created design space as a framework. The main theme of the experience would still be global warming and the different effects this has on Earth. There are many stories, narratives, and effects that can be presented regarding the effects of global warming, but for this experience, it would be limited to three different scenarios, in addition to the overall temperature increase. The different scenarios were chosen based on information about global warming presented by NASA [53]. Wildfires, Melting of ice sheets and Marine heat waves were chosen as the three major effects to be presented in the experience. In addition to this, the data to be used for visualization would be the average increase in temperature every year, the temperature increase difference throughout the world as heat maps, and the mass of ice sheets lost [54], [55].

To pin point the purpose of each visual scenario, the process involved listing the different emotions that each scenario would aim to evoke in the user and how the experience would evoke these emotions by presenting contrast between the normal state and the effects of global warming. These contrasts were visual changes in the scenario, but also the use of audio to create an immersive soundscape that would assist in facilitating the emotions and presenting the contrasts. The set of targeted emotions varied slightly between the different scenarios, but they all had a similar progression starting with the normal state, which could be feelings of harmony and calmness, or feelings of life and vibrancy. But these emotions would shift more into unease and urgency as the effects of global warming are presented, and in the end the desired emotions would be in the realms of grief, emptiness, or hopelessness as the environment is ruined by the extreme conditions. For each scenario, an initial idea of what kind of technology within the software would be used to create the visual elements was outlined, but also how the data could control and alter the appearance of the visualizations. A descriptive scenario, storyboard, and moodboard were designed to create a representation of how visual scenes would progress through the narrative stages, how emotions would be facilitated, and to obtain a reference of the visual style for the experience.

7.4.1.1 World map

You find yourself watching a map of the world. All the different continents that you know, covered in the vast and gigantic sea. Over the world, there is a flowing atmosphere always in motion. The atmosphere consists of a range of colors, where different nuances cover different areas of the world. As you travel through the years, the nuances shift across the map. The world is in a constant state of change. As

you get closer and closer to our present time, the atmosphere seems to turn more and more vibrant, as the nuances get warmer and warmer. The map is covered in different markers, placed on different places of the world. You focus on a marker, and its appearance changes, it seems like it is calling for you. Your curiosity is sparked, and you start to wonder what story might lie hidden there?

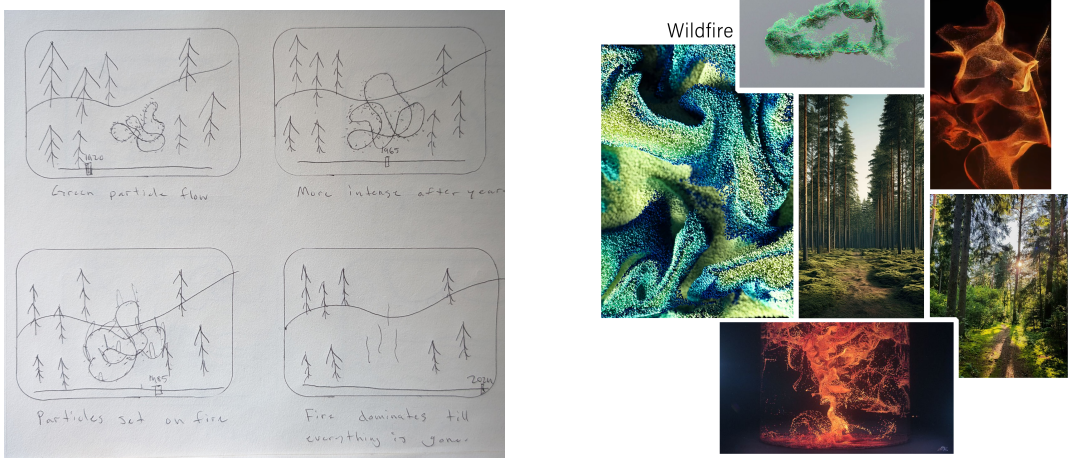


(a) World Map Storyboard (b) World Map Visual reference

Figure 7.6: World Map Storyboard and Visual reference

7.4.1.2 Wildfire

You find yourself in a small grove inside a Scandinavian forest. You stand on a small path, surrounded by the harmonic forest and the sound of birds chirping around you. As you travel through time, you start to hear a crackling sound and you can see sparks emitting from the tree tops. As the years move along, the spark becomes even more present, and the forest that surrounds you is being blended with a fiery element. The wind grows in intensity, and now the forest is being swallowed by a blazing storm. The green life that we once saw, is suffocating in the relentless flame, and greenery now turns black. We arrive today, nature is gone, and all we can see is fire. All that is green has been swallowed and turned to ash. There is no more to set ablaze, and the spark that once was set to life, now slowly fades away.

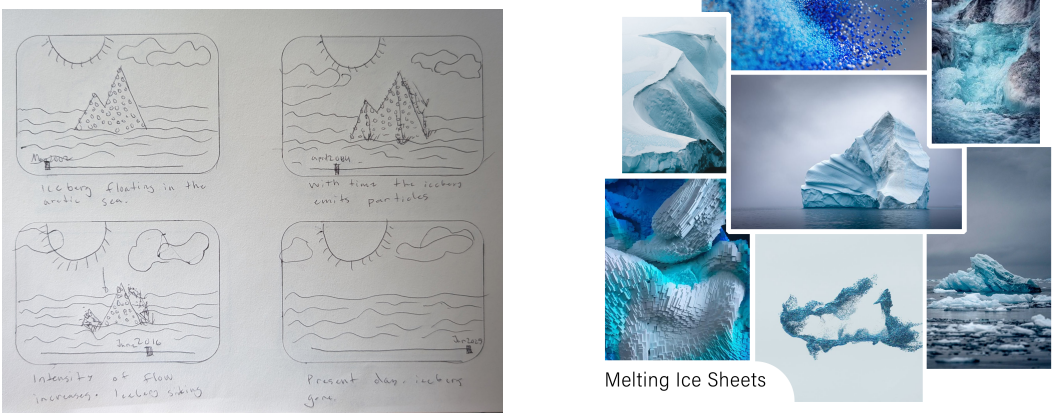


(a) Wildfire Storyboard (b) Wildfire Visual reference

Figure 7.7: Wildfire Storyboard and Visual reference

7.4.1.3 Ice Sheets

You find yourself somewhere drifting in the arctic ocean, some miles from the coast of Greenland. The sun is shining brightly, and the sea is gently rocking you with its small waves. You stand before a colossal giant, a big compound made up of small, white, and icy cubes. The drifting giant is a big iceberg floating freely across the sea. As a drifting observer you see the big iceberg emitting smaller, blue spheres rolling across the sides, and disappearing into the ocean. As you see time moving along, the flow increases more and more. The iceberg seems to eventually slowly sink down into the water, or is it the ocean that is creeping up along the walls of the iceberg? This colossal giant of spheres, slowly sinking and disappearing, and eventually becoming one with the vast ocean. As we arrive at present time, there is no iceberg left, no colossal giant guarding the Arctic sea. All that is left is you and the gentle waves, slowly rocking you across the sea.

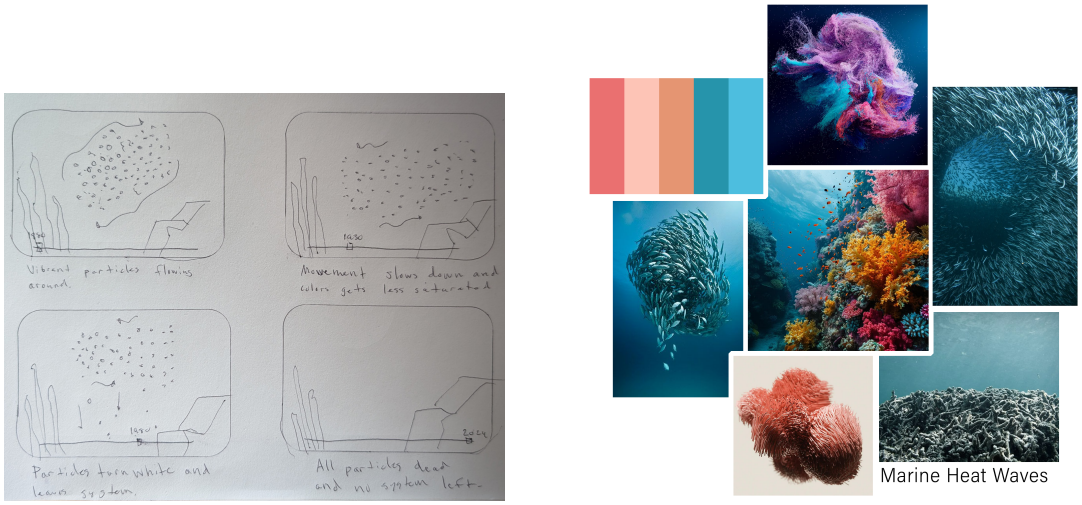


(a) Ice Sheets Storyboard (b) Ice Sheets Visual reference

Figure 7.8: Ice Sheets Storyboard and Visual reference

7.4.1.4 Marine Heat Waves

You find yourself submerged in water, somewhere outside of the coast of Queensland Australia, in The Great Barrier Reef. You are beholding a great shoal of vibrant colors, flowing along in a great and living unit. Every single particle, a living organism in the vast ecosystem of the Great barrier reef. You are watching this wonder of the world through the years, where the movement seems to shift up and down. After some time, you realize that the shoal moves slower and slower, and the sense of life is slowly disappearing in front of you as the vibrant colors seem to lose their saturation. As you move further into time, the ecosystem seems to steadily die. The particles lose their speed, their vibrant colors are bleaching, and one by one they fall out of the gigantic unit. As we get close to present time, the particles are steadily falling off, every one of them white out, sinking to their grave. We arrive today, and there is no shoal left, only an empty and bleached sea.



(a) Marine Heat Waves Storyboard (b) Marine Heat Waves Visual reference

Figure 7.9: Marine Heat Waves Storyboard and Visual reference

7.4.2 The final prototype

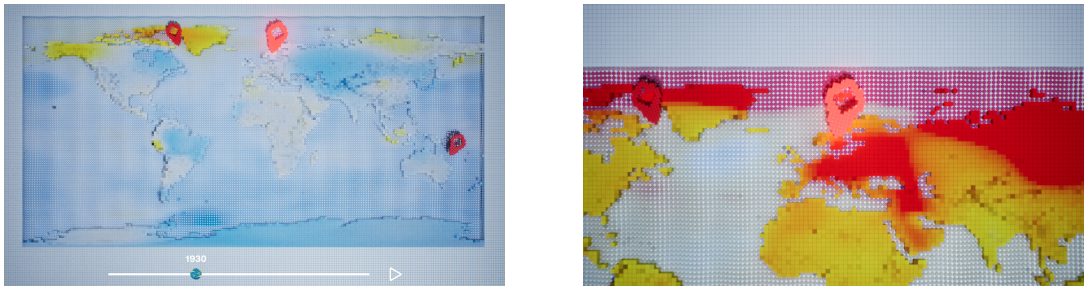
The final prototype is a fully interactive experience consisting of four different visual scenes. The experience is designed with a drill-down story structure with a mix of reader- and author-driven approaches. The experience maintains most of the ideas based on the planning, with some slight changes in different areas. Every visual scene and the data visualization within it use Niagara systems, which is the main technique to create visual effects within Unreal Engine 5 [56].

7.4.2.1 World Map

The world map is the first visual scene with which the user interacts and acts as the starting point for the drill-down story structure. The user takes the role of an observer and sees the entire world from a birds-eye view. The colors that cover the world change every year and represent the increase in temperature in different areas of the world. This is also the first instance of data visualization as these colors are derived from heat maps provided by NASA [54]. In addition to the visual elements, the user is met by the sounds of a howling wind, and eventually music, to create a soundscape that aims to elicit some unease in the audience.

The common theme for all visual scenes is that the user in a sense interacts with the environment by interacting with the data. The user interface consists of a slider and a play-button. By changing the position of the slider, the user moves along the timeline. The temperature distribution map for every year is displayed, and the environment changes based on the position of the slider. This also provides the user with visual structuring, by highlighting where the user is positioned in the timeline. By clicking on the play-button, the user can start an animation of the timeline, see Figure 7.10a. The story starts with a very reader-driven approach, as the user can choose the order in which they experience the different scenarios. scenarios are

triggered by clicking on the map pins that are scattered across the map. The pins are highlighted by an increase in size and a glowing color to give the affordance of a clickable element, see Figure 7.10a. The user interface also uses audio ques for hovering and clicking to further guide the user through the experience. In order to guide the user smoothly between the scenarios, an animation is played when a pin is clicked, which moves the camera closer to the pin, followed by the image and audio fading out. This transitions the user into the scenario, which fades in in the same way, see Figure 7.10b.



(a) Highlighted pins from user interaction (b) Camera zoomed in on clicked map pin

Figure 7.10: The World Map starting scene

7.4.2.2 Wildfire

All the scenarios that the user can dive into from the map are seen from a first person perspective where the user still has the role of an observer but now they see the environment as they would be there themselves. Diagetic methods of presenting data is implemented in the scenarios, where the environment changes based on the values from the dataset. The data used for the wildfire scenario is the temperature increase every year. As the user interacts with the slider, a fire in the forest will become more prominent, where the green tree particles turn into glowing fire and ash, combined with a crackling fire sound that increases in volume as the fire gets closer to the viewer. As we move towards the end of the timeline, the flames start to move more and more with the wind, which is an effect that is controlled by the temperature number from the dataset. The user interaction with the data affects the environment and after a certain point, the possibility of moving the slider back again is disabled. This is to discretely showcase the effect that humans have on the world and that we have gone past a point of no return. As we reach this point, a message will appear on the screen, combined with a red pulsating overlay, and a lower bass tone, to highlight this contrast and give the user a sense of danger and urgency; see Figure 7.11b.

These scenarios provide the user with the choice of experiencing it through a reader- or author-driven approach. When the scenario starts, the user can choose to interact with the slider to move along the timeline. But they can also choose to click on the play button, which starts an animation of the timeline, from the point the slider is currently positioned. This button is also a required interaction, as it is the way to see the climax and end of the scenario, and can be used at any point in the timeline; see

Figure 7.11c. When the timeline reaches its end after clicking the play button, the user interface fades out, and the final state of the environment is presented. For the wildfire, we are left with a forest that has turned to ash, the colors have shifted from green to black, and the sounds of a living forest have been replaced with a howling wind, see Figure 7.11d. To further highlight the contrast between the normal state and the final state of the environment, the atmosphere is also slightly changed, from a bright sky in the background, to a gray and slightly foggy background.

(a) Wildfire increases with the timeline

(b) Point of no return with highlighting

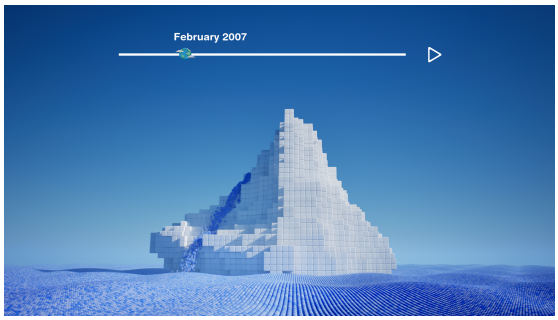
(c) Play button ending scenario

(d) Scenario ends with the ashes of the forest

Figure 7.11: The Wildfire scenario

7.4.2.3 Ice Sheets

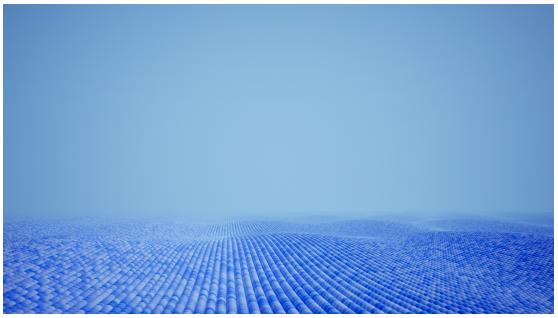
The iceberg scenario uses a dataset of how much mass of the Greenland Ice sheets has been lost. The user is met with an iceberg floating in the sea. As the slider moves, a flow of particles is emitted from the iceberg. The intensity of this flow is based on the value from the dataset. At a certain point in the timeline, a new flow appears from the iceberg. The visual particle system is combined with the sound of flowing water, which becomes louder and more intense as the flow increases. To highlight the urgency even more, the iceberg sinks a few steps at certain points in the timeline. In the end of the scenario, the iceberg starts to sink and becomes submerged by the ocean, and we are left with an empty sea. The atmosphere is also changed here with the aim of creating a more gloomy environment to highlight the loss of the iceberg, by going from a clear sky to a more gray and foggy background; see figure 7.12.



(a) Data points controls flow of water

(b) Iceberg sinks gradually with the timeline

(c) Iceberg disappears into the ocean

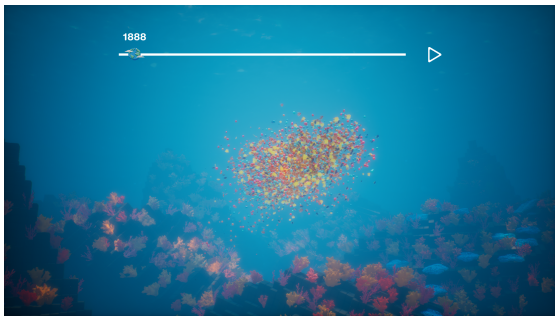


(d) Scenario ends with an empty ocean

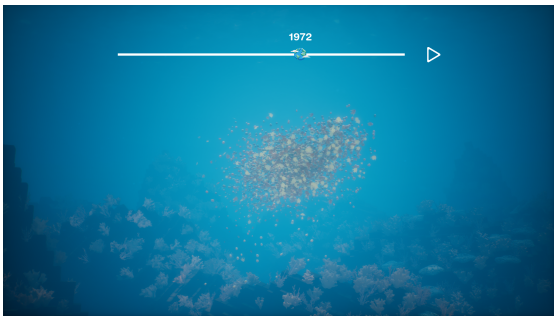
Figure 7.12: The Ice Sheets scenario

7.4.2.4 Marine Heat Waves

The data used for the marine heat waves is the increase in global temperature over the years, and the scenario aims to highlight coral reef bleaching as an effect of global warming. The user is met by a shoal of fish and coral particles beneath the ocean, which moves with a bubbling sound. As time goes on, the movement of the shoal is slightly dampened, which is controlled by the numbers in the dataset, and the bubbling sound decreases in volume. At certain points in the timeline, we can see bleached and dead particles falling off from the shoal and sink towards the bottom. After a certain point in the timeline, the system and the surrounding environment lose some of its vibrant color and begin to bleach out. We can also see more particles dying and sinking from the shoal. As we reach the point of no return, the particles are fully bleached and steadily dying off one by one. As the scenario ends, all the particles lose their flowing movement and instead sink towards the bottom, and the surrounding environment has gone from bright and colorful to dark and gray; see Figure 7.13.



(a) Vibrant shoal of fish and corals



(b) Vibrant colors are gradually bleached

(c) Members of the shoal dies and falls of the system

(d) Scenario ends with the death of all organisms

Figure 7.13: The Marine Heat Waves scenario

7.5 Evaluation

This section aims to present the result of the evaluation of the final prototype. The evaluation involved two parts, a controlled observation and a semi-structured interview. The evaluations were conducted in a studio at the University of Chalmers, see Figure 7.14.

7.5.1 Observations

The result from the observation include a summarization and conclusion based on how the interactions went during the tests, and noteworthy comments and discussions that occurred from the users during the tests for each visual scene.

7.5.1.1 World Map

For the World map, the interaction with the user interface varied between the tests. In one of the tests, the users started to interact with the slider themselves almost immediately. But in all the other tests, the users did not interact with the slider themselves until later in the experience, when they had already viewed one of the environment scenarios. The interaction with the play button seemed to be slightly counterintuitive for most tests, as people tried to use it as a way to pause the timeline. But the play button only starts the animation of the timeline if it is already paused, and pausing it is done by moving the slider manually.

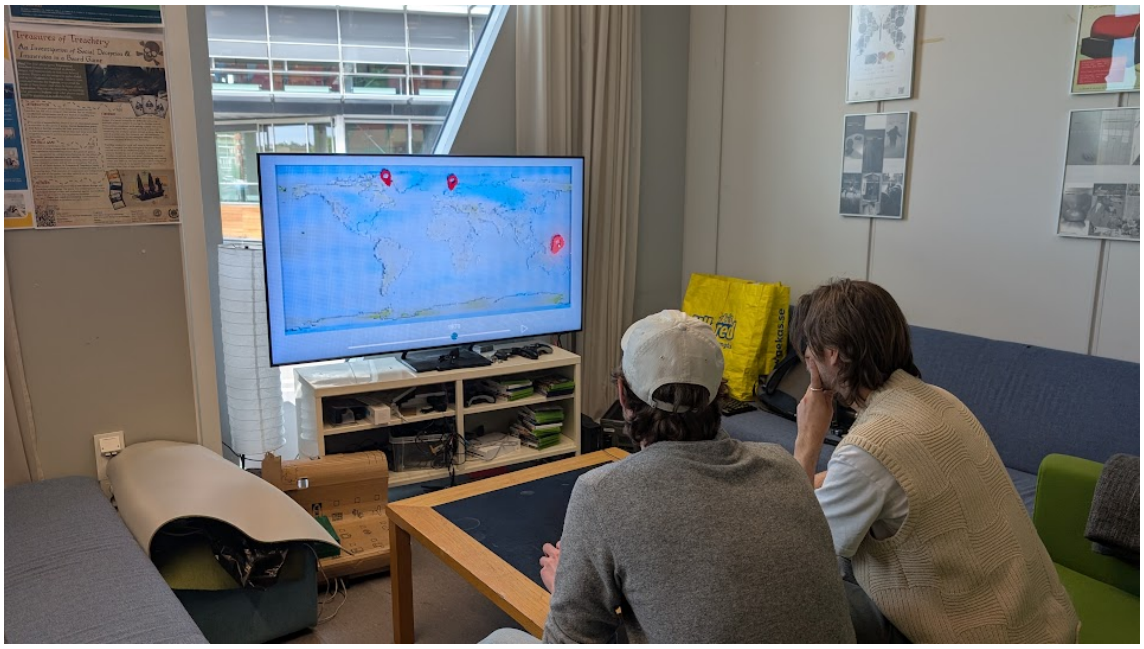


Figure 7.14: The setup for evaluations

The interaction with the map pins came intuitively and quickly for three test subjects, and for one of the tests it came after some time. However, in this test, they found this by hovering over the pins and receiving visual and auditory feedback, which intrigued the users about this newly discovered function. In one of the tests where they quickly discovered the pins, they also expressed intrigue after receiving the feedback.

The World map scene created the most engagement in the sense that it was the most discussed scene. In all of the tests, users went back and forth in the timeline, comparing the color distribution for different years, and discussed what these changes might mean. In every test, the users mentioned that the meaning of the colors could be the change in temperature for different parts of the world, which is what the data represent. But some pairs also mentioned that it could be the pollution density for different areas of the world. This uncertainty of the visualizations meaning sparked a lot of discussions and increased the overall engagement for the experience.

7.5.1.2 Environment scenarios

The way in which users interacted with the different environment scenarios varied between the tests. In the wildfire scenario, only one group interacted with the slider in their first visit. All the other groups clicked on the play-button directly, and got the narrative presented in an author-driven approach. Similar behavior was observed for the other environment scenarios, where users chose to play the scenario with the play-button, at least the first time experiencing it. For the tests where the users went back and explored the environments a second time, it was more common to interact with the slider and explore the scenario more freely.

The Wildfire scenario created some discussions about what the meaning of the burning forest was. One group thought that the forest fire was not a representation of wildfires due to climate change, but rather a metaphor for humans over consumption of the world's resources. Their reasoning for this was that they did not associate wildfires with Sweden, which is where the map pin pointed, but rather other places such as California or Australia. This also created discussions around what "Point of No Return" meant in this case, if it was the loss of forests and trees, or more generally about earth's resources. In another test, they also questioned the presence of wildfires in Sweden, and discussed whether the scenario was an inaccurate representation of reality. But this also led to comments about the fact that this scenario might be more aimed towards the future, and highlights that Sweden will have more wildfires in the future.

Even if all the users might not have interpreted the intended message completely, all the discussions about the visuals and what it represents is a sign of engagement towards the experience.

One of the more interesting notes for the Ice Sheets scenario was that many users mentioned that the slider had a different timeline, where one group explicitly said that it must be based on a different dataset, indicating that in this case the users understood that the experience was based on data.

In general, the amount of discussion for this scenario was rather low. One group mentioned that it was very interesting that the sequence of events was very fast paced. Another group discussed that the message of "Point of No Return" was very discouraging during this scenario. This group also returned to the scenario a second time and interacted manually with the timeline to see when we had reached the point of return. Despite the lower degree of discussion, these observations indicated some sort of engagement towards experience and its theme.

One of the more prominent examples of engagement for the Marine heat waves scenario was that many users explicitly predicted the bleaching of particles. Partly based on previous knowledge, but also because they had already seen other scenarios and built up an idea of what the experience is about.

7.5.2 Interview

The interview section of the test provided users with the opportunity to explain how they had interpreted the experience in terms of what the visualizations depicted, but also if they understood how to navigate the experience, and what the overarching theme of the experience is.

What did you see during this experience? When asked to describe what they had seen during the experience, all users gave similar responses about seeing visualizations of global warming or climate change, and how this event is affecting different environments in different parts of the world. This showed that the overall

design of the visualizations was clear enough, as all interviewees interpreted the general concepts correctly. Here an interviewee also mentioned the point of no return. Even if they said that it was not completely clear what this message meant, they mentioned that the feature of not being able to go back in the visualization gave them an uneasy feeling.

Did you understand how to navigate the experience and what helped you understand that?

Overall, the users found the interface easy to understand and said that it helped them understand how to navigate the experience. The slider for the timeline, at least for the World map, hinted at the possibility of moving back and forth in time. The slider moving automatically in the beginning was also mentioned as a good hint of being able to interact with it.

In two tests, it was mentioned that using a computer mouse as the tool for interaction also hinted at the possibility of interacting with the visual itself, and in that way interacting with the map pins. The auditory and visual feedback from hovering over the map pins was perceived as helpful affordances to understand their function. Especially in the first test where the users did not discover them until after some time, when they accidentally were hovering over them.

Could you understand what happens during each visual scene and how could you draw that conclusion?

This question was asked for all the different visual scenes. The world map seemed to be the most difficult to understand, and all the groups said that they had to think about it for some time before they made their final interpretation. As mentioned during the observations, despite being more difficult to understand, this visual scene led to many discussions about the visualization, and thus engagement in the experience. In one case, the interviewees explicitly stated that this uncertainty was appreciated, as you had to explore and compare different years to interpret the meaning of the visuals.

The wildfire scenario was the most unclear, in the sense that users could not pin down its underlying cause. It was clear for all that what they saw was a wildfire, but as many did not associate wildfires with Sweden, but rather places like California and Australia, the interpretations varied. In one test they tried to find a different meaning for the scenario, which was that the wildfire represented the overuse of the worlds resources. The visual itself however, was easy to interpret as a wildfire, and one comment mentioned that the use of sound in the scenario assisted in adding context to the visualization.

The Ice sheets visualization was the easiest to comprehend, with its straightforward imagery of an iceberg melting and sinking into the sea. An interviewee mentioned that the waves of the ocean, combined with the particles emitting from the iceberg

being of the same material, created an intuitive representation of an iceberg in the Arctic ocean.

The Marine heat waves scenario seemed to be the most appreciated scenario. It was said to be the most effectful visualization by one group, as it represented living organisms dying due to the effects of climate change. With the bleaching of particles, it is also more prominent that something beautiful is being destroyed. One group also mentioned that colors are often associated with life and living things in general, making the loss of these colors very powerful. In regards of what the shoal of particles represent, one group mentioned that it might be difficult to comprehend what the particles represent and that it is up for discussion. Another group mentions that the shoal represent sea life in general, with the different colors and particles representing the entire ecosystem.

Could you understand what the underlying theme of the experience is?

In many of the interviews, users gave an answer for this in the first question, by saying that they saw global warming and its consequences. In one case, there was a comment about the fact that humans have already done so much damage, which makes it feel like we are at the end. Another important comment that highlights the Point of no return, and the feature that you cannot go back in the timeline after crossing it, was that the experience represents our actions. The comment stated that the experience is participatory, where the movement of the slider represents real life actions, and the effect it has on the environment. This was a great example of where engagement in the experience led to real-life reflections.

Additional discussions

The interviews often ended with an open discussion between the users and the interviewer that provided additional information about the experience.

In one of the tests, the users mentioned that crossing the point of no return and seeing the final ending of the scenarios gave a feeling of hopelessness, which was one of the desired emotions in the design of the experience. However, the interviewees stated that they would have liked more information on what can be done to prevent further destruction. They also mentioned that this feeling of hopelessness might have been intended, but this comment highlights how important the general purpose of the experience is. A comment from another group that relates to purpose was that the melancholic atmosphere of the experience, to which the music and quite anticlimactic endings contributed, felt more effective in conveying the reality of the visualizations, compared to dramatic music.

One group mentioned that they appreciated the format in which the experience was presented, that is, with less text and concrete information and more visual elements. They said that this style made you more curious and engaged in trying to interpret the content. In addition to this, the interviewees felt that the soundscape was a

big part of the experience and made it easier to comprehend the seriousness of the different scenarios as the soundscape changed with the visualizations.

To see notes and quotes from the evaluations, see Appendix D.

7.5.3 Result summary

The result of this project can be summarized and categorized into four different findings.

- A design space with key factors to take into consideration when integrating narrative storytelling and data visualization in 3D-environments, derived from existing research and theory within data storytelling.

- A set of different data story concepts created using the design space showcasing how it can be implemented for different data subjects.

- A final high-fidelity prototype and a design process that illustrate how you can design and develop an engaging data story within an interactive 3D-environment.

- A user evaluation that gives examples of user interaction and engagement, but also important points for discussion in regard to the prototype, the design space, and whether it consists of key factors for promoting user engagement and enhancing emotional connection and understanding of complex data.

8

Discussion

This chapter aims to present discussions surrounding the project, including process reflections, the design space, key findings from the design challenge, generalizability, ethical issues, and proposals for future research.

8.1 Process reflections

This project was done alone, which meant more responsibility and workload. The practical design challenge of developing a fully interactive prototype in Unreal Engine 5 was also something that I was not familiar with before this project. This task was itself a big challenge, in addition to building the theoretical foundation and the early design solutions. Despite these challenges, I consider the project successful and can say that the process has followed the planned project timeline. The supervision sessions during the process were very helpful, both from Chalmers and also from Brickland. Working in collaboration with a company like Brickland has been an interesting and educational process. Combining and integrating perspectives from both the industry that Brickland provides, and the more scientific and academic perspective from the nature of this project being a Master's thesis at Chalmers, has been a fun and creative process in itself. I also believe that this combination is essential in the subject of data storytelling, where scientific data can be presented through entertainment, which is often the purpose of visualization for companies like Brickland.

During the development process, a lot of time was spent programming and building up the different scenes within Unreal Engine 5. The preparatory work done at the start of development made it possible to always have a solid design foundation to look back at. Although iterative and exploratory, the development process could have benefited from continuous evaluation sessions. During different times in this project, the vision was very clear for me as a designer, but could be more difficult to understand for someone not invested in the project. Supervision sessions did help steer the project towards a greater result, but evaluations of lower-fidelity prototypes during the process could have provided more insight in how users perceived the visualizations.

8.2 The Design space

This project successfully created an interactive and immersive experience within a 3D-environment that uses data as inspiration and source for visualizations. The foundation upon which this experience was created was a design space with some of the key factors extracted and compiled from previous research on the subject of data storytelling, see Figure 7.1. The extensiveness of the design space, with its nine different categories, combined with the extension of Freytag's Pyramid for data stories created by [23], provides designers with a solid foundation of key factors to consider when creating immersive data stories in 3D-environments. The design space has a very broad range of factors that bring up many different important factors that must be considered. With the category **Data and purpose**, the designer has to get an understanding of the data and also define the purpose of the experience, which will influence how you design the entire experience. With **Narrative stages** and **Driver**, the designer can build up the narrative in connection to the presentation of data, and the approach of how this narrative is presented through an author- or reader-driven approach. **Environment**, **User perspective**, **Visualization design**, **Interactivity** and **Progression and guidance**, are categories that focus more on immersive parts of the design process, with the intended environment, role of the user and data visualizations. These categories are what presents the story, the narrative, and the data through visual scenes, and helps the user progress and interact through it. **Narration and messaging**, adds the possibility of integrating more information about the data, or assist in presenting the narrative, with textual or auditory messaging, or narration. Depending on your purpose, this can further immerse the user or help them to understand the data to a larger extent.

All these categories are some of the key factors for creating an engaging and immersive data story. The design space, however, does not provide the users with any insight in which order these categories should be worked with. With the exception of starting with **Data and purpose**, it might be overwhelming to start the design process with so many factors to consider. But at the same time, many categories intersect with each other, and a decision within one category will affect your decision in another. One of the more prominent examples of this is the **Driver** approach that you chose. This is itself affected by the purpose of your experience. If a presentation of a story and its narrative is more important than the data itself, an author-driven approach is more suitable, and if exploration of data and patterns is more important, a reader-driven approach is more important. This approach will then itself affect categories such as **Interactivity** and **Progression and guidance**. As design is a highly iterative process, this design space can be used as a checklist of considerations when refining and developing a design.

In Section 7.3, the project presents four different concepts of data stories that include narrative structure and attempts to create emotional responses. In general, the design space can be considered a great tool for creating engaging data experiences, as it leverages emotions by including storytelling with narrative structures. One thing that the design space could perhaps improve upon is explicitly highlighting

the need to evoke emotions, either by developing a new category or by integrating it into an already existing one.

8.3 Design challenge findings

The final prototype is a great practical example of what kind of data experiences you can create within interactive 3D-environments. The use of data to control and change visualizations is a great example of how you can implement datasets and visualize them in a creative way within the context of 3D-visualization. These more abstract and creative visualizations also highlight the method of using visualization to make people feel the data, rather than trying to present numbers. This strategy of trying to create an experience where users feel data could arguably be more effective in engaging the users and making them remember the message of the experience.

The final prototype was evaluated to determine whether its design effectively created user engagement and emotional connection with both the data and the experience theme, giving an answer to whether the design space consists of key factors for engagement and emotional connection, which answers the research question.

What are key factors for integrating narrative storytelling and data visualization in 3D-environments to promote user engagement and enhance emotional connection and understanding of complex data?

8.3.1 Evaluation accuracy

The evaluation involved four separate tests, each conducted with two participants, totaling eight users, all of whom were students in the interaction design program. This specific user group likely had a deeper understanding of design and data visualization, which may have made the experience easier for them to comprehend and connect with emotionally. As a result, their engagement levels might not accurately reflect those of a more general audience. If the evaluation were to be repeated, it would be beneficial to include a larger and more diverse group of participants, particularly individuals without a background in interaction design, as the design is intended to be experienced as an installation at a museum, where anyone could visit. This brings us to the context in which the tests were conducted. All observations were made in a controlled environment in a studio at the University of Chalmers. The users were aware that they were observed, as the observations were not naturalistic. The controlled environment and the awareness of the test could affect user behavior and perhaps make them more focused and aware of the experience, and thus being more engaged. Even if there were no mentions of engagement being the main topic of observation, the result could have inaccuracies due to the more controlled context. It is important to take these potential issues into account when interpreting the result of the evaluations.

8.3.2 Does the design space foster engagement?

One of the most notable examples of user engagement emerged in the World Map scenario. Many participants did not immediately interpret the meaning of the visuals, which prompted a higher level of curiosity and led to collaboration between users to analyze and understand the content. This form of abstract representation was perceived positively during the interviews, and some mentioned that the lack of explicit information appeared to be an intended design choice that contributed to increased engagement. By not revealing too much, the prototype encouraged users to actively explore and form their own interpretations. This highlights how abstraction and ambiguity can be used as an effective strategy to draw attention and promote deeper user interaction.

The importance of visual cues, such as the map pins that are highlighted when hovering above them, became apparent during the evaluations. These elements served as critical affordances that guided user attention and maintained focus, showcasing that guidance and highlighting are key factors. Interactive design features such as the play button and timeline slider enabled varying degrees of user control across different scenarios. These interactions represent a combination of reader-driven and author-driven storytelling, giving users both structure and freedom and highlighting the importance of interactivity, but also how interactivity relates to the driver approach. Notably, some users chose to revisit the scenarios, focusing more on the data during their second visit. This not only demonstrates replayability, but also emphasizes the potential for interactive storytelling to support multiple modes of engagement, promoting narrative immersion or deeper data exploration.

Several moments in the prototype sparked confusion and reflection, further underscoring the role of engagement through ambiguity. In the wildfire scenario, for instance, many users struggled to associate Sweden with wildfires, leading to discussions and speculative interpretations. This illustrates a dual effect: while the lack of contextual information may hinder immediate understanding, it also encourages questioning and reflection. This highlights messaging as a key factor, but also how messaging can be designed to support your purpose. Limited messaging can foster critical thinking and speculation. But if the purpose of the experience is to educate and encourage, more detailed information would be necessary.

Other scenarios, such as the ice sheets, users noticed that the scenario followed a different timeline. Where some users mentioned that this scenario most use different data, suggesting a deeper understanding of the data-driven nature of the experience. In this case, the messaging on the timeline was a key factor in illustrating a different dataset.

In the marine heat waves scenario, often encountered later in the experience, users were sometimes able to predict bleaching effects before seeing it based on a formed understanding of the theme and previous knowledge on the subject. This scenario exemplified how the setting in the narrative stages, combined with the environment and visualization design, created an understanding about the theme of the experi-

ence.

The marine heat waves scenario was considered by many as the most impactful scenario. The reason for this was said to be that the shoal of particles represented something living and beautiful, and the death of them had more emotional impact than, for example, the Iceberg. This highlights the importance of including details in the story that resonate with users and that these emotions can be elicited with proper narrative structure. User perspective can also be a key factor in this case, where the user being a participant of a scenario immerses them in to the event and thus emotions are more effectively triggered. One example is that one participant reflected on how crossing a 'point of no return' left a lasting impression, particularly because their actions within the experience appeared to have consequences. This example highlights the potential of user agency to enhance emotional engagement and provoke reflection on real-world behaviors.

Some users reported feelings of hopelessness and expressed a desire for guidance on possible solutions. This suggests that if the experience is intended to inform or inspire action, it must clearly convey that through its narrative stages, visualization design, and interactive choices. This highlights the key factor of defining the purpose of your experience and working with the different categories of the design space to support that purpose.

Finally, the role of soundscape emerged as a crucial factor in the immersive experience. The participants noted that changes in audio not only reinforced the seriousness of the scenarios but also contributed meaningfully to their understanding. This illustrates how the soundscape in the environment can work together with the visualization design to enhance immersion. Moreover, it opens up the possibility of exploring non-visual data storytelling, where audio becomes a primary mode of communication. This could be a compelling direction for future research and design exploration.

Ultimately, the final prototype showcases how you can create engaging data stories in interactive 3D-environments. All categories in the design space are important factors in creating impactful data experiences for people to engage in.

8.4 A wicked problem

As wicked problems involve problems in which there are no definitive solutions, it can be argued whether the research questions of this project can be considered a wicked problem. The project set out to identify important factors for designing engaging data stories within 3D-environments, which has been done, and giving a clear answer to the research question. However, the wicked problem has been revealed during the process of this project. As mentioned previously, one potential flaw in this design space is that it does not provide any systematic approach on how to work with the different factors and in which order. It was also revealed that these factors are related to each other and that making decisions in one factor will

have consequences and limitations in another. This makes it very difficult to find a systematic approach to working with the design space, in combination with different data and different stories will also affect the how you implement the different factors. This dependency on data, story, and design choices in different factors makes this a wicked problem, as there is no definitive and general approach to implementing these factors in your experience, and that the approach will differ and change for every experience that you design.

8.5 Generalizability

That the design space is applicable to many different types of data is showcased in the early stages of the project's development phase. In section 7.3, four different stories and experiences are presented, all using different types of data and all with different combinations of author- and reader-driven approaches. All these examples however, are experiences based on very big and impactful themes. Themes such as global warming, the Covid pandemic, and fatal traffic accidents are areas that affect and have affected people worldwide, which automatically makes it more emotionally loaded. In these cases, it is a much easier process in extracting interesting narratives to present, in addition to a large amount of accessible data, which in turn makes the design space and data stories in general applicable across a wide range of topics. In section 7.2, the theme of responsibly sourced materials for the automotive industry was presented. This is another great example of a very emotionally loaded subject, with instances of child labor and poor working conditions as the main takeaways that could be presented. This example was not further explored in this project due to the complexity of the situation and the lack of easy accessible data, and therefor a greater challenge in creating a great data story. But it is an additional example of where the design space and data storytelling could be applied.

It is hard to tell if the strategy of data storytelling and the design space of this project are applicable to any data theme. As this project only focused on themes of higher significance, there are no examples of the design space being a solid framework for creating interesting stories out of smaller issues. The design space itself does not express how to create a story and find a narrative, but rather how to present an already existing story within a 3D-environment. Creating an engaging and emotionally loaded experience using the design space from a dull theme could be an interesting challenge in itself. But for future subject of research, it could be interesting to explore how to extract stories and narratives from data.

8.6 Ethical issues

Data visualization can play an important role in decision-making, as it provides decision-makers with a thorough understanding of the problem at hand. With data visualization, it is easier to see relationships and trends that otherwise are hidden in between tables of data [57]. The use of data storytelling combined with data visualizations has become an excellent tool to present data in an engaging way. The

use of narrative in data visualizations can enhance critical thinking, which in turn also enhances the abilities of decision-making. As these methods of conveying data are getting more popular, it is also becoming more and more important to consider various ethical implications that come with these methods.

When implementing narratives into data visualizations, it is important to consider biases. When you present raw data, the purpose is often to present the scientific numbers with an unbiased representation. In the case of data storytelling however, it can be discussed whether the total absence of bias is possible. As data stories want to present a narrative, and leverage emotional responses in viewers, you could argue that there will always be some sort of bias in the final representation. When you tell an engaging story, you are often doing it for the purpose of entertainment or conveying a message. And this entertainment factor requires there to be something that works towards evoking the desired emotional response. Take, for instance, the final prototype of this project. The desired emotion for the end of each scenario was often aimed at hopelessness, grief, or similar. These emotions connect to the purpose of conveying the message that global warming is something that affects the world negatively, and this intention to evoke negative emotions toward global warming can be considered a bias. In a complex subject of varying opinions, one way to work towards less bias is to include many different perspectives of the subject that can evoke emotions in many different directions, giving the user the opportunity to align themselves with the perspective that they most strongly connect to [57]. But at the same time, if you were to make a statistical analysis on this type of experience, and the opinions of the audience would swing more towards one direction, would that not make the experience biased? The subject of bias in data storytelling is complex, and perhaps it is impossible to completely eliminate biases. However, one step towards unbiased experiences is transparency. By openly communicating data practices, including how data is collected, analyzed, and used, you can build trust and ensure accountability for decision makers and users of data [57]. By ensuring transparency about the data and the process of collection it, it allows for people to examine the data themselves, validating it, and also contribute to the decision making [57]. In the case of the story and narrative involving some sort of bias, the designers can be transparent about this as well.

In regard to decision making, bad design of data visualizations could lead to inaccuracies and misunderstandings. Designers must ensure the accuracy of the data they present to avoid spreading misinformation [58], [57]. At the same time, to show contrasts in data with the purpose of triggering emotional responses, a designer might need to curate visualizations to make data differences visible. This creates another balance that a designer has to consider, where the data should be presented as accurate as possible, while still creating visual changes to present a narrative. On the subject of spreading misinformation, the different strategies presented in this paper could be used to create fake news. This could eventually be a problem, which further highlights the importance of transparency in data storytelling.

When it comes to accessibility, it may be challenging for people with different impair-

ments to use and understand data visualization effectively. An example would be people with visual impairments, which causes difficulties in analyzing visualizations and thus making the information inaccessible to these people [57]. In many cases, data can also be designed to be examined and explored by professionals and those with technical knowledge. If the information presented is essential for all members of a community to understand, it is important to consider the platform and its accessibility to people with both greater, but most importantly lesser technical tools and knowledge [59]. This highlights how the process of abstracting visualizations can be a suitable method to create accessible visualizations. By simplifying the data and creating effective visualizations, designers can focus more on letting users "feel the data" instead of remembering numbers, and the very essence of what the designer wants to communicate becomes accessible to more people.

8.7 AI, humans, and storytelling

With increasing use of artificial intelligence across many different disciplines, it is important to discuss the implementation of AI in immersive data storytelling. As AI has the ability to construct comprehensive and engaging stories from simple prompts, it can be discussed what role humans and AI will play in design work. Most often AI is trained on vast amounts of data and generalizes what it learns on new areas. This means that AI could most likely be used to design different data stories on different subjects. However, this project emphasizes a lot on the use of narratives in visualization and also on the importance of promoting emotional connection through the narrative. This brings us to a more philosophical approach to this question, whether AI can construct emotional stories without having any feelings itself? This is outside the scope of this project, but it is an important thing to discuss. And as a designer, I have my own personal views on this, that humans play a very important role when it comes to creating stories and experiences that elicit emotions, as we are the ones that can feel these emotions ourselves. AI could create a very emotional story, based on the data it has learned from, but how could it ever surely know if the story is emotional, if it is incapable of feeling these emotions itself? This is why I believe that human intervention is vital in the design of these types of experiences, if only to validate that the story and narrative presented by the AI evoke emotions.

8.8 Future work

One attribute of the **Interactivity** category, is to consider which tool to use for interaction. Similarly, the category **Visualization design** has an attribute that refers to what type of media display the experience will be presented on. For the final prototype in this project, the interaction tool was a regular computer mouse, and the media display an ordinary TV-display. The prototyping phase focused more on developing the visualization and the overall presentation of the narrative and data. As the TV-display is the most common media display, it was decided in this case to design the experience based on a native TV-screen in order to focus

more on the visualization design, and less on exploring possibilities with different media displays. In the same fashion, the experience was designed with the use of a computer mouse, as it would be to time consuming to explore and develop the design based on another interaction tool. Considering the aim of designing for engagement, it can be discussed whether these common tools contribute to that engagement. A great example of an interesting interaction tool and media display installation is the interactive installation made by FutureDeluxe, called Your System is a Garden, Too [52], seen in Section 7.2. In this project, the interaction is controlled by motion, but as a twist, it encourages the user to not move in order for the visualizations to change. The installation uses regular TV-displays as well, but the installation around it created an interesting atmosphere and overall makes the experience more appealing. An interesting avenue for future work would be to further investigate how the choice of interaction tools, display technology, and the overall installation design can enhance user engagement. Specifically, future research could explore the use of immersive technologies, such as virtual reality, motion control, and similar interactive systems, in the context of data storytelling, aiming to deepen engagement and advance the field of narrative visualization.

With the strength that data storytelling has in the aspect of communicating information in an effective and engaging way, which in turn helps people make well-informed decisions, it is a subject with great development potential, despite being a prominent subject for many years. This project has focused on some of the key factors for data storytelling in the medium of 3D-environments, by implementing the theory with popular and well-known subjects. In these cases, there has already been a prominent and commonly known story and narrative where the project has focused on presenting this story in 3D. As telling stories with narrative is a great way of engaging users, for future research, there would be great potential in exploring how to systemically analyze data in order to find and extract the specific stories and narratives within it.

9

Conclusion

This project set out to explore how narrative storytelling and data visualization can be meaningfully integrated into interactive 3D environments to foster user engagement and enhance emotional connection with complex data. Through analysis of existing research, key factors were identified and shaped into a design space, which was then explored through a series of conceptual data stories and ultimately realized in a high-fidelity prototype built in Unreal Engine 5.

Today, data is very important to us and help us understand the world. However, in its raw form, data is often inaccessible and hard to comprehend for many. Visualization makes data more comprehensible, and as data become increasingly complex, storytelling has emerged as a suitable strategy to make it not only understandable, but also emotionally engaging. By integrating narrative into data visualization, we can move beyond conveying facts to creating impactful and memorable experiences.

The use of 3D-environments in data storytelling is an exciting subject. It opens up possibilities for interactivity and immersion, offering users more engaging and dynamic data experiences. This project contributes to interaction design and data visualization by proposing a design space that brings together narrative storytelling and interactive 3D visualizations. This design space aims to bridge existing gaps and serves as a practical guide to design compelling data stories in 3D. The four concept designs developed from this framework illustrate its flexibility and potential across different data themes. The final prototype demonstrates how these principles can come together in a tangible and immersive experience.

For further research, I propose an exploration of how interaction tools, physical installations, and various display technologies can enhance engagement in 3D data storytelling. There is also significant potential in developing methods to systematically extract stories and narratives in any dataset, broadening the reach of data storytelling across different fields and helping to make data more approachable for the general public, and thereby fostering better-informed decision making.

This project has tackled a wicked problem, designing engaging and meaningful data stories in a complex, interactive medium. The process of combining research, design, and 3D development has challenged and expanded my skills, creativity, and tenacity.

I hope that the proposed design space, the demonstrated design process, and the final prototype can serve as both inspiration and as a practical resource for those working with data storytelling in 3D, but also elicit further curiosity and research on the subject.

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A

Freytag's Pyramid for Data Stories

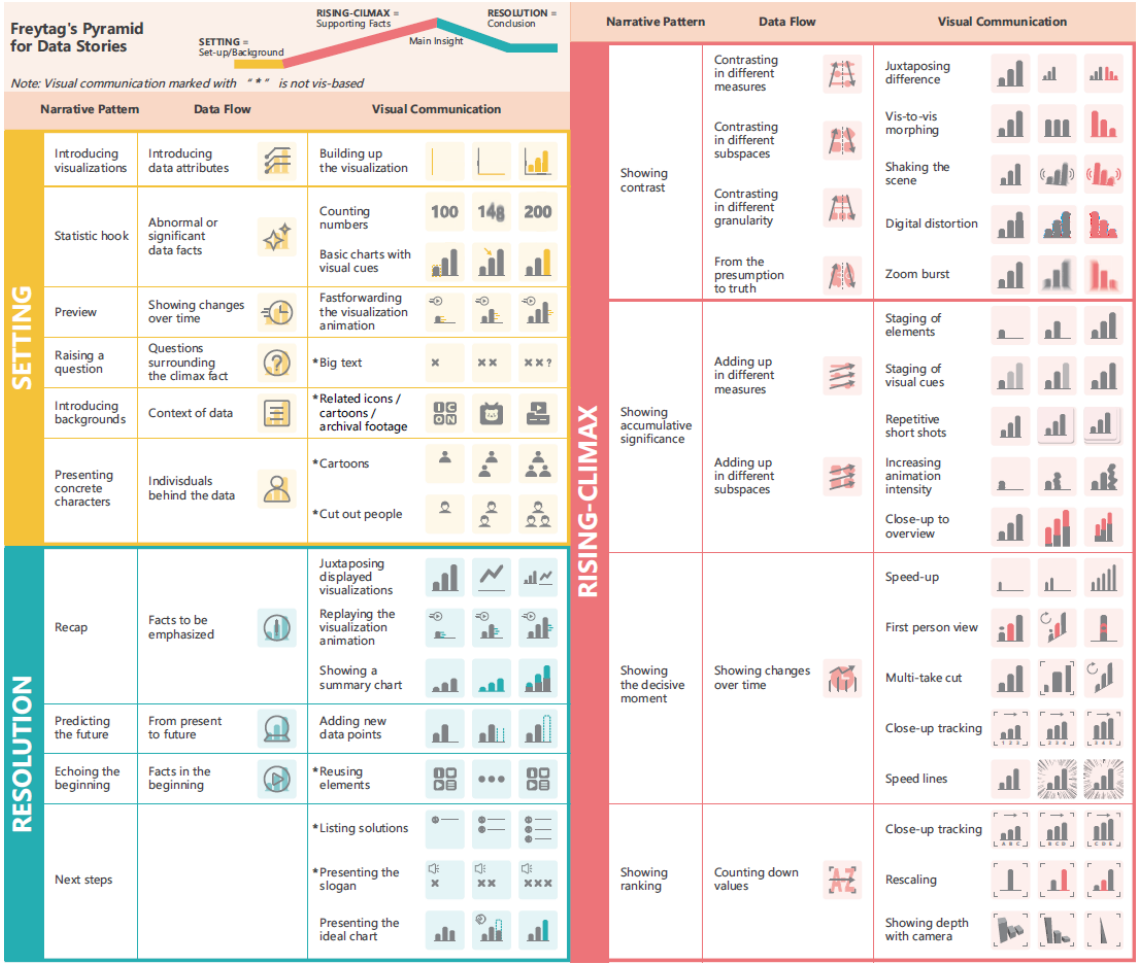
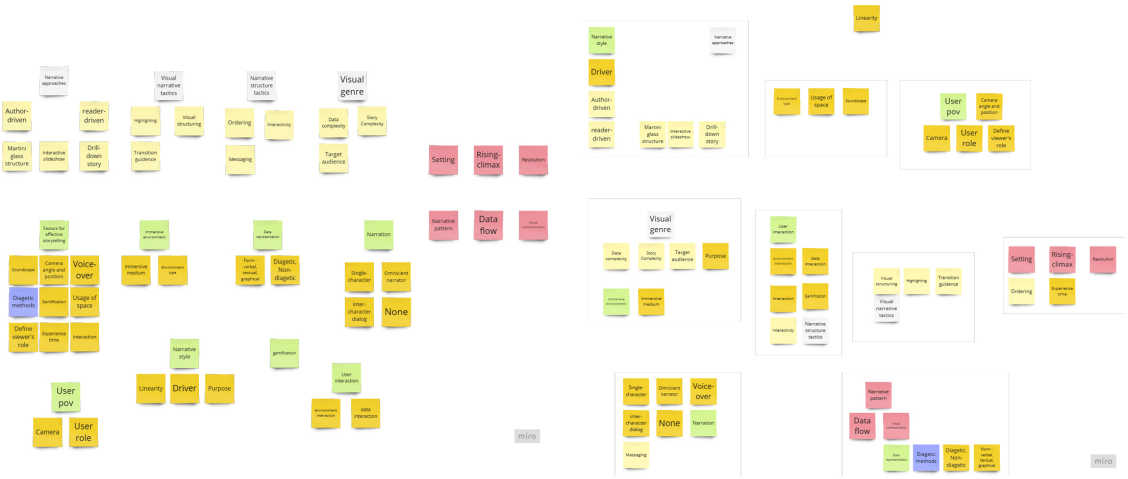


Figure A.1: The design space presented by [23]

B

Thematic analysis



(a) Extracted codes

(b) Iteration 1

(c) Iteration 2

(d) Iteration 3

Figure B.1: Thematic analysis iterations

C

Evaluation form

Following is the document for the evaluation form, including things to observe and questions for the interviews.

Test: _____

Introduktion

Framför er har ni en installation. Tanken är att ni ska få testa denna installationen tillsammans. Till er hjälp har ni en datormus som ni styr upplevelsen med. Ni får gärna tänka er att ni ser denna installation på ett museum eller liknande och att ni testar den tillsammans. Ni får också gärna diskutera upplevelsen med varandra allt eftersom ni går igenom den. Efter ni testat klart och känner er nöjda så har jag några få avslutande frågor till er.

World map

Interaktion

Interagerar man med slider?

- [ ] Direkt
- [ ] Efter en stund
- [ ] Interagerar inte alls

Interagerar man med play-knapp?

- [ ] Direkt
- [ ] Efter en stund
- [ ] Interagerar inte alls

Förstår man att man kan interagera med kartan?

- [ ] Direkt
- [ ] Efter en stund
- [ ] Förstår inte alls

Engagemang

- [ ] Diskussion om vad man ser
- [ ] Diskussion om hur man navigerar genom upplevelsen
- [ ] Diskussion om vad som händer
- [ ] Diskussion om det bakomliggande temat
- [ ] Samarbetar man

Noteringar:

Wildfire

Interaktion

Interagerar man med slider?

- [ ] Direkt
- [ ] Efter en stund
- [ ] Interagerar inte alls

Interagerar man med play-knapp?

- [ ] Direkt
- [ ] Efter en stund
- [ ] Interagerar inte alls

Förstår man “Point of no return” och att man ej kan dra tillbaka

- [ ] Direkt
- [ ] Efter en stund
- [ ] Förstår inte alls
- [ ] Använde inte slider själv

Engagemang

- [ ] Diskussion om vad man ser
- [ ] Diskussion om hur man navigerar genom upplevelsen
- [ ] Diskussion om vad som händer
- [ ] Diskussion om det bakomliggande temat
- [ ] Samarbetar man

Noteringar:

Ice Sheets

Interaktion

Interagerar man med slider?

- [ ] Direkt
- [ ] Efter en stund
- [ ] Interagerar inte alls

Interagerar man med play-knapp?

- [ ] Direkt
- [ ] Efter en stund
- [ ] Interagerar inte alls

Förstår man “Point of no return” och att man ej kan dra tillbaka

- [ ] Direkt
- [ ] Efter en stund
- [ ] Förstår inte alls
- [ ] Använde inte slider själv

Engagemang

- [ ] Diskussion om vad man ser
- [ ] Diskussion om hur man navigerar genom upplevelsen
- [ ] Diskussion om vad som händer
- [ ] Diskussion om det bakomliggande temat
- [ ] Samarbetar man

Noteringar:Noteringar:

Marine Heat Waves

Interaktion

Interagerar man med slider?

- [ ] Direkt
- [ ] Efter en stund
- [ ] Interagerar inte alls

Interagerar man med play-knapp?

- [ ] Direkt
- [ ] Efter en stund
- [ ] Interagerar inte alls

Förstår man “Point of no return” och att man ej kan dra tillbaka

- [ ] Direkt
- [ ] Efter en stund
- [ ] Förstår inte alls
- [ ] Använde inte slider själv

Noterar man blekning av partiklar?

- [ ] Ja
- [ ] Nej

Engagemang

- [ ] Diskussion om vad man ser
- [ ] Diskussion om hur man navigerar genom upplevelsen
- [ ] Diskussion om vad som händer
- [ ] Diskussion om det bakomliggande temat
- [ ] Samarbetar man

Noteringar:

Frågor

Vad var det ni såg under denna upplevelse?

Förstod ni hur man skulle ta sig igenom upplevelsen?

- Hur förstod ni att ni skulle göra på det sättet ni gjorde?

Kunde ni förstå vad som händer under varje visuell scen?

- Hur kunde ni förstå att just det händer?

World map

Wildfire

Ice Sheets

Marine Heat Waves

Kan ni förstå vad grundtemat är bakom hela upplevelsen?

D

Notes and quotes from evaluations

Presented following are the notes and different quotes from the users during the evaluations.

World map

In the first test the interaction with the slider comes naturally

In the third test, the users do not interact themselves with the slider until they get to the world map the second time.

In the first test the interaction with the play button comes quick and naturally

In the first test, the interaction with pins comes after a little while and the users seem intrigued to have discovered it.

In the second test the interaction with pins is realized very fast.

In the third test the users realize the pins are clickable after hovering over them and getting the visual and auditory feedback.

“Is it about heat relations in the world?”

“What do the colours mean” - discussing what the colours of the world map might mean.

“This one goes only to 2021, there must be different sets of data”. Discussions understanding that it is about data.

“You can see the global warming”

The users went back and forth a lot in the timeline to try to understand what the colours meant. They talked about pollution, destruction etc. They also mention that they think it might be a temperature increase. It sparked a lot of engagement and discussion in this pair.

Users discuss a lot about the visualization, trying to figure out what the colours mean and what it represents. They discuss temperature but say that it can be warm in the north pole. Eventually they mention that it might be the temperature increase, as they have heard that people talk about the ices melting first. They also start to wonder if the time of the map can affect how the scenarios are perceived when you enter them.

“Seems like its about temperature, that it is getting warmer and warmer”
“Like that the start is moving automatically.”

Wildfire

“The play button auto plays”. Understanding that you get a linear presentation.

First test: “We cannot go back” - about point of no return.

“This makes me very sad”

“What does PONR mean in this case? Is it about the loss of trees? Earth resources being taken by humans?”

Not really understanding that it is about wildfires but see it as a metaphor that we take the world's resources.

“Does the fires really start that early in the timeline”

“The experience feels uneasy, sound adds to that”

“Almost provocative”

Realize that PONR makes it so that you cannot go back after the initial free testing.

Ice Sheets

The users understand after some scenarios that you can choose which way you interact with the experiences, either by using the slider, or by using the play-button. Using different methods at different times.

“Would be cool if the slider head changed visuals during PONR”

Mentioning that it would be cool to see how an urban environment is affected.

Mentioning that it is interesting to see that it can go so fast. Indicating that some emotional connection has been sparked as they grasp the speed of what happens.

“This was a bit scary”

“But this is 2002?” - Notice different timelines.

“PONR feels discouraging and not motivating”. Here they go back and discuss if PONR is a certain date, trying to understand when this point has been reached.

Marine Heat Waves

Second test, trying to pause after clicking play but realizing it does not work eventually

Second test: “Now we can't go back” - realizing that point of no return makes it impossible to go back in the timeline

“They will probably get bleached” - After having seen other scenarios and thus getting an understanding of the theme, they can predict what will happen in the coral reef based on previous knowledge about the subject.

Mentions that the particles fall off in “one click”.

“No pleasant changes”

Here they seem to notice the bleaching but does not mention it during the watching

Frågor

Vad var det ni såg under denna upplevelse?
“Global warming, the timelapse of it and its impact on different parts of the world.”

“You did not really understand it at first until the later stages of the world map where you could see a big difference.”

“We saw the world and climate change and the effects it has on the environment in different places in the world.”

“With PONR, it was not clear what it completely meant but it did not feel good that I could not go back. Uneasy feeling.”

“Different climate changes due to global warming.”

“Temperature changes and its consequences during time at different places in the world and different environments.”

Förstod ni hur man skulle ta sig igenom upplevelsen?

- **Hur förstod ni att ni skulle göra på det sättet ni gjorde?**

“The clear timeline made it easy to understand that you could move back and forth.”

“We did not understand at first that you could interact with the pins but when we moved over them we got the visual and auditory feedback that it was possible.”

“Map pins express that they can be clicked.

“It feels like a part of the experience is that you do not exactly know what happens. When you move the slider you feel like you have done something wrong and it adds to the experience.”

“Sliders and buttons help showing that you can move in the timeline.”

“It's natural to move around when you are using a mouse.”

“Good auditory and visual feedback from the map pins.”

“It is clear that you can interact with the slider as it plays automatically when you start the experience.”

“Using a mouse makes it easy to understand that you can interact with things, touch might have not made it as clear for the pins.”

Kunde ni förstå vad som händer under varje visuell scen?

- **Hur kunde ni förstå att det hände?**

World map

“In the start it was hard to understand. But when you compared the beginning and end of the timeline you started to understand. It was not explicitly presented, but that was good, as you had to think about what it represented a bit.”

“It took some time to understand what the colours meant but eventually we decided that it must be an average temperature change.”

“The temperature increases every year” - but we're thinking about climate effects and other things.

“Easy to understand with heat maps. red warm, blue cold.”

“You see the time changes things, they are escalating.”

Wildfire

“The wildfire was the most unclear, it was clear to understand that it was a wildfire but not so much of what caused it. Was it a weather condition or if it was to to it getting warmer in areas that we are not used to seeing as warmer.”

“You associate wildfires more with like California so it was hard to understand what it was about. Did not connect it to wildfires as it is in Sweden."

“The sound made it more clear that it was a wildfire. also that it increased with the visuals made it more clear.”

“Thought that it was a skyline city in the background before they understood that it was a stump.”

“Forest that catches fire, more wildfires.”

Ice Sheets

“It was clear that it was about glaciers melting. Maybe not the most interesting to look at as not much happens with the visuals, it would be even cooler if something changed on the model of the iceberg.”

“It was clear that it was ice melting with the water falling down.”

“It gave a scary and uncontrollable feeling.”

“It was easy to understand that it was a glacier melting, as the block was floating in waves, and the block turned into the same material as the sea.”

“Glaciers melting.”

“Different timeline to showcase more changes between points?”

Marine Heat Waves

“This was the most effectful visuals, as it involved living organisms that died as an effect of climate change. Also more clear that something beautiful is destroyed, with the vibrant colors going white.”

“It is not completely clear what it represents first, but that makes it open for discussion.”

“Even if all particles are not fish, it is easy to understand that it is a shoal of fish.”

“The corals lose their color.”

“”The “Shoal” in the middle seemed to represent life in the sea in general, with its different colors representing different species.”

“They are greyed out and disappear, quite drastically.”

“You can see life in organisms and plants dying as they are bleached.”

“Colours can be connected to living things and life itself.”

Kan ni förstå vad grundtemat är bakom hela upplevelsen?
“It is clear that it is about global warming and the effects that we as humans have on the world.”

“Climate change”

“It is also an experience where you participate. I move the slider and eventually I cannot move it back. It gives a representation of what I do in real life, that my actions have an effect on the world.”

“It is about the environment and sustainability.”

“We are at the end sort of, we have already done so much damage.”

“Heating of the environment and its consequences.”

Additional notes

“When we are presented with the point of no return it feels very hopeless, as I feel like I would like some additional information about what we can do about it. But maybe this is the message, that we are beyond no return.”

“It would be nice that more visuals had a more human connection, as that might have helped in evoking more emotions. For instance seeing the effect in a city or other place where humans live.”

“Also tests different interaction methods for different scenarios and different times going through scenarios.”

“The visual style was playful and you can clearly see what every visual is trying to portray.”

“The users did not use the slider for any of the scenarios and only used the play-button during the initial play. But when asked questions about how they knew how to navigate through the experience, they went back as they started to wonder if the slider was interactable.”

“The users seemed more focused on watching the scenarios than discussing them during play.”

“As they never used the slider during play, they also see that the point of no return makes it impossible to go back in the timeline.”

“I had a happy feeling in the beginning, and I started to explore using the interface, but then I realized that I could not undo what I had done.”

“It was nice with more visuals and less text, as it made me more curious.”

“The soundscape felt like a big part of the experience, and made it easier to comprehend the seriousness of the experience.”

“It feels like we are in a time where a lot of things are going bad.”

“The overall vibe of the experience, being more melancholic with the music etc. Could eventually be more effective than using dramatic music. Depends on what your purpose is.”