

Discovering Nature's Designs: A Biomimicry Interactive Exhibit at Museon-Omniversum



Yellow sunflower in close up photography
(Gomes, 2020).

Colophon

Discovering Nature’s Designs: A Biomimicry Interactive Exhibit at Museon-Omniversum

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In collaboration with
Museon-Omniversum

Contribution to
Museum Future Lab | TU Delft
Play Well Lab | TU Delft



Preface

Dear reader,

I am pleased to present you with my final year project. This project is something I am very proud of. It has taken sweat and tears, but all in all it has been a learning experience. During this project I immersed myself in the world of biomimicry, museums and transformative experiences in collaboration with Museon-Omniversum.

Looking back on the past seven months, I'm truly grateful for the many people who have inspired, guided and challenged me during this project. As this project marks the end of my time as a student in Delft, I'd like to take a moment to acknowledge and thank them before delving into the contents of the report.

During my thesis I worked as an intern at Museon-Omniversum. I'm grateful that they gave me the opportunity and freedom to design an exhibit for the new 'Biomimicry' zone. I would especially like to thank Diederik, my coach at Museon-Omniversum, for guiding me through this great opportunity and showing me the ins and outs of 'working in a museum'. It has been a wild journey, but I am glad that I was able to experience it at Museon-Omniversum.

Secondly, I would like to thank my supervisors at TU Delft for their support and guidance. Arnold, thank you for helping me from the very beginning. You put me in touch with different museums to find the right project. Thank you

for introducing me to the world of museums. Mathieu, you have really helped me to take my writing skills to the next level. The way you give feedback is really constructive and clear. All in all, I have learnt so much from both of you during this project.

Next, I would like to thank the biomimicry group at The Hague University of Applied Sciences, initiated by Laura Stevens. You were all amazing people with a lot of knowledge about biomimicry. They really inspired me and helped me where needed.

Furthermore, I would also like to thank all my friends for being there. You brought comfort, help and warmth. Your kind words really helped me through the project. Last but not least, you were perfect sparring partners during the brainstorming sessions.

I would also like to say my special thanks to Pieter. Thank you for your unconditional support over the past seven months and for putting up with all the stories about my thesis project.

And last but not least, a big thank you to you, the reader, for taking the time to explore my work for Museon-Omniversum.

Have fun!

Sven



Abstract

We humans have drastically changed the world in the last few centuries. We have upset the balance of nature. Humanity is forgetting that we are part of nature and dependent on the earth's resources. Our take-make-dispose mindset needs to change.

Biomimicry may be a solution. It is a relatively new movement, a philosophy, that looks to nature and recognises its value. It takes inspiration from biological strategies and translates them into sustainable design solutions. Respect for nature is central to this approach.

The focus of this project was to design a playful and interactive exhibit on biomimicry that could change the visitor's perspective. This was done for Museon-Omniversum, a science museum that wanted to explore such a transformative learning experience for a new exhibit in a biomimicry zone of their current exhibition One Planet NOW!

A transformative experience is a life-changing experience. They often occur after a sense of awareness that leads to a deeper understanding of one's beliefs. By exploring the subject through hands-on activities, the chance of changing one's perspective over time increases.

This project uses the double diamond method to explore these topics. Desk research, interviews, observations and exploration of museums all contributed to defining the project direction 'Solving relatable events through biomimicry'. Events refer to a relatable situation that visitors encounter (daily). This led to a more detailed design goal:

Design a playful and interactive exhibition suited for families with children (8 years and up) to explore biomimicry and let them understand the usefulness of biomimicry for future problem-solving for the coming 'biomimicry zone' at Museon-Omniversum.

This consists of four phases:

1. Make the visitor aware of what biomimicry is and can do.
2. Encourage dialogue between families to stimulate self-reflection and deeper understanding of biomimicry by presenting information invitingly.
3. Let the visitor interact with the concept of 'biomimicry' in a playful way by solving 'events' through simplified steps taken from Biomimicry Thinking.
4. Plant a seed for future problem-solving (to use biomimicry).

Ideas were then generated through brainstorming sessions, leading to several physical prototypes. Evaluation testing of these prototypes provided insight into the experiences and effects of the designed prototypes. These insights all contributed to the final design concept of 'Superpowers of Nature'. A concept that allows the visitor to explore and reflect on biomimicry.

Visitors explore biomimicry through an interactive choosing system. They can explore specific organisms displayed on activation blocks. After placing one of the organisms, they can explore the superpowers (biological strategies) of the organism and its corresponding biomimetic innovations. The video clips guide the visitor through a simplified version of the biomimicry thinking method. During the video clips, visitors have the opportunity to reflect on the content through open-ended questions that stimulate discussion. Finally, they are shown real-life examples related to their chosen superpower.

Overall, the exhibit is successful in addressing biomimicry. However, further modifications are needed to improve the design and to test the impact in the long term (Phase 4).

Table of Content

<i>Colophon</i>	<i>1</i>	<i>Chapter 4 – Develop</i>	<i>104</i>
<i>Preface</i>	<i>3</i>	4.1 Design Approach	105
<i>Abstract</i>	<i>5</i>	4.2 Concept ‘Explore Biomimicry’	106
<i>Chapter 1 – Project Introduction</i>	<i>10</i>	4.3 Evaluating Concept ‘Explore Biomimicry’	119
1.1 Start	11	<i>Chapter 5 – Deliver</i>	<i>130</i>
1.2 Biomimicry	15	5.1 Design Approach	131
1.3 Museon-Omniversum	17	5.2 Concept ‘Superpowers of Nature’	132
1.4 Transformative Learning	21	5.3 Evaluating the Concept ‘Superpowers of Nature’	139
<i>Chapter 2 – Discover</i>	<i>24</i>	<i>Chapter 6 – Conclusion</i>	<i>146</i>
2.1 Project Approach	25	6.1 Outcomes	147
2.2 Biomimicry	29	6.2 Limitations	151
2.3 The Museum as Context	49	6.3 Recommendations	153
2.4 Transformative Museum Experience	57	<i>Epilogue</i>	<i>157</i>
2.5 Interactive Exhibitions	67	<i>References</i>	<i>159</i>
2.6 Overview of Insights	71	<i>Appendices</i>	
<i>Chapter 3 – Define</i>	<i>76</i>	The appendices can be downloaded as a separate document from the TU Delft Repository.	
3.1 Exhibition Approach	77		
3.2 Concept ‘Problem Approach’	80		
3.3 Evaluating the Concept ‘Problem Approach’	85		
3.4 Evaluating the Process	95		
3.5 Overview of Insights	97		

1.

Project Introduction

This chapter introduces you to the motivation to start this graduation project. Next, it will dive briefly into the main areas of this project: biomimicry, involved party: Museon-Omniversum, and transformative learning. More in-depth information is given in Chapter 2.

- 1.1 Start
- 1.2 Biomimicry
- 1.3 Museon-Omniversum
- 1.4 Transformative Learning

Figure 1: Looking at nature through magnifying glass (Hellberg, n.d.).

1.1 Start

The original design brief can be found in Appendix A. A summarised version of the project is presented below. The research was very extensive, so some parts are presented in Appendix B.

Project scope

In this study, we explore the potential of exhibition design in the context of Museon-Omniversum (Figure 2) to facilitate transformative experiences related to biomimicry. Biomimicry, a discipline focused on developing sustainable design solutions inspired by nature, serves as the thematic foundation for this exploration.

One of the main target groups of Museon-Omniversum is families. The project therefore focuses on families with children between the ages of 8 and 12. The goal is to let them explore the concept of biomimicry through a playful exhibition. An interactive learning experience can enhance their understanding of biomimicry. The exhibit tries to stimulate the visitor to alter their view, creating a new way of thinking. Ideally, the visitor will start to look for answers in nature, outside their daily environment, to solve (future)

problems.

Museon-Omniversum's aim is to change someone's behaviour towards the complex problems presented in the museum through its exhibits. Ideally, this will lead to a change in the visitor's worldview. This change can be seen as a transformative experience. Research shows that museums as institutions can create exhibits that stimulate transformative experiences (Chisolm et al., 2020). However, this research area is



Figure 2: Museon-Omniversum Museum in the Hague (Museon Omniversum | Museon Omniversum, n.d.)

relatively new; There is still room for exploration.

Collaboration

Museum Futures Lab

Museum Futures Lab

This lab, part of TU Delft, studies the design of creating meaningful experiences for museum visitors by using digital means or cultural artefacts. Meaningful experiences can cause a new understanding of the world, provide new opportunities for research and lead to the development of new technologies in a museum context.

The lab is interested in methods and knowledge for creating meaningful experiences in museums, more precisely, the design of transformative experiences (About - MuseumFutures Lab, 2022).

Play Well Lab

Play Well Lab

The focus of this lab is on children's wellbeing in and through play. They aim to bridge the gap between playfulness and academic research. It explores how the design of facilities can contribute to children's physical, mental and emotional flourishing. The lab stimulates the recognition of 'play' as a high quality experience in itself, and focuses on creating methods, models or techniques that can be used by designers (Play Well Lab - Play Well Lab Lab, 2023).

museon omniversum

Museon-Omniversum

In short, Museon-Omniversum is an interactive family museum that guides the visitor in being a good cosmopolitan. Its exhibitions show how to contribute to a better world by addressing present-day complex problems and explaining the usefulness of the 17 Sustainable Development Goals (Museon-Omniversum,2020).

Project Goal

Design an interactive exhibition that stimulates awareness & deeper understanding of biomimicry (Phases 1. & 2.) in families with children aged 8-12 years and let them learn in a playful way (Phase 3. Explore) (Figure 3).

These phases are part of a transformative learning experience consisting of four design challenges. These four phases: awareness, deeper understanding, exploration, and integration, are derived from Vermeeren (2023).

Personal Interest

One thing that was clear from the start was that this project should include designing something for/with children. They are easily amazed and are open to new experiences. New knowledge is regarded with enthusiasm. These characteristics should be reflected in the final project. There is no better place to address these characteristics than in a museum (which many, including myself, enjoy). Next, when biomimicry passed by, I was impressed. This was a new (and challenging) subject that I had never heard of before. In my humble opinion, others should know about it too. By happenstance, Museon-Omniversum had decided to design a new exhibition on 'Biomimicry'.

The following chapters will briefly explain the following terms. First, an introduction to biomimicry: 'What is biomimicry? Secondly, a deeper understanding of the collaborator in this project, Museon-Omniversum, is discussed: 'Who are they and what is their mission/vision? Finally, a brief understanding of the transformative experience is addressed: 'What does it entail, and why do we want to pursue this experience?'.

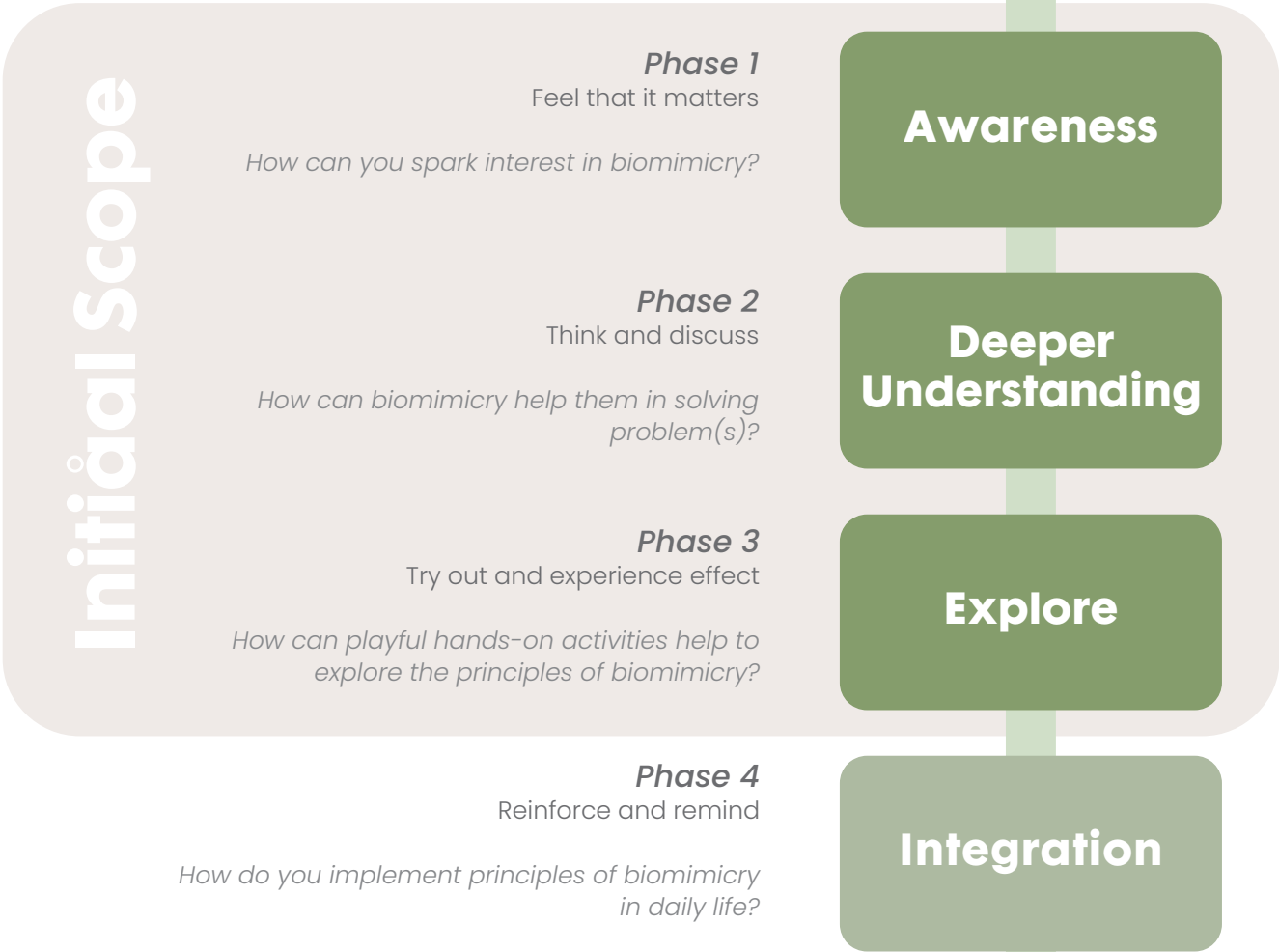


Figure 3: Overview initial scope of project with transformative experience phases.

1.2 Biomimicry

The biomimicry movement all started with Janine M. Benyus in 1997. She can be seen as the founder of biomimicry as we know it today. She describes biomimicry as

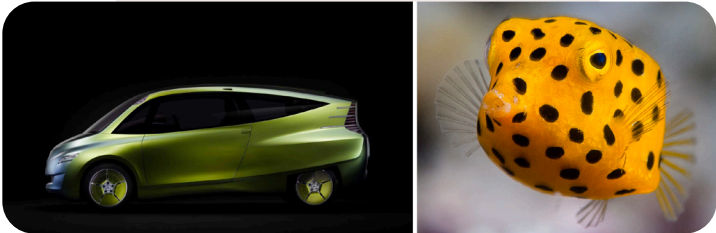
“The conscious emulation of nature’s genius.”

Meaning that you acknowledge nature’s cleverness, which evolved to prospering solutions within the constraints of a planet with finite resources. The conscious learning from living things and applying those insights to humankind’s challenges is what biomimicry stands for (Pawlyn, 2019) (Biomimicry 3.8 et al., 2010).

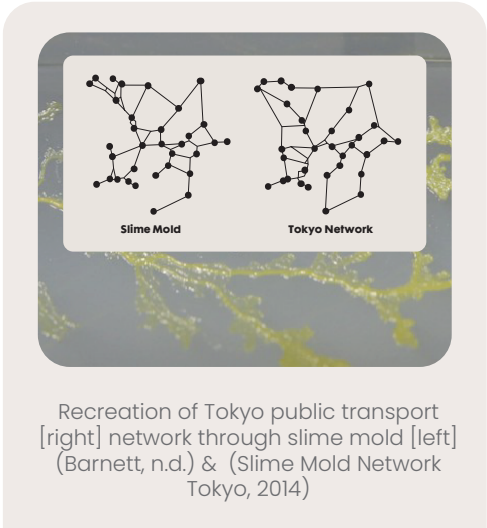
The meaning of biomimicry has shifted over the last 25 years, moving closer towards reconnecting with nature. Therefore, many examples of biomimicry invented at the beginning of the movement would now be classified as bionics rather than biomimicry (personal communication, L. Stevens, 6 November 2023). Some examples are shown in Figure 4. The traditional approach of bionics focuses on separating humans from nature.

Bionics focuses on imitating living organisms to create artificial products. Improving the current status quo. However, nature is often exploited in the process. In contrast, biomimicry embraces nature and sees humans as part of the natural world. It strives for a harmonious relationship. Inspiration is taken from nature’s design and used to create sustainable solutions (Wahl, 2017). There is a fine line between these two fields, which is rather vague and open to interpretation. Literature still uses examples of bionics and biomimicry as one today. Therefore, in agreement with Museon-Omniversum, they will be considered one in this project, thus being biomimicry examples. However, Chapter B lists the current requirements for checking whether a design or innovation is biomimicry (as it stands today), followed by the requirements that will be used for this project.

Bionics
Bionics focuses on the scientific translation of biological systems, leading to radical technological advancements that outperform current technologies to reach financial success (Wahl, 2017; L. Stevens, personal communication, November 6, 2023).



An aerodynamic car based on the form of a boxfish
(Bionincs and Biomimicry, n.d.)



Biomimicry
Biomimetic and biomimicry are used as synonyms in literature. Biomimicry derives its inspiration from biological principles and translates these to production and design. A philosophy that sees nature as a model that meets sustainable development challenges (social, environmental, and economic). However, themes such as ‘Re-connection with’ and ‘Respect for Nature’ are equally important in a biomimetic ‘design process’ (Biomimicry Institute, n.d.).

Figure 4: Overview of the difference of bionics and biomimicry.

1.3 Museon-Omniversum

The partner in this project is Museon-Omniversum, a science museum focused on education. The museum aims to convey knowledge and interest in the human and natural sciences among families and primary and secondary schools. It presents global challenges in a museum context by combining culture, science, collection, and interaction into refreshing exhibitions (Museon-Omniversum, 2020).

Mission and Vision

Museon-Omniversum challenges visitors to be active cosmopolitans. They aim to search for solutions together for a better world. Their programming evolves all around Earth. It addresses global challenges by presenting multiple perspectives on this complex problem. Their exhibition brings these perspectives together under the banner ‘We are One Planet!’. They try to motivate the visitor to participate in the current debate through inspiring exhibitions, with the end goal of treating the world with respect. The exhibitions let the visitor experience how the Earth changes and how this affects your daily life. Different cultures, perspectives, and narratives are used to explore the planet’s future, without the museum imposing an opinion on the visitor. They believe that the path to a better world is shared by everyone (Museon-Omniversum | Museon-Omniversum, n.d.; Museon-Omniversum,2020).

Showcasing

Museon-Omniversum has an extensive and varied collection of objects from all over the world. The museum presents its exhibits in a way that it appeals to all senses. In addition to interactive and playful exhibitions, they also use engaging stories to accompany their collection pieces. They are letting the visitor engage with science, culture, or the collection. They try to make each visit an adventure, allowing visitors to discover solutions that contribute to a more sustainable world (Museon-Omniversum,2020).

Target Audience

Museon-Omniversum appeals to a wide audience. Families are its main target group, but it also focuses on primary and secondary education. However, they believe that you are never too young to learn (Museon-Omniversum, 2020).

Exhibitions

The theme ‘One Planet’ is designed to inspire, learn from each other, and work together. Since the fusion between Museon and Omniversum in early 2022, the museum can be divided into three sections (Museon-Omniversum | Museon-Omniversum, n.d.).

The ground floor presents ‘One Planet NOW!’ (Figure 5, Top) and is a temporary exhibition zone that reinforces their main mission and vision. They change one zone every two years to respond to (future) current debate topics. It consists of five zones, each covering a normal-to-daily life topic, such as Food & Drinks or Mobility.

The first floor presents the ‘One Planet expo’ (Figure 5, Middle), which displays the 17 Sustainability Development Goals (SDGs) created by the United Nations (UN) to show the challenge we have as a society. This is a permanent exhibition untill 2030, the year in which the SDGs are to be achieved. These SDGs are their starting point to tell visitors about climate resilience, the energy transition, and much more. There are also several adjacent rooms, each with its own exhibition theme.

The One Planet Dome (Figure 5, Bottom) is a big-screen movie theatre that displays documentary-like movies about the wonders of our planet (nature, culture, science) that strengthen the museum’s main message.

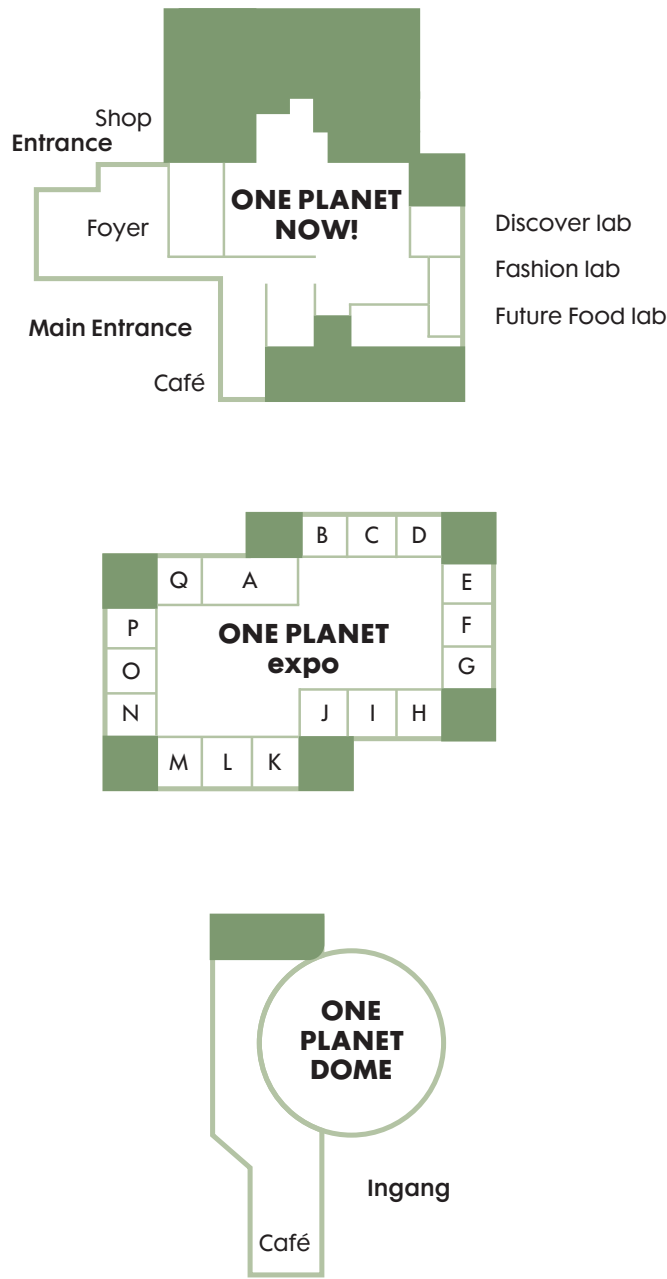


Figure 5: Floorplan of Museon-Omniversum. Top: Ground floor presenting ONE PLANTET NOW!. Middle: First floor presenting ONE PLANET EXPO. Bottom: ONE PLANET Dome.

One Planet NOW!

The area for this project is on the ground floor of One Planet NOW!. The ground floor of the museum does not have a clear path due to the architectural structure of the building. Therefore, the ground floor is designed with an open layout in mind. Museon-Omniversum connects each zone using wooden block-like modules to present information and collection pieces (see Figure 6.). Figure 7 shows the current layout of the ground floor with the corresponding zones. The yet-to-be-designed exhibition space will replace Sports & Exercise. They will try to guide the visitor to have a clear walking route after implementing all new areas (Orange arrow) by placing fake walls (Black line).



Figure 6: Wood block-like modules used in One Planet NOW! in Museon-Omniversum.

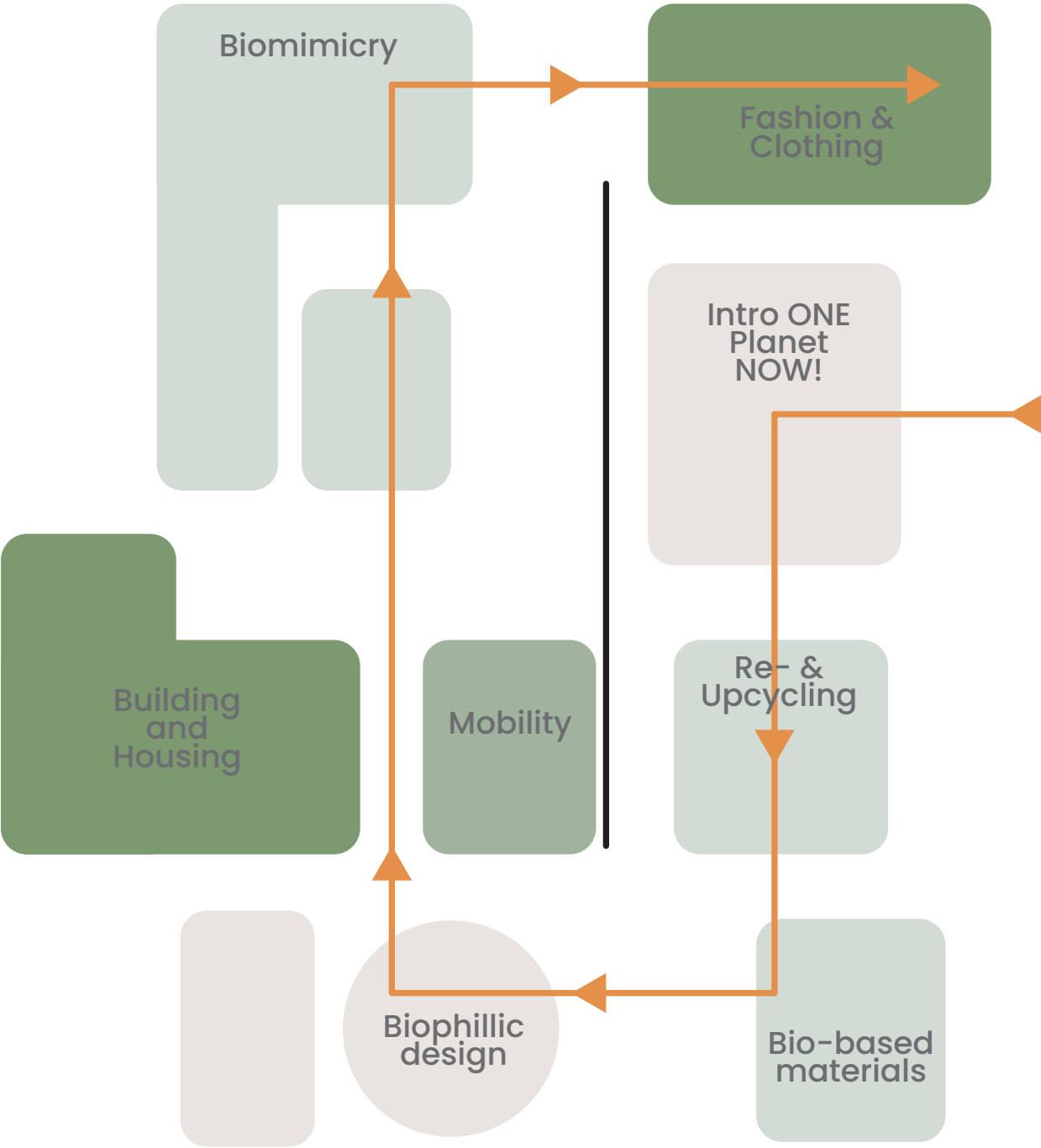


Figure 7: New floor plan of One Planet NOW! in Museon-Omniversum.

1.4 Transformative Learning

This section briefly explains what transformative experiences are and why they should be pursued.

A transformative experience is a profound and life-altering event, that fundamentally changes an individual's perception of themselves. These experiences often involve a heightened sense of awareness, a deeper understanding of one's values and beliefs, and a shift in perspective. All of this leads to personal growth and a renewed sense of purpose. They can be triggered by various events, such as travel, education, personal encounters, artistic expression, or moments of deep reflection (Paul, 2015; Mezirow, 1997). A transformative experience can be very simple, as depicted in Figure 8 through a storyboard.



Figure 8: Storyboard of a transformative learning experience based of an example of bird watching in Pugh et al. (2009)

Opportunities for a transformative experience in museums

The world is becoming more complex by the minute. Complex problems are often at a global scale and society needs to change to overcome and solve these problems. A complex problem can be defined as a problem that is difficult to solve. Due to the complexity of these problems, there is no single solution and no clear 'end' (see Figure 9). Solving one problem may create or lead to other problems. Therefore, a transition in behaviour is needed to achieve a sustainable future and solve these complex problems. This is where transformative experiences come in. Transformative experiences happen on a personal level and renew people's worldviews by altering interests, behaviour, or perspectives (Bergevin,2018; Soren, 2009). Museums are a great place to create such transformative experiences as they have a strong influence on the development of society. They should repeatedly ask the question 'What would our future be like?' (ICOM, 2017). Museums have the space to address complex problems that are present in society through (interactive) exhibitions.

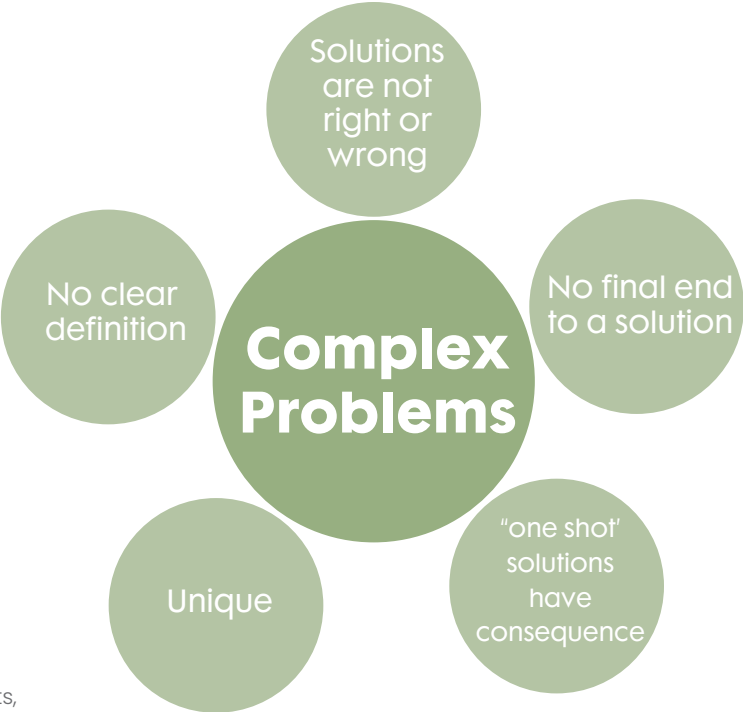


Figure 9: Complex problems and corresponding aspects, inspired by (Christian, n.d.)

A close-up photograph of a sunflower head, showing the intricate patterns of the petals and the center. The image is overlaid with a semi-transparent green and brown tinted glassware, which appears to be a collection of small, circular, textured pieces arranged in a grid-like pattern. The overall effect is a blend of natural and man-made textures.

2.

Discover

Several directions need to be explored to come to guidelines that can help in the ideation process of this project. Firstly, a thorough understanding of biomimicry is needed in order to apply it to this project. Next, the do's and don'ts of a museum, types of visitors, etc. need to be explored to set the context, followed by the process of transformational learning and various frameworks. These areas will be explored through desk research and qualitative research to design a transformative experience around biomimicry in a museum context.

- 2.1 Project Approach
- 2.2 Biomimicry
- 2.3 The Museum as Context
- 2.4 Transformative Museum Experience
- 2.5 Interactive Exhibitions
- 2.6 Overview of Insights

Figure 10: Green and brown tinted glass ware (ID, 2019)

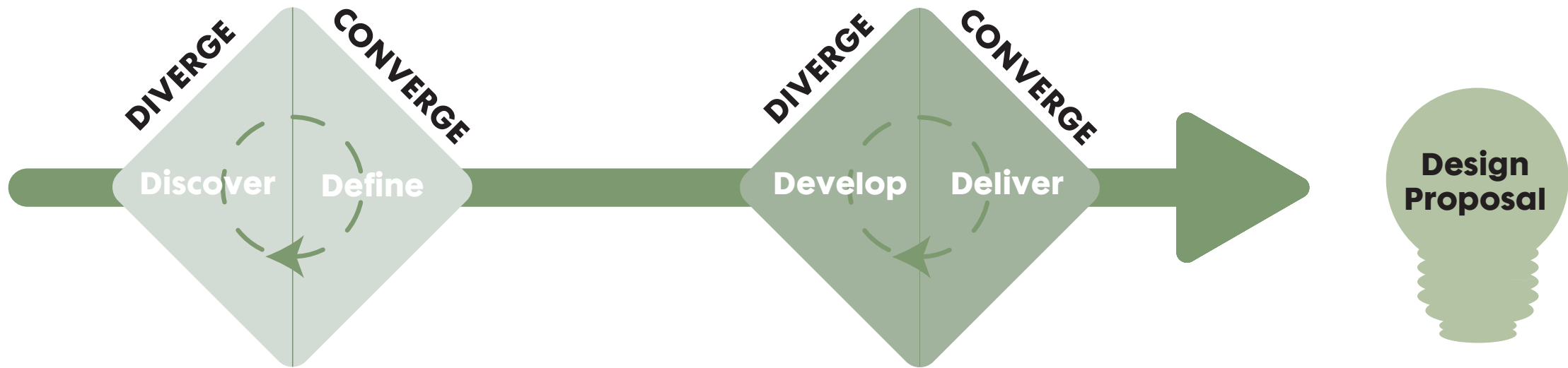
2.1 Project Approach

The method used in the design process is explained first, followed by the project goal. The corresponding research areas are derived from the project objective and are used to define a main research question per area. Finally, the research activities used to define answers to the research questions are listed.

Method

The overall method used in this project is the double diamond. This method has four phases: discover, define, develop, and deliver (see Figure 11)(Design Council, n.d.).

Firstly, the context is explored (discover) to gain insights that will help in choosing a design direction (define). Next, the direction is explored through ideas and iterations to arrive at a final concept (develop). The final step is to prototype the design and evaluate the final concept with the target audience (Deliver).



Discover

It helps people to understand the context and problem. Assumptions are (dis)confirmed.

Define

The insights gathered to define a design direction for the project.

Develop

Ideas are explored and validated by peers, experts, or the target group. Iterations are still made to come to a feasible concept.

Deliver

Testing the final concept and let the 'exhibit' be evaluated. Small improvements contribute to the final design.

Design Proposal

The final outcome of this project. Design is based on research and user test.

Figure 11: Overview of Double Diamond Method, used in this project.

Research Areas

This chapter is focused on gathering information about the main research question of this project.

“How to design an **interactive exhibition** that stimulates **awareness & deeper understanding** of **biomimicry** in families with children from 8 – 12 years old and let them **learn in a playful way**?”

Four research directions emerged by dissecting the main research question, each with its own research question. By asking these questions, a comprehensive and integrated understanding of the situation is sought after.

The insights of every research area can be used for future guidelines in the design process. They are depicted in an overview for later reference (Chapter 2.6).

Research activities

Multiple activities were performed to find answers to the research questions:

- Desk research through reading articles
- Testing through testing materials and interviews
- Observations through observing families in the museum
- Informal conversations between involved or relevant parties

Research questions

The top question in each section is the main question of the research direction

Biomimicry

- How can we use nature’s wisdom to solve human challenges and create a more sustainable future?
- What is biomimicry?
- What can we learn from biomimicry by looking at nature?
- How to apply biomimicry?

Transformative experience

- How can museums create transformative experiences that foster deep understanding that stimulate change within the visitor?
- How does a transformative experience start?
- What are the key characteristics of transformative learning?
- How to design a transformative museum experience?

Behind the exhibit in a museum context

- How can museums design for playful learning experiences that present information in an engaging and accessible way to all visitors?
- What is the purpose of a museum?
- What motivates museum visits in visitors?
- How to address playful learning in a museum context?

Interactive exhibits

- How to design an interactive exhibit?
- What are desired qualities of an interactive exhibit?
- How does Museon-Omniversum approach interactive exhibits?
- How do other museums approach interactive exhibits?

2.2 Biomimicry

This section explores the scientific discipline of biomimicry. Biomimicry is a growing movement that is relatively young. The meaning and definition behind it can be difficult to grasp at first as it quite broad and extensive.

“Biomimicry derives its inspiration from biological strategies and translates these to production and design. A philosophy that sees nature as a model that meets sustainable development challenges (social, environmental, and economic). However, themes such as ‘Re-connection with’ and ‘Respect for Nature’ are equally important in a biomimetic design process’ (Biomimicry Institute, n.d.). “

This section attempts to explain biomimicry by answering the question:

“How can we use nature’s wisdom to solve human challenges and create a more sustainable future?”

This is done by finding answers to the sub-questions: What is biomimicry? What can we learn from biomimicry by looking at nature? Why should we learn about biomimicry? How to apply biomimicry?

It’s time to ask nature

To explain what biomimicry is, this subsection starts at the very beginning. Over the course of 3.8 billion years of Earth’s history, today’s biological systems have evolved through natural selection. Preferred traits remained in the population and the ‘good’ genes were passed on to the next generation.

From a biomimicry perspective, a more sustainable future starts by looking at nature. How does she solve things? Biomimicry design tries to solve problems we encounter as a species by finding sustainable solutions in nature by asking the question ‘How does nature?’.

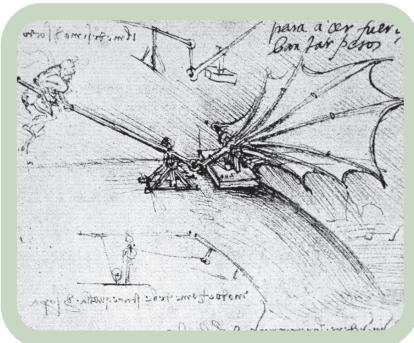
Biomimicry is a growing discipline that focuses on biological mechanisms, patterns, and structures and applies them in a diverse range of study fields. Harnessing the genius of nature can help solve human problems in a more sustainable way (The Biomimicry Institute, n.d.).

Three famous examples of (early) biomimicry designs are shown in a timeline in Figure 12. Velcro is a design solution inspired by a natural structure and function that we still use today. [Note] Today, however, it is debatable whether this example would be classified as bionics or biomimicry due to the shift within the definition of biomimicry towards sustainability; this example lacks the aspect of sustainability and ‘respect for nature’.



The Greek legend of Daedalus and his son Icarus revolves around mimicking the flight of birds to escape their island.

Later in time, during the Renaissance, Leonardo da Vinci studied the autonomy of birds to create an apparatus that could ‘fly’.



An even more recent discovery happened in the 20th century. George de Mestral, a Swiss engineer, was curious at how burrs attached to his dog’s fur during walks in the Alps. By studying this principle, he discovered that the burrs had small barbs, which let them hold on to the dog’s fur. This led to the invention of Velcro, a design that imitates this principle.

The term 'biomimicry' is new to most people. However, there are some well-known examples that most people have heard of that are part of biomimicry. Figure 13 shows some examples of biomimicry. From left to right: the organisms and their corresponding biological strategy, that led to the innovation.

1.

The Shinkansen, also known as the bullet train, is a high-speed train in Japan. The front end of the trains is designed to mimic the shape of the head of the kingfisher bird. This bird can slash through the air and dive into the water to catch prey with barely a splash. This design resulted in lower air pressure waves and therefore a higher speed (High-Speed Train Inspired by the Kingfisher – Innovation – AskNature, n.d.).
2.

The Sharksuit (LZR Racer) is a swimsuit based on the microstructure of shark skin. A shark's skin reduces the friction it experiences underwater because of its microstructure. The skin is made up of many tiny overlapping scales with longitudinal grooves that follow the flow of the water as the shark moves forward. Speedo used this phenomenon to create the LZR racer swimsuit (Scales Manipulate Flow – Biological Strategy – AskNature, n.d.; USC Viterbi School of Engineering, 2017).
3.

Due to the uneven distribution of wax crystals, lotus leaves have a natural water and dirt repellent layer. This microstructure of the leaves results in reduced surface contact with dirt and water. This also makes it easier for water to form pellets. Due to the curvature of the leaf, the water rolls over it, taking the (remaining) dirt with it and thus cleaning the lotus leaf (Surface Allows Self-Cleaning - Biological Strategy - AskNature, n.d.). This strategy is used by Lotusan in their paint. They claim that their paint keeps facades clean longer than normal paint (Lotusan Zelfreinigende Gevelverf | Sto, n.d.).






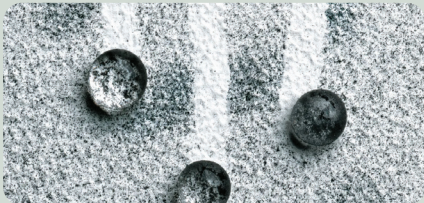
Examples of biomimicry		
Organism	Biological Strategy	Innovation
 <i>Kingfisher (Birdfact, n.d.)</i>	Aeordynamics & Reducing atmospheric pressure Nanostructure of skin for less water friction Self-cleaning surface due to hydrophobic bumps	 <i>Shinkansen, bullet train (Boswell, n.d.)</i>
 <i>Shark (Enescu, 2021) and scales (Hyde, n.d.)</i>		 <i>Shark suit (Speedo, n.d.)</i>
 <i>Nelumbonaceae Lotus (Asknature, 2012)</i>		 <i>Lotusan (Sto, n.d.)</i>

Figure 13: Examples of biomimicry and the corresponding innovations.

The core of biomimicry

There are three ways of looking at nature, to help to understand why biomimicry can help in creating more sustainable solutions. The more holistic approach of biomimicry is that humans use nature’s wisdom to change the way they live, creating a harmonious balance. The three roles of nature are explained separately in the following subsections (see Figure 14)(The Biomimicry Institute, n.d.; Stevens, 2021).

These roles are present in all its practices and are linked to why we should look at nature differently. Nature can be seen as:

- *Nature as model*

Knowing that everything is connected and humans are part of nature. Through practice and exploration, the connection with nature is strengthened through understanding (and restoring what has been lost).
- *Nature as measure*

Ethos is at the core of biomimetic intentions. The underlying philosophy for practising biomimicry. Respect, responsibility and gratitude for nature's capabilities.
- *Nature as mentor*

Learn by replicating the forms, patterns, processes, and ecosystems found in nature, to be able to scientifically incorporate them into innovative, sustainable designs.

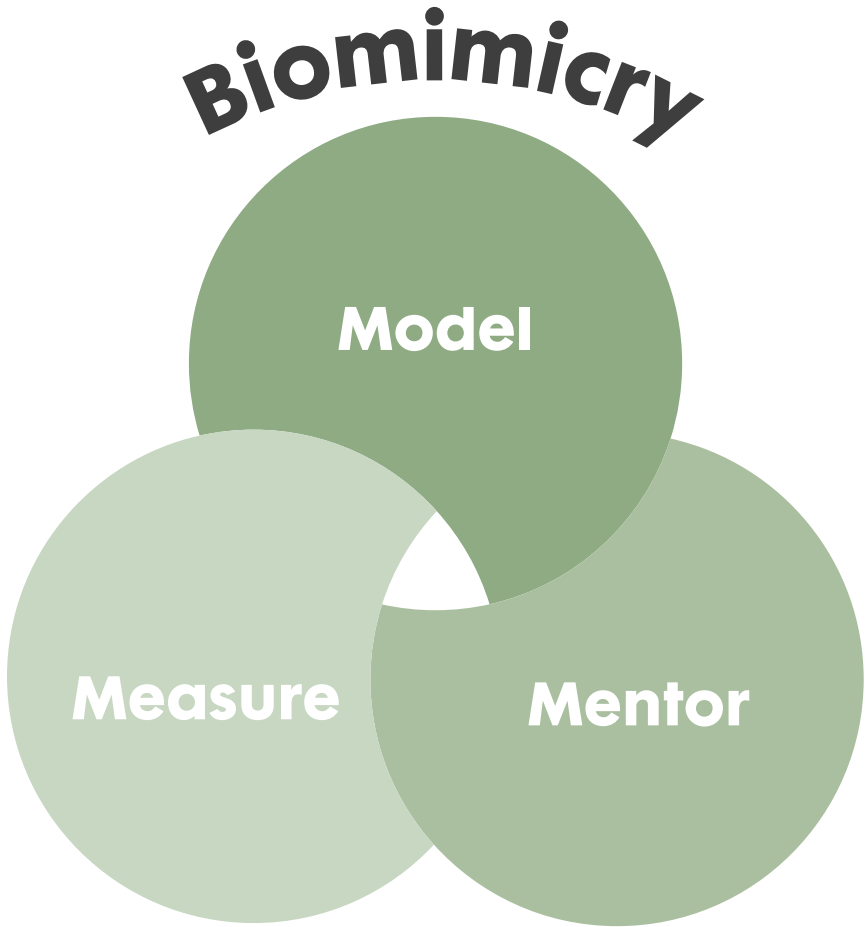


Figure 14: The core principles of biomimicry.

Nature as model

Biomimicry can be a tool to create a more sustainable future. The blueprints are out in nature. Biomimicry is an interdisciplinary approach that studies nature’s forms, processes, and systems to solve human problems sustainably. Well-evolved strategies of nature (biology) are brought to the design table to create solutions which are conducive to life.

“It could be argued that biomimicry is the logical conclusion of a shift in human thought, which has gone from attempting to conquer nature, then trying to preserve it and now striving for reconciliation with nature.”
– (Pawlyn, 2019)

Biomimicry has three levels of organising biological strategies: form, process, or system. Figure 15 show an example of each level (Stevens, 2021; Asknature, n.d.).

Form
In order to achieve specific functions, natural forms, shapes and patterns have evolved to be the most effective. By looking to nature, innovative improvements in design can be made. Nature is often far more effective at achieving a desired function.

Process
Nature has adapted to create life-friendly situations. Replicating physical or chemical processes in nature can help us find life-friendly solutions to design challenges, such as manufacturing materials at low temperatures.

(Eco)System
Natural systems can vary from neurological systems to nutrient cycles or ecosystems. These systems have evolved to function at their best with minimal effort. As a species, we can gain insights to improve our own systems, such as energy networks or information systems. Applying biomimicry at a systems level can have a significant impact on the design of our world.

Types in biomimicry

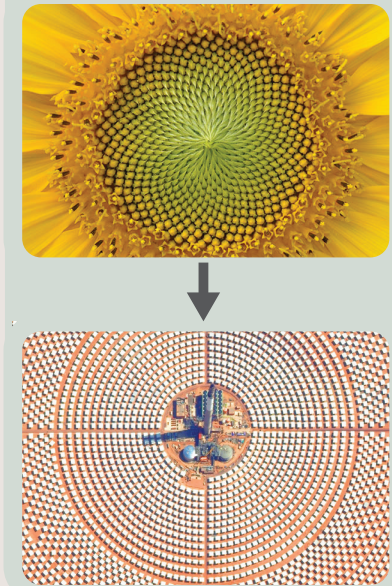
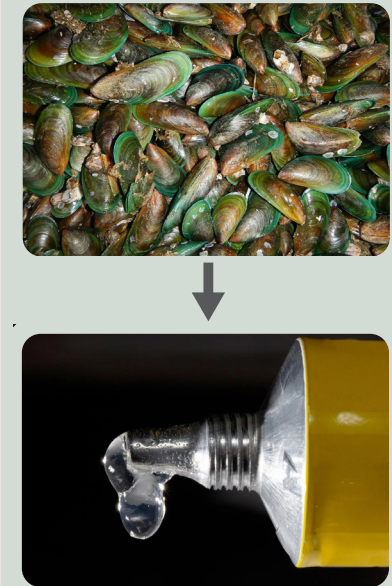

Form	Process	(Eco)System
<p>The natural placement of sunflower seeds have a particular pattern that are efficient in catching maxiamal sun per seed. This pattern is used in massive solar power plants to use each single panel to its full potential (Getty images).</p> 	<p>Mussels can produce water adhesive glue on natural basis. This natural process led to development of man-made glue that sticks together under water (Strasser, 2021; Aalex, 2012).</p> 	<p>Nature consist of many ecosystems. The mangrove forest is a system that is home to many species and creates a nursery ground for fish. This system was inspiration for coastal management to prevent corosion (Waranont, 2020; Douglas, n.d.)</p> 

Figure 15: Three levels of operating within biomimicry: Form, Process and (Eco)System.

Nature as measure

Nature makes highly economical use of materials by folding, vaulting, ribbing, inflating, etc. Structures one can find today are some of the best that have evolved throughout life on Earth. Nature has mastered the art of taking “low-value” materials to create high-value outcomes through the use of form (Pawlyn, 2019).

“In nature, materials are expensive and shape is cheap.”
- Professor Julian Vincent (Pawlyn, 2019)

Figure 16 shows the building blocks that humans (technology) and nature (biology) use to build the world around them. The y-axis shows the amount of ‘building blocks’ needed to complete the product/process. The x-axis shows the order of magnitude in which these ‘building blocks’ are used in their environment. It shows that humanity uses mainly energy and material, while nature uses structure and information. This graph clearly shows that we as humans can learn how to structure our world differently by looking at nature (Biomimicry NL, 2013; Pawlyn, 2019).

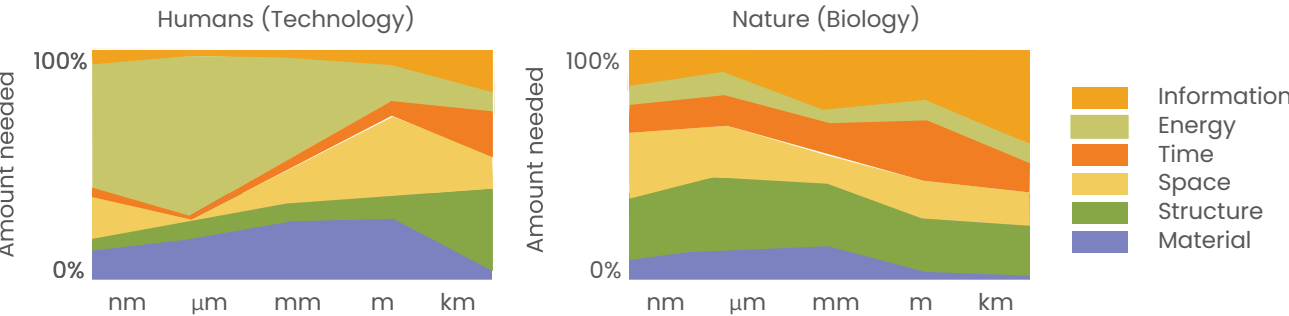


Figure 16: Differences in usage of design variable at orders of magnitude between humankind and nature (Biomimicry NL, 2013).

Next to this, through observations and research, Biomimicry 3.8 (2023) states that nature follows a few simple principles that are consistent with the Earth’s operating systems. Nature is always in dynamic non-equilibrium, using only cyclical processes. The principles represent the evolutionary success factors. Nature uses these twenty-seven principles (see Appendix B for a full overview) to create conditions that are conducive to life.

These twenty-seven principles can be categorised into six overarching life principles. These ‘life principles’ can be seen as design lessons from nature to design sustainably. The six overarching principles of life are depicted in Figure 17.

Since man-made design solutions are not yet at their best, the principles of life can be seen as aspirational goals, to be used as a benchmark for current (and future) design (Baumeister et al., 2013).

- 1. Adapt to changing conditions**
Respond to dynamic conditions
- 2. Be locally attuned and responsive**
Fit in and integrate with the environment
- 3. Use life-friendly chemistry**
Use materials and processes that support life at all levels
- 4. Be resource efficient** (material and energy)
Optimise the use of resources and create opportunities
- 5. Integrate development with growth**
Balance investments to move towards an enriched system
- 6. Evolve to survive**
Continually use new information to ensure best performance

Figure 17: The six overarching life’s principles.

Humanity's principles

As biomimicry focuses on sustainable innovation, many innovations are positively linked to the corresponding seventeen Sustainable Development Goals (SDGs). These are created by the United Nations (Figure 18) and can be used as additional guidelines against which to measure a design solution, alongside the life principles of nature. The SDGs help visualise a shared future that we as a species have (or rather need) to reach.

Figure 19 shows two examples of an organism’s biological strategy in terms of its correlative innovation, which in turn contributes positively to specific SDGs and life principles.

The first example shows how the human eye inspired a non-toxic, biodegradable sunscreen. Currently, we use synthetic sunscreens made from chemicals. These chemicals have found their way into the oceans through our use. These compounds are now damaging marine life and us. The chemical compounds persist in our bodies and the environment for a long time. However, the biodegradable sunscreen uses the amino acid ‘kynurenine’, which has a natural sun-blocking chemistry. The inventors of this natural product modified the amino acid by adding additional bio-based compounds to make it too large to enter the body through the skin, while retaining its sun-blocking properties. This development contributes positively to a few SDGs. For example, SDG 6, Clean Water and Sanitation & SDG 14, Life below Water (Sunblock Inspired by Compounds in Our Eyes – Innovation – AskNature, n.d.). This innovation contributes positively to life principle 3: Use life-friendly chemistry.



Figure 18: The seventeen sustainable development goals (Sustainable Development Goals|Nissan Tokyo Sales Holdings Co., Ltd., n.d.)

The second example shows how owl wings inspired an aerofoil with fins to stabilise the flow and reduce turbulence. The innovators wanted to reduce the energy consumption of fans in greenhouses. By mimicking the design of an owl’s wing, the aerofoil reduces turbulence, allowing the fans to operate more smoothly, resulting in lower energy consumption. This development contributes positively to two SDGs: SDG 9, Industry Innovation & Infrastructure & SDG 11, Sustainable Cities & Communities (Turbulent-Reducing Aerofoil Inspired by Owl Feathers – Innovation – AskNature, n.d.). This innovation contributes positively to life principle 4: Be resource efficient (material and energy) & life principle 5: Integrate development with growth.









Biomimicry				
Biological Strategy	Benefits	Application	SDGs adressed	
 Sunblock inspired by compounds in our eyes	Non-toxic UV Protection Biocompatible	Skin protection Cosmetics	 3 GOOD HEALTH AND WELL-BEING	 6 CLEAN WATER AND SANITATION
			 12 RESPONSIBLE CONSUMPTION AND PRODUCTION	 14 LIFE BELOW WATER
 Turbulent-reducing aerofoil inspired by owl feathers	Reduced cost Increased efficiency Reduced noise	Aviation Heating and cooling systems	 9 INDUSTRY INNOVATION AND INFRASTRUCTURE	 11 SUSTAINABLE CITIES AND COMMUNITIES

Figure 19: Pupil by Michele (2023) & Owl by Nuij (2020). Information from AskNature.org (n.d.)

Nature as mentor

Nature is diverse and ingenious. Everything is interconnected; everything is part of a circular system. Animals, plants, and microbes all work together using the most efficient amount of [resources, energy, water, etc.] (Eadie & Ghosh, 2011; Biomimicry Institute, n.d.). However, humans evolved and began to slowly disrupt the balance of nature. The ‘damage’ that humans have done compared to the time we have been on this planet is extraordinary.

This extensive was partly due to technological developments in the 19th and 20th centuries and to a lack of knowledge of ecosystems (at that time). The Industrial Revolution led to a divergence from nature (Rogers, 2010). Today, the consequences of past inaction are visible in climate change.

The Earth has changed drastically due to human intervention. Humanity is forgetting that we are dependent on the Earth’s resources. As a result of our actions, a new geological epoch has begun ‘the Anthropocene’ (Biomimicry Institute, n.d.).

As such, humanity needs to move away from the take-make-dispose mindset of the industrial era and towards something new. Biomimicry is a new way of looking at and valuing nature. It introduces an era based not on what we can extract from the natural world but on what we can learn from it. Opportunities lie in circular, closed-loop systems (Pawlyn, 2019).

The example of a tree is used to illustrate what we can learn from biomimicry. It shows the difference between learning about a tree and learning from the tree (Figure 20). We can learn about the scientific name of the tree or its structure. But if we learn from the tree, we can understand how it captures energy and try to replicate this approach in human design.

Learning About → Learning From

Name:
Oak (Quercus spp.)

Leaves:
Simple but alternate, with irregularly rounded lobes

Range:
Broad, Temperate to tropical

Uses:
Furniture, Veneer

Canopy
Humidifies air, increasing inland rainfall

Leaves
Capture solar energy with nontoxic and biodegradable materials.

Limbs
Create structure; support with minimal materials

Trunk
Moves water against gravity without motorised pumps

Figure 20: Showing the difference between learning about & learning from. Inspiration taken from image Biomimicry Insitute 2022

Design with Biomimicry

This section attempts to address the question of ‘how to apply biomimicry’. A clear understanding of the method of ‘biomimicry thinking’ is required to achieve the intention of the design goal of this project. This is followed by the biomimicry requirements used in this project.

Biomimicry Thinking

Biomimicry Thinking is a method proposed by Biomimicry 3.8 (2023) that can be used to find solutions in nature to human design problems. It translates biological strategies into usable guidelines (abstract them) that help solve the problem. Biomimicry Thinking provides a context for where, what, how and why biomimicry fits into the process of any discipline or design. Biomimicry Thinking is a framework that is intended to help people practice biomimicry in the design process. The method consists of four phases, with each phase consisting of multiple steps. There are two ways to approach this method. The best results are achieved by going through the cycle several times. The full process is shown in Figure 21.

Phase 1: Scope

- Define: Setting boundaries for the project (Context setting). What are the criteria and constraints?
- Identify: Determine what you want to achieve. What challenge (design problem) do you want to overcome? Do not ask yourself “What do you want to design?” but ask, “What do you want your design to do?”. Followed up with constantly asking the question, “Why?” to discover the real challenge behind the perceived challenge.
- Integrate: Which one of the twenty-seven principles can be integrated into the challenge? Keep the six overarching life principles next to you to keep them in mind in the design process.

Phase 2: Discover

- Discover: Biologize the question. Ask yourself “How does nature ... that function?”. Look around! Research similar situations and solutions in nature. What can you learn from them?
- Abstract: Dive deeper into the behaviour or aspect of the chosen organism. Rephrase them in non-biological terms to create a design strategy. “How can this be useful for the design problem? Can you abstract the biological principle?”

Phase 3: Create

- Brainstorm: Play with the design principles to come up with multiple ideas. Bring the life principles into the design process and see what emerges. Which idea can be developed into a concept?
- Emulate: Decide on a design strategy (e.g. through the list of requirements). Which one solves the design problem? Consult experts if needed.

Phase 4: Evaluate

- Measure: Check if everything works and is in line with life’s principles. Is the design created with nature in mind? Does the idea comply with the prerequisites of biomimicry?

Challenge to biology

This cycle goes through the steps of Biomimicry Thinking chronologically. One can start with a specific problem in mind. This is followed by looking at nature: “How does she solve it? Translating biological knowledge into solutions. Useful in ‘controlled’ environments or in an iterative design process.

Biology to design

This cycle follows a specific path through the steps of biomimicry thinking. This approach begins with the discovery of a wonderful aspect that amazes. This is followed by identifying the corresponding life principles and trying to implement them in the solution to solve the problem at hand.

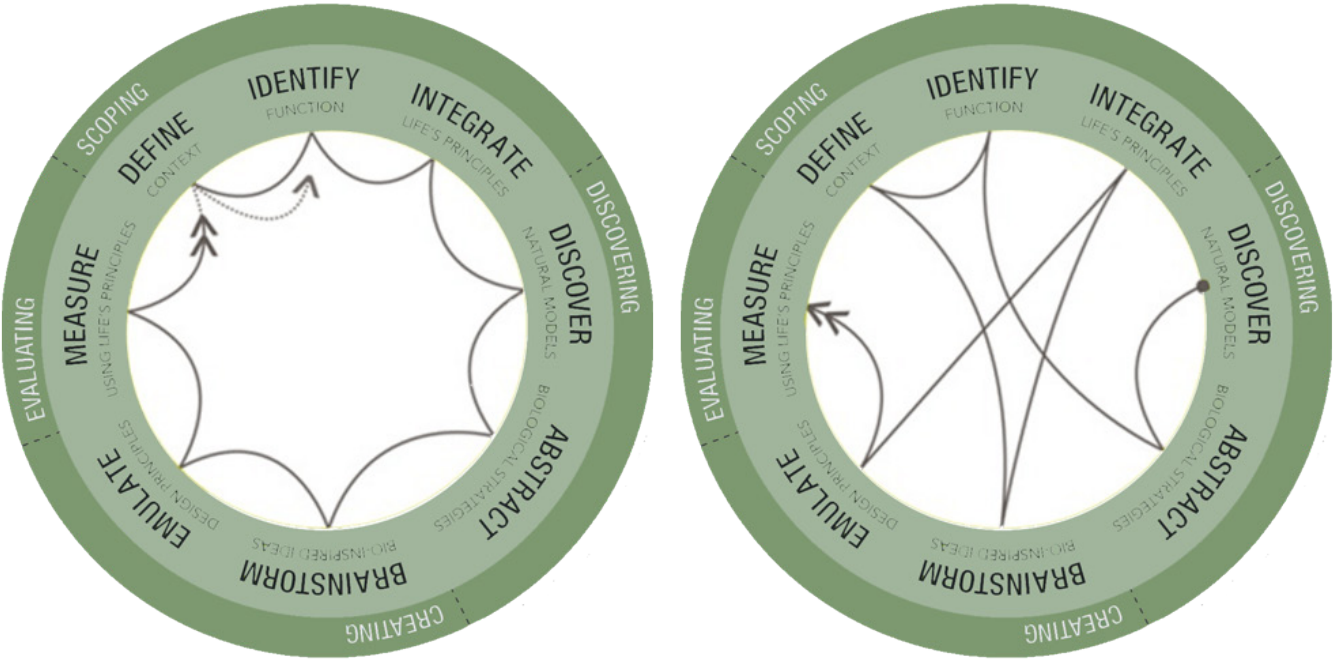


Figure 21: Two different approaches to Biomimicry Thinking. Left’s approach is called ‘Challenge to biology’. Right’s approach is called ‘Biology to design’.

Prerequisites for this project

In the introduction (Chapter 1.2) it is mentioned that the meaning of biomimicry has shifted more towards sustainability and reconnection to nature. Early inventions of biomimicry would nowadays be regarded as bionics (personal communication, L. Stevens, November 6, 2023). Based on the literature review so far, biomimicry is a difficult subject to grasp, even for adults. In the literature, examples of bionics and biomimicry are used interchangeably. In agreement with Museon-Omniversum, the definition of biomimicry used in this project will be broadened to make the subject more accessible. Examples of bionics and biomimicry (see Figure 4 in Chapter 1.2 to see the differences) will be used to explain the concept of biomimicry in the yet-to-be-designed exhibit. The main message to be conveyed is that we can learn from nature.

The definition for biomimicry used from now on:

"A design is regarded as biomimicry if it complies to the following prerequisites

- 1) the solution must mimic the chosen biological strategy or mechanism
- 2) it must mimic form, process, (eco)system, or one of Life's Principles
- 3) it must be an inter-disciplinary effort, meaning that multiple fields work together to create a new solution. This can be a combination of all fields, e.g. biology and design, as well as economics and chemistry.

The current guidelines to define if something is regarded as biomimicry can be seen in Appendix B.

Discussion and Conclusion

This chapter started with the research question 'How can we use nature's wisdom to solve human challenges and create a more sustainable future?' The question is addressed by finding answers to the sub-questions. In this conclusion, the questions are also answered concerning the perspective of children, as they are part of the target group. This is done to ensure that the topic of biomimicry (for the yet-to-be-designed exhibition) is also relevant to them.

1. What is biomimicry?

Biomimicry is a relatively new movement that draws inspiration from nature to solve human (design) problems in a sustainable way. At its core, biomimicry has three roles that are essential in translating biological strategies into design. Nature as mentor addresses form, process, or (eco)system. Nature as measure focuses on the ethics of biomimicry, designing within Earth's boundaries. Nature as model addresses the fact that we, as humans, are still part of nature and can learn from her.

The concept of biomimicry may be difficult to grasp for visitors, especially children. Therefore clear and easy-to-understand examples should be used, preferably ones they can relate to (e.g. well-known animals).

2. *What can we learn from biomimicry by looking at nature?*

Biomimicry shows us that we can innovate while maintaining Earth's boundaries. Future designs must adhere to the prerequisites of biomimicry. The designs should be benchmarked against life's principles to check if they are designed sustainably. The focus is on creating conditions conducive to life. As it is not always possible to adhere to all prerequisites yet, one can use the SDGs as an additional benchmark.

Biomimicry is a discipline that can be applied in many different fields, from design to biology. As a species, we need to change our behaviour towards the world and try to adhere to Earth's limits. Therefore, showing visitors about biomimicry can help them realise that answers are much closer to home. Start by looking at nature and start asking the question 'How does nature?'. They may begin to see the technology in nature, opening their eyes to a sustainable world that already co-exists next to ours, consisting of plants, animals, and all other organisms.

Ultimately, visitors need to understand that we can learn from nature by imitating the characteristics of an organism that contributes positively to the design problem and thus to a better world. Learning about this approach can be useful for children as it can plant a seed for (similar) future situations. Ideally, the yet-to-be-designed exhibit will encourage them to think outside the box in future problem-solving situations.

3. *How to apply biomimicry?*

One can apply biomimicry to their design process using the Biomimicry Thinking method. This is a framework that abstracts a biological principle to be used in the design; solving the original design problem. The method consists of several steps.

1. Define the context
2. Identify the intended design problem/goal.
3. Integrate as many as possible of the twenty-seven principles into the design.
4. Discover nature and biologize the question.
5. Abstract the biological principle to be suited for the design.
6. Brainstorm to discover possible solutions.
7. Emulate one concept that solves the design problem best.
8. Evaluate the design against the life principles or seventeen SDGs.

To make the concept of biomimicry more approachable, the definition is broadened for this project. A design is regarded as biomimicry if it

- Mimics the biological strategy or mechanism of the organism.
- Mimics form, process, (eco)system, or one of life's principles.
- The solution combines two disciplines together (e.g. biology and design)

This chapter has provided an insight into biomimicry and the background to the movement. These insights can later be used as design guidelines in the ideation process. The research provided answers to the research question of this chapter. However, additional research, such as interviews or prototype testing, needs to be done to verify that the topic is accessible to children. Examples used in the exhibition to explain biomimicry should be checked against the requirements of biomimicry to see if they comply with current guidelines.

2.3 The Museum as Context

As the project is set in a museum context, this section will explore the context of a museum by trying to find an answer to the following question.

‘How can museums design for playful learning experiences that present information in an engaging and accessible way to all visitors?’

Museon-Omniversum is a science museum that uses its collection and knowledge to present multiple perspectives on treating Earth respectfully. To design an exhibition piece that fits in their museum, they have to combine entertainment, education, and social interaction.

To understand how to create a meaningful interactive exhibit for Museon-Omniversum, you must understand what the role of a museum is. What is their purpose and why do people visit the museum? This is followed by the question: How do you address playful learning in a museum context? A final answer should be derived to the main question by answering these sub-questions.

Role of Museum

This subsection tries to find an answer to what the purpose of a museum is. Initially, they used to exhibit their collection as the main focus of attention, creating a context where one-sided knowledge transfer was the norm —educating the public on culture and history (Ghani et al., 2011). In addition, they had the role of collecting new items and preserving the collection. However, the role of museums has changed over the years. Currently, the International Council of Museums (ICOM) (2022) defines a museum as: “A museum is a not-for-profit, permanent institution in the service of society that researches, collects, conserves, interprets and exhibits tangible and intangible heritage. Open to the public, accessible and inclusive, museums foster diversity and sustainability. They operate and communicate ethically, professionally and with the participation of communities, offering varied experiences for education, enjoyment,

reflection, and knowledge sharing.” Museums are still a place to learn, but the ‘role’ of a museum has shifted towards the visitor’s experience. Education and entertainment have become more important for museums to achieve visitor satisfaction (Vermeeren et al., 2018; De Hartog & Remmelink, 2012). The focus of the museum is often the starting point for exhibitions, with the collection playing a supporting role (rather than being the main focus, as it used to be). Many museums use interactive exhibits to engage visitors with their content (main focus), resulting in meaningful learning experiences. Museums fulfil multiple roles in society. They can be all-encompassing or have a more specific focus (like Museon-Omniversum). Although every museum is different, every museum must fulfil the following roles (see Figure 22) (Musées & Lewis, 2004).

1.

Collection
The role of a museum is to collect heritage. These can be works of art or (cultural) artefacts from different periods. They are essential to society as they express the course of history. The collection is often expanded over the years.
2.

Conservation and restoration
The collection they have should be kept in the best conditions to preserve history. This includes restoring works to their previous glory.
3.

Affiliation
Museums can connect different groups in society through their collection and exhibitions. Multiple fields come together in a museum context.
4.

Relevance
Perspectives are ever-changing. Museums have to keep up with society's demands to exhibit current relevance.
5.

Educational
The visitor visits the museum to learn something about the present exhibition. Through the exhibitions, informal learning occurs. Interactive exhibitions work best to transfer knowledge towards the visitor. The young visitors (children) are exposed to new perspectives in an informal way, which is important for their development.
6.

Experience
Museums are more than just knowledge hubs; they have evolved into places for leisure. Exhibits should aim to let visitors think and reflect. In addition, the exhibits should be diverse (in interactions).

Figure 22: The six tasks each museum has to fulfil (Musées & Lewis, 2004).

Reaching visitors

The following subsection searches for an answer to what motivates museum visits in visitors. It will dive deeper into the types of visitors in a museum and the expectations they may have beforehand.

Visitor's motives and role

Before going to a museum, visitors are already biased. Each visitor uses their personality, norms and values, and beliefs to decide where to go and what to like. Visitors do have expectations of a museum before they visit (Sheng & Chen, 2012). In addition, visitors can be categorised by the role they adopt in a museum context. As mentioned above, each visitor experiences their visit to a museum differently. Visitors' experiences and motivations can also be categorised into 'visitor types' of attitude towards the museum. According to Falk (2006 & 2011), there are seven types of museum visitors, categorised by interest and needs (see Figure 23). However, it does not define them personally; they only take this 'role' during their visit to the museum. The first five are the most well-known. The latter two supplement the first five after Falk performed additional research into this topic.

Falk did his study in the California Science Centre. The three foremost types of visitors that they had observed could be categorised under:

- Explorer (often the children),
- Facilitator (usually the parents) or,
- a combination of Explorer/Facilitator.

The main focus for the yet-to-be-designed exhibit will be on the explorer or explorer/facilitator. This is due to the fact that Falk found that explorers retained the knowledge they gained from their visit in the long term, in contrast to facilitators who showed a decline in knowledge retention. He argues that this is due to their personal motivation to learn during their visit.

During the observations in the Museum-Omniversum, these three types were also present. Children often explore the exhibitions and start to 'play' with them directly. The role of (grand)parents varies from family to family. Some (grand)parents participated intensively in the exhibition with their children (explorer/facilitator), while others only explained the content or intention of the exhibition (facilitator) and let their children explore. However, for the explorer/facilitator group, their role could be regarded as fluid as it differed per exhibition.



Figure 23: The seven different 'roles' visitors can take during their visit to a museum (Falk 2006 & 2011)/

Playful learning

The question of how playful learning may occur in a museum context is addressed in this subsection.

The LEGO Foundation has been studying playful learning, as its vision is to build a future where learning through play empowers children to become creative and lifelong learners. The paper by Zosh et al. (2017) was written by multiple well-credited researchers in the field of human development at different universities. They looked at existing approaches to playful learning, shared their expertise and acknowledged that there are still areas for improvement that need to be explored. As LEGO is a toy-based company, they benefit from the outcome of the review paper, and therefore, this literature is considered as reliable. Research in child development has shown that learning is much broader and more interconnected than previously thought. Playful learning experiences are an effective way to develop (interconnected) skills. The paper states that playful learning occurs through experiences that are joyful, actively engaging, meaningful, iterative, and socially interactive experiences (see Figure 24).

1.

Joyful
joy is at the heart of play. It has to create a thrill of surprise or success in completing challenges.
2.

Meaningful
making sense of experiences. It has to connect to something they already know. Children explore what they have already seen or done themselves, or what they see others do. This helps them create new connections and gain a deeper understanding of the displayed content.
3.

Actively engaging
learning through hands-on activities while being focused. The child has to be actively engaged in the content
4.

Iterative
neither play nor learning is static. Children can decide what they want to do, so let them explore and experiment in a safe space.
5.

Social interaction
helps children learn about others. Sharing thoughts allows children to understand how others think. This direct interaction communicates ideas and creates relationships while building a deeper understanding.

Figure 24: The five characteristics of playful learning (Zosh et al.,2017)

These five characteristics are essential and provide a compelling picture. The data used is based on early childhood processes. Therefore, this project assumes that the five characteristics are still applicable in later childhood, as the researchers state that playful learning is effective for development in later life. Playful experiences can be defined as learning experiences that contribute to development in (later) life. The experience must be presented in a way that the child can understand. The connection to the content must be made in order to stimulate deeper understanding and to allow them to apply their knowledge in new situations. Abstract concepts that do not relate to children’s real-life experiences therefore lead to little memorisation of content. Playful learning can be seen as an umbrella term that includes free play, guided play or the use of games. Children can be supported by adults during these processes but should not be directed.

Playful learning in a museum

The book ‘A Family-Friendly Museum’ (translated from Dutch title ‘Een familievriendelijk museum’) by De Hartog & Remmelink (Chapters 1– 4, 2012) delves deeper into characteristic ‘social interaction’. Families can discover information together and learn at their own pace. Intergenerational learning may even occur within families during their visit. Accompanying children from the (grand)parents’ point of view; they learn to see issues from different perspectives. Working together leads to conversation by asking each other questions, solving problems together, or sharing experiences. In addition, children need to be emotionally engaged while interacting with the content to increase the likelihood of retaining the knowledge presented (Falk, 2006). All this can contribute to playful learning in a museum context.

Discussion and Conclusion

This chapter started with the research question ‘How can museums design for playful learning experiences that present information in an engaging and accessible way for all visitors?’ To arrive at an answer, sub-questions were answered through desk research and observation.

1. What is the purpose of a museum?

Museums play an important role in society. They bring different groups together through their exhibitions. They need to address relevant issues that appeal to visitors. As museums are seen as places of leisure, experience is crucial in exhibition design. Through a playful approach where visitors can interact with the exhibition, informal learning takes place and helps them discover new perspectives while having fun.

2. What motivates museum visits in visitors?

Visitors may have different motivations for visiting a museum. Personality or beliefs influence these motivations. In addition to these motivations, visitors can also be categorised according to the ‘role’ they adopt during their visit. Falk (2006 & 2011) derived seven types of ‘roles’, but three are most prominent in science museums:

Explorer (often the children) – the explorer is the curious type who wants to learn something. The focus lies primarily on themselves. This group is most prominent in maintaining knowledge over time.

Facilitator (usually the parents) – Facilitators are characterised by helping others during the visit. They are there to support. or a combination of Explorer/Facilitator – a bit of both and switches roles during their visit.

As the transformation in perspectives is the starting point of this project, the focus will be on explorers or **explorers/facilitators** as they tend to maintain knowledge over time.

3. How to address playful learning in a museum context?

Playful learning is an effective way of developing children’s interrelated skills. There are five characteristics of playful learning: it must be enjoyable and should be experienced as fun. Playful learning is stimulated by making the experience meaningful for children (the content must relate to their prior knowledge) and by letting them explore the context through hands-on activities. Another important feature is social interaction; they learn from and through others. Parents can support their child’s play and exploration, but should not take the lead.

Museums can play their part in creating environments accessible to all that stimulate exploring, having fun and social interaction. The museum can design exhibits where the parents and children have to work together, using the knowledge they already possess. Thus, an exhibition has to combine education, entertainment, and social interaction into one ‘piece’ to make it a fun exploration for both parent and child (De Hartog & Remmelink, 2012, Chapter 1– 4). They should present the content at a level so that everyone can understand (optionally with the help of a parent).

In response to the main research question of this chapter ‘How can museums design for playful learning experiences that present information in an engaging and accessible way to all visitors?’, the findings provide design guidelines for the ideation phase, as well as aspects to consider when designing an exhibition. The project continues with one assumption: “... the five characteristics are still applicable in the later stage of childhood, as Zosh et al. (2017) state that playful learning is effective for development in later life.”

Furthermore, the yet-to-be-designed exhibit should focus on social interaction to stimulate intergenerational learning within a family.

There is no clear answer as to how to present information clearly to all visitors in relation to the ‘presenting information’ aspect of the research question. The text to be used in the yet-to-be-designed exhibit will be discussed and revised with personnel from Museon-Omniversum. All current information presented in the museum is written by themselves (personal communication, D. Veerman, October).

2.4 Transformative Museum Experience

This section tries to explain what a transformative experience is and how this can be applied in a museum context in attempting to find an answer to the following question:

‘How can museums create transformative experiences that foster deep understanding that stimulate change within the visitor?’

By encompassing the following sub-questions, the overarching question can be answered. The sub-questions help define an answer based on literature research into this topic by finding an answer to ‘What starts a transformative experience?’ and ‘What are the key characteristics?’. This is followed by finding an answer to the question of ‘What is transformative learning?’ and ‘How can it be applied in design?’. At last, this section tries to define guidelines for how to design a transformative museum experience.

The findings can be used later in the design process to ensure that the yet-to-be-designed exhibition may lead to a transformative experience.

Transformative learning

This subsection attempts to define an answer to the question of what constitutes a transformative experience and what its key characteristics are. Transformative experiences are those that profoundly affect an individual’s worldview, values and behaviours, leading to significant personal growth and change. To create a transformative learning experience, you need to step out of your frame of reference and challenge the beliefs that shape you, creating new insights that you put into action. This personal change is often associated with strong emotions.

Mezirow derived a theory of transformative learning from women who returned to education to re-enter the workforce after a period of absence. In his study, he derived ten steps which are present in transformative learning, leading to a transformative experience (1978, 1997) (see Figure 25). Tho steps are explained in more detail as they are crucial to the project scope:

A disorienting dilemma refers to the first phase ‘Awareness’.

A critical assesment of assumptions refers to the second phase ‘Deeper Understanding’.

Such dilemma is described as an experience that reveals hidden assumptions that predetermine how we see ourselves and the world around us. Such a disorienting dilemma arises when one goes through a transition in life, such as a life crisis. You open up to new things in order to expand your consciousness. This personal change is called a change of perspective. These dilemmas cannot be solved by ‘just’ getting more information or improving your problem-solving skills. You are (un)consciously searching for ‘that’ thing that is missing. Context can be a catalyst for progress (Calleja, 2014).

By thinking for oneself and examining one’s own norms and values, beliefs or intentions, you challenges yourself. This can change one’s mind (Kitchenham, 2008). Critical reflection is based on objective reframing. Questioning your assumptions to see if what you believe is still true, can be caused by an external factor, e.g. reading a book or hearing a friend’s point of view. Self-reflection on your own assumptions, ideas or beliefs is called subjective reframing. You are internally questioning your actions, social norms, thoughts, etc. You are the factor itself.

1. A disorienting dilemma.
2. Self-examination with feelings of fear, anger, guilt, or shame.
3. A critical assessment of assumptions.
4. Recognition that one’s discontent and the process of transformation are shared.
5. Exploration of options for new roles, relationships, and actions.
6. Planning a course of action.
7. Acquiring knowledge and skills for implementing one’s plans.
8. Provisional trying of new roles.
9. Building competence and self-confidence in new roles and relationships.
10. A reintegration into one’s life on the basis of conditions dictated by one’s new perspective.

Figure 25: The ten steps of transformative learning (Mezirow, 1978,1997).

The transformative learning process is complete when all ten steps have been experienced. The process is not sequential or time-bound. The time it takes to go through all the steps can vary from person to person; some have a transformative experience after a single experience, while others take months to years before it happens (Taylor & Cranton, 2012).

The effectiveness and usefulness of these steps were tested and revised by Mezirow himself, and others soon took up his work. They have also critiqued, tested and revised his work over the years (Kitchenham, 2008) and continue to do so. Although some researchers would label certain steps differently, many have used his work to build on and this has resulted in a variety of frameworks for transformative learning.

Occurrence

Most experiences in everyday life are mundane and repetitive. Every now and then, however, an unexpected moment occurs. These unexpected moments (can) lay the foundation for a lasting change in worldview (Gaggioli, 2015). These experiences are neither good nor bad; they just happen. The basic rule of transformative experiences is that they are difficult to create artificially; they only happen by chance. Favourable conditions can be created to increase the chance of such an experience occurring. To illustrate their rarity, a study of transformative experiences in education found that only 9% of participants had a truly transformative experience in biology class. That is, participation in school led to engagement with biology outside of school (Pugh et al., 2009).

Purpose

One might wonder why one should seek transformative experiences through learning if the return rate is low. As mentioned in the previous paragraph, transformation occurs when one replaces one's old worldview(s) with a new one. This process is inherent to the visitor and cannot be provoked. Therefore, the idea of transformative design may seem contradictory. However, by providing knowledge and creating the 'right' space, transformative experiences can be stimulated (Gaggioli, 2015). This is where museums can step in by creating the right space. They can address complex problems in a playful way, which has the potential to change visitors' perspectives. To facilitate transformative learning, 'learners' need to become aware of and critically reflect on their assumptions. New information must be meaningful and fit into an existing frame of reference. It should touch the visitor's thinking and/or feelings, as described in the previous section (2.3) (Calleja, 2014).

Four phases of transformative experience

This section introduces the four phases of a transformative experience that are used to define the project aim of this thesis; these form the basis of this project. The four phases are derived from the original ten steps. These four overarching phases are based on recurring patterns in several studies of transformative experiences (Figure 26, Vermeeren, 2023). A museum context of Museon-Omniversum is used to outline the need and usefulness of a museum in presenting the four phases to people (hereafter referred to as visitors).

1.

Awareness – Feel that it matters

The first phase in the process is awareness: making the visitor aware of the discussion. A dilemma should confront the visitor with their current beliefs, assumptions, views or behaviour. This project will focus on (one's) contribution to a better world [main theme of One Plate NOW!]. Biomimicry can be one approach to solving this problem. Visitors should understand the importance of the dilemma and feel emotionally connected to it.
2.

Self-Reflection – Think and discuss

The visitor may reflect on their perspective through discussion, but only if they can relate to the situation. Creating an immersive environment can stimulate this. This is where the museum can play its part. Presenting knowledge, arguments, and perspectives illuminating the problem and showing possible solutions. The museum tries to help the visitor to define an answer to the following questions:

How does the visitor contribute to the problem?
What can the visitor do to help solve the problem?

The problem in these questions refers to the core of One Planet NOW!: one's own contribution to a better world. Addressing these questions can help guide the visitor through this phase. This phase succeeds when the exchange of views and ideas between visitors happens.
3.

Explore – Try out and experience the effect

The visitor should interact with the subject matter through hands-on activities. This may help the visitor reach the third phase in the transformational process. Active participation in the problem increases the chance of this happening. These activities will expand on the previous two phases, awareness of the problem and their self-reflection.

Museon-Omniversum can present new ideas and opportunities to let the visitor experience the steps that can be taken towards a better world.
4.

Integration – Reinforce and remind

If succeeded, the visitor's self-belief, assumptions, view, or behaviour will change (over time). The chance of this happening during or after seeing the exhibition is small, but if it succeeds, their worldview will be changed. Although this step is not part of the initial scope, the step will constantly be kept in mind during the design process. The design should aim for long-term engagement with the content (in this case Biomimicry).

Figure 26: Four phases of transformative experiences (Vermeeren, 2023)

Designing Transformative Museum Experience

This subsection defines guidelines that can help design a transformative experience in a museum context.

Framework Transformative Experience Design

Gaggioli (2015) derived a framework that can help to create transformative experience designs. To be transformative, visitors need to be actively involved in the design. The content of the exhibit needs to be relevant to them. By applying the following aspects, as in Figure 27, an interactive experience can be designed that can lead to a transformative experience.

- Medium

Different mediums, such as storytelling, films, music, etc., need to be used to stimulate the visitor.
- Content

The content provokes and challenges current worldviews and presents novel content that stimulates visitors to open their minds, creating moments linked to strong emotions.
- Form

This is more focused on the style through which the content is presented. Emotional and cognitive involvement needs to be present. This can be enhanced through narratives.
- Purpose

Initiating a transformative experience is hard, but considering an using an interactive experience as the start for a transformative experience increases the possibilities of one happening.
- Goal

All in all, based on the previously provided information, creating an interactive exhibit that stimulates visitors to use creative learning to question their worldview, hopefully leads to a transformation.

Figure 27: Five aspects that can help in the design of a transformative experience (Gaggioli, 2015).

Museum context

Gorman (2020) wrote the book *Idea Colliders: The Future of Science Museums*. The content is based on his speculation of the future based on current trends. He also addresses transformative experiences being part of future museums in the following quotation:

“While many museums have succeeded in engaging the curiosity of visitors, only a few are successful in stimulating shifts in perspective, and very few indeed are able to stimulate agency, in the sense of helping to stimulate follow-on action by visitors beyond the duration of the museum visit.”

Most museums use only one narrative to tell the story behind the artefact. Garner et al. (2016) believe that the frame of reference can also include learning goals by implementing self-engagement into the exhibition to encourage the visitor to learn more about the topic presented. They claim that this can be divided into three steps.

Re-framing
The visitor should be able to interact with the content to try out new ideas or explore new ways of thinking through cognitive and affective means.

Re-seeing
The aim is to trigger identity explorations through similarities and discrepancies between their current identity.

Re-enacting
This step is focused on the moments after the museum visit. Currently, museums use exhibitions that stimulate interaction to reveal or demonstrate something about an artefact. Garner et al. (2016) advocate for possibilities for self-reflection integrated into the exhibition so that they also act or think about it after they leave the museum.

The visitor is their own catalyst during their visit for the second and third strands on transformative experience and identity exploration, as seen in Figure 28. The museum can provide support through text-based prompts. For example, personal narratives can help visitors reflect on themselves, allowing them to become objects of discovery during their museum visit. In addition, a museum needs to create a safe space for emotional and physical comfort, where visitors can explore and respond to dilemmas presented in the exhibition.

In conclusion, for the museum to create transformative experiences that foster developmental engagement, it must integrate the learning objectives of the exhibit with the ‘affective and motivational characteristics of the visitor’, leading to personal engagement and relevance.

Relevance is of great importance in exhibit design. It’s based on one’s feelings and ideals. If the exhibition is not relevant to the visitors, they will (probably) not interact with it. If the information presented has a positive cognitive effect, it is easier to draw new conclusions. The lower the threshold for absorbing this new information, the greater the chance that visitors will find it relevant. Relevance helps to create a connection between the visitor and the message [the museum wants to convey] in a way that might unlock meaning for that visitor (Simon, 2016).

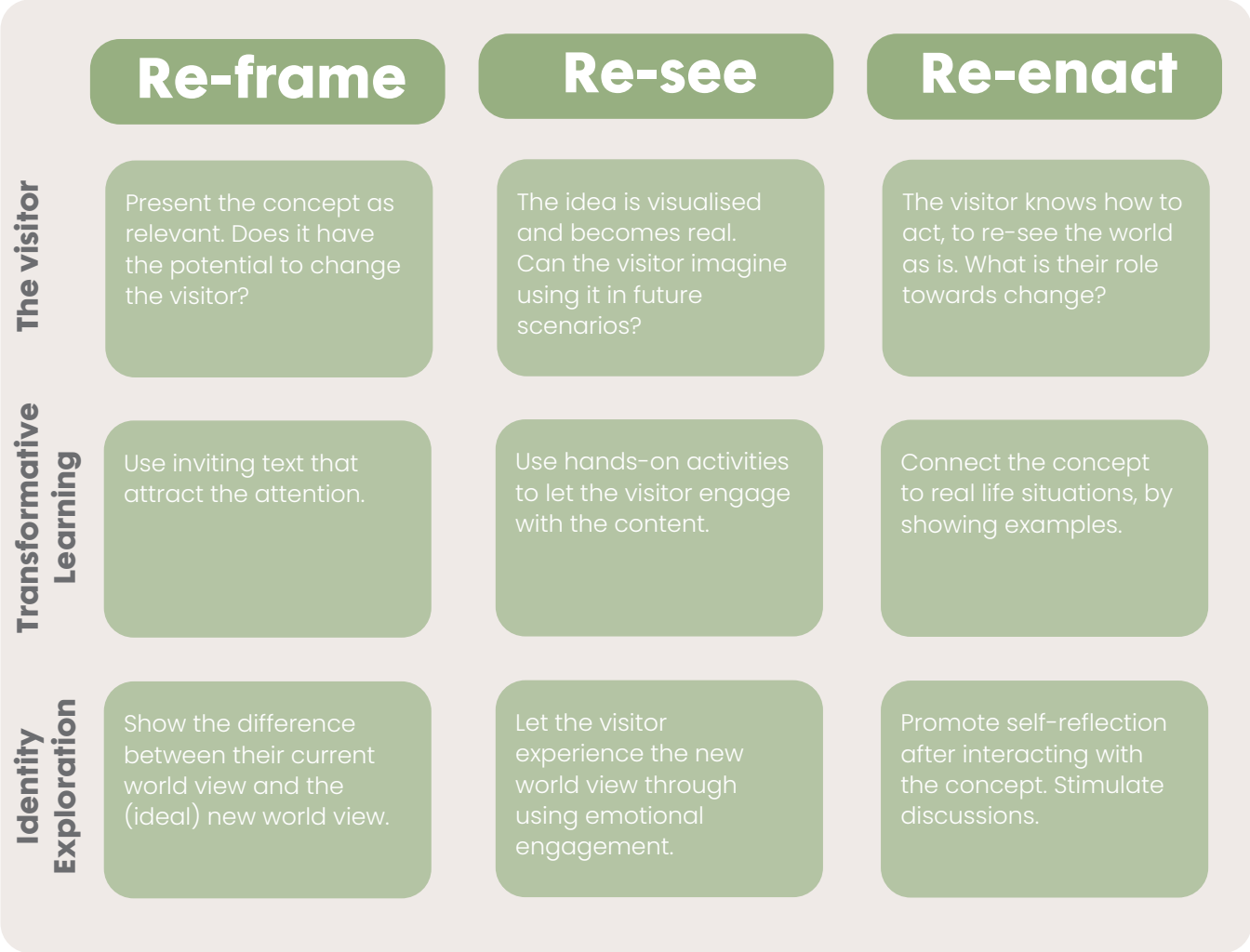


Figure 28: Overview of how to approach a transformative exhibit in museum context. Based on a model proposed by Garner et al. (2016).

Discussion and Conclusion

This chapter started with the research question ‘How can museums create transformative experiences that foster deep understanding that stimulate change within the visitor?’ Through literature research, meaningful insights have been gathered regarding transformative learning experiences. An answer has been derived to the main question by finding answers to the sub-question.

1. How does a transformative experience start?

Transformative experiences can begin at any point in life, but are more common when one is going through a transition. It has been argued that one needs to be faced with a disorientating dilemma for the process to begin – a process in which one’s assumptions and beliefs are challenged. Context can be a trigger, e.g. Immersive spaces.

2. What are the key characteristics of transformative learning?

The transformative learning process consists of 10 steps, as defined by Mezirow. These ten steps can be divided into four overarching phases.

Awareness	Bringing the subject to the visitor’s attention and showing the importance by stimulating an emotional connection.
Self-Reflection	The visitor should reflect on their perspective through discussion by creating an immersive environment.
Explore	The visitor should interact with the subject matter through hands-on activities.
Integration	The visitor’s self-belief, assumptions, or behaviour will change over time if the transformative experience succeeds.

3. How to design a transformative museum experience?

Transformation requires the visitor’s active participation in the exhibit relevant to them. Four aspects are identified to design a transformative museum experience: Medium, Content, Form, and Purpose
A museum can increase its chances of creating a transformative experience by striving to use suggested triggers, to provoke the visitor. Next, education and entertainment should be combined within an exhibition, as novel exhibits can trigger a transformative experience. By re-framing the visitor’s mind through cognitive and affective exploration, they might start re-seeing their worldview, which leads to possible re-enacting of these new beliefs after the visit.

Based on the literature research, the research question of this section is answered. Guidelines are presented that can help a museum design an exhibition that may provoke a transformative learning experience.

2.5 Interactive Exhibitions

Museums need to constantly update their exhibitions to stay relevant. Every exhibit should create and provoke a meaningful learning experience. This can be achieved by stimulating the five senses. This chapter tries to find an answer to ‘How to design an interactive exhibit?’.

A few sub-questions are derived to help define an answer to the main question. What are the desired qualities of an interactive exhibit? And how does Museon-Omniversum approach this compared to other museums?

Museums approach

Museums often have interactive exhibits that let the visitor immerse in the context. An exploration of Museon-Omniversum exhibits is done to get insight into their approach. This exploration is also done in three other museums to explore their approach.

- 1. ‘Wereld Museum’ – Leiden
- 2. ‘Belasting & Douane Museum’ – Rotterdam
- 3. ‘Maritime Museum’ – Rotterdam.

Each interactive exhibit is marked with the corresponding senses it stimulates and whether the exhibit is experienced alone, together or both. In addition, the exhibits are examined as to whether the information is presented as text or in a playful way. The full analysis can be found in Appendix C of the selected exhibits. The exhibits are placed on a C-box, to visualise areas for improvement (see Figure 29). The X-axis represents the social cohesion of the exhibit while the Y-axis represents the transition from informative to playful exhibits. In the figure, a target area is outlined for the yet-to-be-design exhibit.

It is noticed that there is room for exploration in interactive exhibits that are playful, informative and can be done with multiple people. The yet-to-be-designed exhibit should pursue to fulfil this target area to maintain a diverse set of interactions within Museum-Omniversum.

It stood out that other museums did not have as many interactive exhibits as the Museon-Omniversum. The overview only shows a glimpse of the interactive exhibits they currently have on display. They excel in this area compared to the other museums visited. Museon-Omniversum has a huge variety in different interactive exhibits. A lot of inspiration can be drawn from the current exhibits on display during the brainstorming phase. However, other museums excelled in other areas. ‘Wereld Museum’ – Leiden and ‘Maritime Museum’ – Rotterdam were better at creating immersive environments where the collection and information were displayed. The ‘Belasting & Douane Museum’ – Rotterdam excelled in creating extensive, well-functioning digital interactive exhibits. These visits served as inspiration in the process.

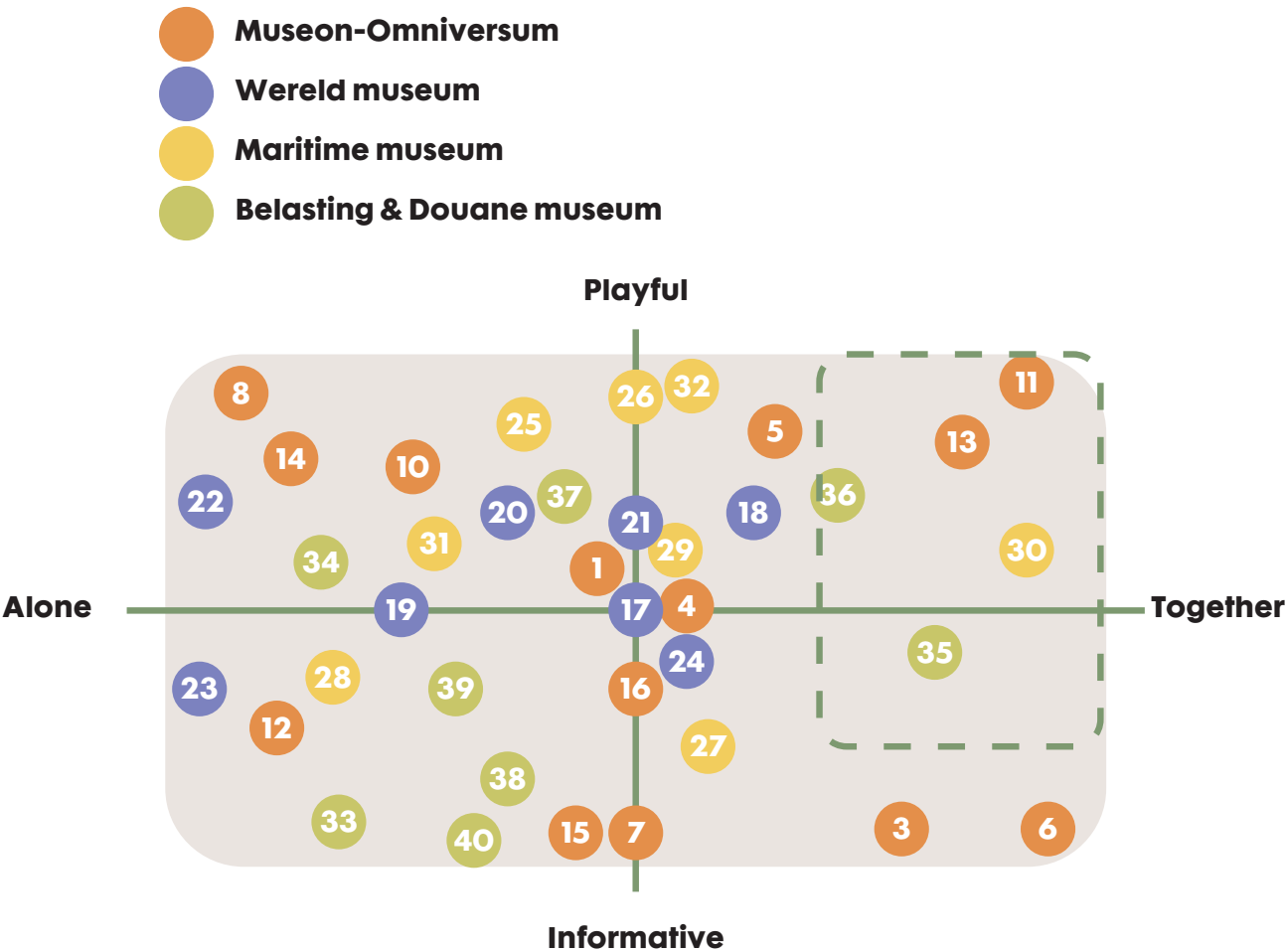


Figure 29: C-box about analysis of interactive exhibits in four different museums. The outlined area is the target goal for the yet-to-be-designed exhibit.

Discussion and Conclusion

This chapter began with the research question ‘How does one design an interactive exhibit? Through literature research and exploratory visits to museums, insights can be derived and used to define an area of exploration for the yet-to-be-designed exhibit. An answer to the main question was derived by finding answers to the sub-questions.

1. *What are desired qualities of an interactive exhibit?*

Exhibits should stimulate learning by creating relevant exhibits. Visitors can be engaged by stimulating one of the five senses in the interactive exhibit. Each museum is assigned the task of presenting the information at a level their target group understand, hereby bridging the knowledge gap. Stories and narratives are an effective way of bridging this gap as they let the visitor immerse in the content

2. *How does Museon-Omniversum approach interactive exhibits?*

Museon-Omniversum does use interactive exhibits in almost every display. They let the visitor explore the content through interactions fitting the subject. They have a diverse range, from playful to informative, which can be used for inspiration.

3. *How do other museums approach interactive exhibits?*

The museum visited for this analysis approaches the content mostly in a way that museums are used to, causing one-sided knowledge transfer. Although they are experimenting with new ways of presenting information, they have far fewer interactive exhibits than Museon-Omniversum. They mainly served as inspiration and discovery for the yet-to-be-designed exhibit.

The analysis of the interactive exhibits showed what was already out there. The target area for the yet-to-be-designed exhibit is identified as something playful yet informative, something to do together. Some exhibits already meet the requirements for this target area, but the number is small. There is a lot of room for exploration within the target area.

2.6 Overview of insight

The research to explore the project context is summarised into an overview. This overview is created to ensure that the conclusions and insights are preserved during the subsequent phases. They can help as guidelines, inspiration for the ideation phase, or be used to analyse and evaluate design choices.

Figure 30 shows the requirements stated so far and the most important guidelines based on the literature research and observations. Most requirements are not written in terms that have observable or measurable characteristics. However, they are clear enough to allow the project to proceed.

Guidelines based on		Insights - overview	
Museon-Omniversum	Museums & Interactive exhibitions	Biomimicry	Transformative Experiences
<div>Requirements<ul style="list-style-type: none">- The design should be understood by visitors from 8 years and older.- The information should be clear and presented in NL & ENG.- The information should be at A2 niveau (personal communication, D. Veerman, September 2023).</div> <div>Guidelines<ul style="list-style-type: none">- They want the visitor to experiment with the content.- The exhibition should illuminate a new perspective on the core message of 'One Planet NOW!'.- The exhibition should leave the visitor with a positive feeling.- The exhibition should have humoristic elements.- The the collection should support the exhibition.</div>	<div>Requirements<ul style="list-style-type: none">- The exhibition should be interactive.- The visitor should undergo playful learning.- The exhibition should stimulate social interaction.</div> <div>Guidelines<ul style="list-style-type: none">- The exhibition should be relevant to the visitor; The information should build further on existing knowlegde.- Create meaningful learning experiences.- The exhibition should combine education with entertainment; The exhibition should make use of games or guided play.- The exhibition should let the visitor think and reflect.- The visitor wants to be confroted in a positive way.- Immersion into the context may amaze visitors; The exhibition should appeal to the senses.- Playful learning happens through joyful, actively engaging, meaningful, iterative, and socially interactive experiences.- The exhibition should provoke dialogue between families.- The exhibit should be divers (new interaction).</div>	<div>Requirements<ul style="list-style-type: none">- Constantly ask 'How does nature ... ?'.</div> <div>Guidelines<ul style="list-style-type: none">- Biomimicry is a new way of viewing and valuing nature; It shows what we can learn.- Design solutions must emulate a biological strategies.- Design solutions should be life-friendly and help heal the planet; Design solutions should respect nature.- Design solutions should replicate form, process or system.- Design solutions should addres one or multiple life principles.- Design solution meets social, environmental and economic challanges.- The concept should use clear and easy-to-un-derstand examples.- The design solution can be benchmarked against the 17 SDGs.</div>	<div>Requirements<ul style="list-style-type: none">- The visitor should be made aware of biomimicry perspective (disorienting dilemma).- The visitor should reflect on their own values and beliefs by learning about biomimicry.- The visitor should interact with the content (biomimicry) through hands-on activities.</div> <div>Guidelines<ul style="list-style-type: none">- The exhibtion should lead to integration of 'biomimicry' in their daily life, altering their worldview.- New experiences may start the first phase: awareness.- Use different mediums to present the content.- Emotinal and cognitive invovlement of the visitor should be stimulated.- Create relevance to the visitor; Re-frame, Re-see and Re-enact</div>

Figure 30: An overview of all insights gathered based on literature research, categorised per subject.

One last thing to mention is that many examples of biomimicry are based on organism --> biological strategy --> innovation. A museum can display the product next to the stuffed animal with a bit of information next to it. Museon-Omniversum already displays some biomimetic examples in this way (see Figure 31).

- 1. A bicycle helmet based on the head structure of a woodpecker.
- 2. The Shinkansen, a bullet train, was inspired by a kingfisher's beak
- 3. The shark suit was inspired by a shark's skin.

However, this is exhibited in a way that museums used to do. One-way knowledge transfer is encouraged. Interaction is needed to create a transformative experience and engage the visitor with the content. The stimulation of dialogue will lead to the retention of knowledge over a longer period of time, based on previous research. In future phases, creative approaches are needed to come up with an idea to get around this obstacle.

Next steps

The research was carried out in a relatively short period of time. This overview only covers as much as the study was long. Therefore, a critical view should be maintained in the future process. New findings may emerge from additional research or feedback from tests. The overview is an abstraction of the research and cannot be used directly for the ideation phase. The subsequent phases: define, develop and deliver [double diamond], should explore ways of integration.



Figure 31: Three different exhibits about biomimicry currently on display in Museon-Omniversum. 1] A helmet based on a woodpecker. 2] The Shinkansen is based on the kingfisher. 3] The Sharksuit is based on a shark.

3.

Define

This chapter converges the data gathered from observations and desk research, pursuing a direction. Multiple approaches have been used to engage with the target group in order to define a starting point for the yet-to-be-designed exhibition. This starting point should be relevant to the visitor to increase the chance of triggering a transformative experience. This chapter will close the first diamond of the Double Diamond (Chapter 2.1). The conclusions of this chapter will be used for a new (diverging) exploration to define a concept direction; the start of the second diamond in the double diamond method.

- 3.1 Exhibition Approach
- 3.2 Concept 'Problem Approach'
- 3.3 Evaluating the Concept 'Problem Approach'
- 3.4 Evaluating the Process
- 3.5 Overview of Insights

3.1 Exhibition Approach

The guidelines derived from literature research of the previous chapter are the basis for the next phase. The abstract guidelines need to be translated into an exhibition direction. This chapter addresses the first user test, which leads to a project direction.

Below you find a short summary of the four phases of a transformative learning experience in regard to biomimicry, as described in the project scope (Chapter 1.1). The first three phases are part of the project scope and will be addressed in a museum context (see Figure 33).

- 1. make the visitor aware of the concept of biomimicry and show why it is relevant to them.
- 2. create deeper understanding of biomimicry is needed to self-reflect on your beliefs.
- 3. can 'practise' biomimicry through hands-on activities that stimulate interaction with the content or discussion.
- 4. Integration cannot be tested during this graduation project, as the project is too short. However, it can be thought of in advance. How do we create the most suitable conditions to reach phase 4 for within visitors?

Figure 33: The four phases of the project scope.

Project direction

The most intuitive way to depict biomimicry is to show the original product next to the innovative product. It was discovered that most examples are difficult to visualise. Many innovations are quite technical and most young visitors have not yet been exposed to such products. In order to build on existing knowledge of visitors, a shift in direction is needed.

As mentioned in Chapter 2.6, Museon-Omniversum currently displays the innovation next to the organism that was used for inspiration (see Figure 31). However, this approach is relatively straightforward and misses the spark wanted in the yet-to-be-designed exhibition. It provokes one-sided knowledge transfer. Most visitors will likely forget about biomimicry after their museum visit as it lacks interaction with the content. No afterthought would (probably) occur after they leave the museum. Therefore, this approach should be adjusted to fit the design goal of this project (as stated in Chapter 1.1):

make families with children (8 -12 years) aware that nature holds many solutions to (everyday) man-kind problems through hands-on activities.

Thus, a change of direction is needed. The design challenge includes a transformative learning experience alongside biomimicry. As biomimicry has been difficult to pursue, the approach of the design problem is reversed.

How to design a transformative learning museum in Museon-Omniversum?

For a transformative learning experience to be effective to the visitor, the experience needs to be relevant to them. Through brainstorming and discussions with peers, the idea came to approach the yet-to-be-designed exhibit through relatable 'frustrations and problems' that families encounter. Literature research showed that by using close-to-home situations in the exhibition design, visitors can (more) easily recollect the information they have absorbed during their visit to Museon-Omniversum. This may increase the chance of falling back on biomimicry in similar future situations. In agreement with a program-maker of Museon-Omniversum, this approach is pursued.

Reaching out to the target group

The next sub-section is focussed on what kind of frustrations and problems families encounter.

Efforts to understand the frustrations and challenges faced by families involved reaching out to the target group through a primary questionnaire. This questionnaire, addressing queries like 'What recurring events do you find unpleasant?' or 'What are your major concerns within the family or environment?', was designed to elicit responses from both parents and children. Despite attempts to engage the target audience via social networks, the response rate was notably low (N=8), with only parent-responses received. Responses were categorized into thematic clusters, as detailed in Appendix D. While the questionnaire yielded insights into family challenges, these insights were limited to the parental perspective. Key issues that emerged included:

- Too much screentime
- Children do not listen
- They never clean or tidy up
- Showing no respect to friends or parents
- Children not wanting to eat healthy

The formulation of this direction was prompted by an intuitive impression. However, it shaped the subsequent direction of the design process.

Ideation

The goal of this user test is to explore the approach starting from 'problems and frustrations'. This is primarily based on the questionnaire that is sent out. Would they prefer an approach close to home? Can they relate to this situation? In addition, the goal of this user test is to discover visitors' explicit knowledge about biomimicry. Are they aware of nature's potential solutions to the problems we face as a species?

The conclusion of this user test can be used for the next ideation phase.

Methods

Various methods were used to explore and generate an idea for the first user test. Individual brainstorming, discussions & brainstorming with peers and the guidelines from the literature review were the basis for the idea. In agreement with Museon-Omniversum, a first user test was derived from the idea.

Concept: 'Problem Approach' 3.2

This sections explains the design of the concept that is tested in user test 1. It consisted of three different settings, each one addressing a research question.

Explanation of the concept 'Problem Approach'

The concept 'Problem approach' introduces visitors to biomimicry. The concept consists of four activities which can be performed in any order:

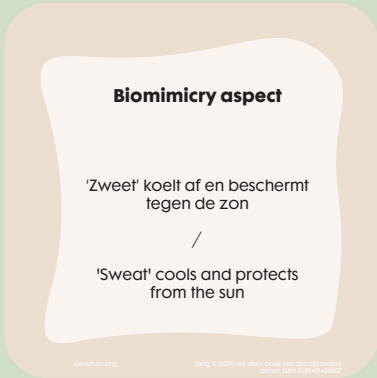
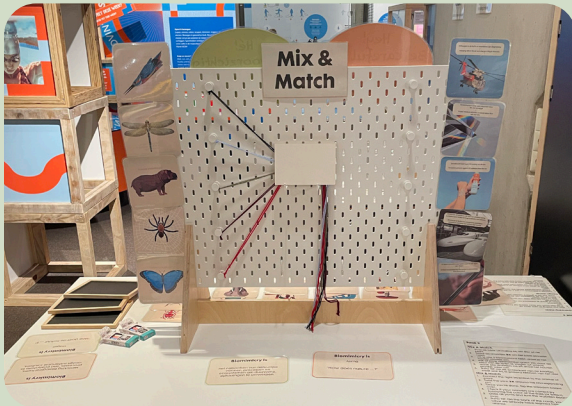
- A Mix & Match – An interactive game where visitors have to match the organism to the corresponding innovation.
- B Design Along! – Visitors are challenged to apply biomimicry themselves by solving recognisable and relevant statements.
- C Vote! – Visitors are able to vote for the questions they would love to be solved through biomimicry.

Each activity is further explained in Figure 34.

The design tested in User Test 1

A Mix & Match

is a game of matching pairs. Five different organisms should be connected to the corresponding innovations by connecting the correct string. It challenges the visitor to consider the biomimicry principle that inspired the innovation. The answers can be found by turning the wooden block. Extra information on 'why' they match, is presented on the back of the cards. [left-to-right] Organism - Biological principle - Innovation. Multiple sets are created to change every now and then. The cards are attached with Velcro.



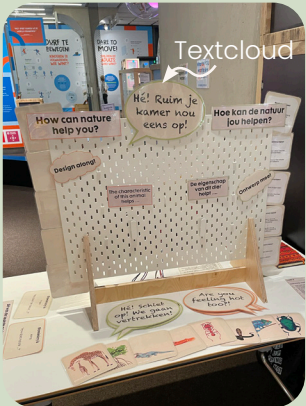
B Design Along!

focuses on exploring the ingenuity of visitors. A situation (or problem) [Textcloud] is chosen and put onto the board with Velcro. Visitors are then asked to find a characteristic of an organism to be used to help them solve that situation. There are four situations and twenty organisms in total to choose from.

One example of organism card is depicted. Additional information on their biological strategy is written on the back. The four situations that are used in the textclouds are the following:

- Hey! Tidy your room already!
- Hey! Be careful on the road today!
- Are you feeling hot too?
- Hey! Hurry up! We're leaving!

The chosen card can be hung on the board. The visitors are then asked to discuss among themselves the reason 'why' that organism can help solve the situation.

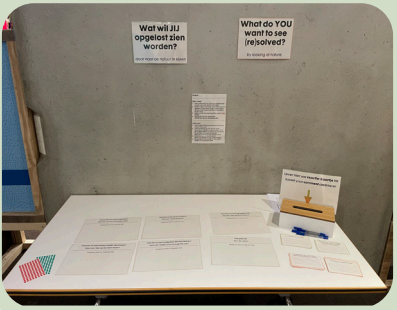


C Vote!

the concept creates a passive setting where visitors can give their opinion. No interference from the researcher is needed to succeed. Visitors can vote for the question they want to see solved through biomimicry by using stickers (Green = Like) and (Red = Dislike). The following six questions were presented:

1. How do I stay active or healthy?
2. How do I (or my house) stay cool?
3. How do I safely cycle through the city?
4. How can I save the Earth?
5. How can I tidy up my room faster?
6. How do I plan?

Any additional ideas could be written on cards and put in the box next to it.



Meaning behind the concept

Through different approaches, the visitor comes into contact with the term 'Biomimicry'. Interactive and challenging activities around biomimicry are displayed.

A *Mix & Match* stimulates interaction to connect organisms to innovation. Deepening information about the organism's biomimicry strategy can be read on the back of cards about the 'how and why' for the interested visitor.

B The steps taken in Biomimicry Thinking are simplified and addressed in *Design Along!* What can biomimicry bring the visitor? Open discussion is stimulated between families to discover (hidden) abilities of organisms that could be useful in the design.

C They have an option to *Vote* for the problem that appeals most to them.

Building the prototype

The prototype consists of four parts. An introduction, an interactive game, a participatory setting and a voting system. The introduction depicts the central question to biomimicry and explains biomimicry. The illustrations of organism for setting B – Mix & Match and C – Design Along! are taken from Het dikke boek van alle bijzondere dieren and Het dikke boek van onze bijzondere natuur by Hoare, B. (2019 & 2020). Information to corresponding organisms and innovations is taken from AskNature (2021). The prototypes are made with materials from Ikea regarding the SKÅDIS line.

The six questions used in 'D – Vote' were derived partly from the answers from the questionnaire and partly from discussion with a program-maker of Museon-Omniversum. Current themes used in One Planet NOW! inspired the direction of questions. The questions were described in such a way that they could be applied to parents as well as children. It was deliberately chosen to make the questions differ in complexity (some close to home while others address complex problems).

3.3 Evaluating the Concept 'Problem Approach'

This section is an evaluation of the 'Problem approach' concept that was tested as a prototype in user test 1. The summary of the test is supported by the findings, which are discussed in the conclusion. This led to a first iteration on the design goal, with focus points for the next design iteration.

Summary of user test

The results of this test helped to delineate the design goal and the direction of the exhibition. Table 1 presents a summary of user test 1. The complete test plan, together with a more detailed explanation of the results and used materials can be found in Appendix E. The test was held on the ground floor, in between the current exhibits of One Planet NOW! (Figure 35), next to three biomimicry examples that are already displayed..

Table 1: Summary of user test 1.

Set-up user test 1

Who 46 families observed, 26 families (qualitative) interview

What Validate the design with respect to the design goal through the research questions. Discover existing knowledge of biomimicry in the visitor.

When 16 to 22 October 2023, the fall break

Where Between 'Sport & Movement' and the 'Mobility' Area in the One Planet NOW! exhibit.

Why To discover existing knowledge of biomimicry and to delineate the design goal for future ideation in regard to the 'problem approach'.

How Through observation and interviews.

Role of Researcher

The researcher was present at all times but held a distance to the settings. Interference was only needed when the visitor did not understand the flow. Families could approach in their own time and discover the settings. They were approached for interview questions afterwards.

Research question

1. What do visitors (already) know about biomimicry?
2. What ingenuity are visitors using (in finding biomimetic aspects)?
3. How would they want to engage with the content (problem approach vs. example approach)?

Reflection

During the fall break, the museum was very crowded (approximately 1750 visitors per day, personal communication, Veerman, 15-01-2024). It was not always possible to interact with each participant. The results are, therefore, mainly based on observations.

The ideal situation, wherein each family would participate in all settings chronologically, could not be performed. There is no clear walking route yet on the ground floor of Museon-Omniversum; visitors approach from multiple sides. Future conversation/observation would be done per setting instead of the whole process. In addition, the process took too long to complete; young visitors lost interest and attention. Therefore, the chronological order was discarded.

Setting B – Design Along! underwent a small iteration by connecting organism to a situation rather than choosing one themselves. The interactions between each setup can be seen in Appendix E.

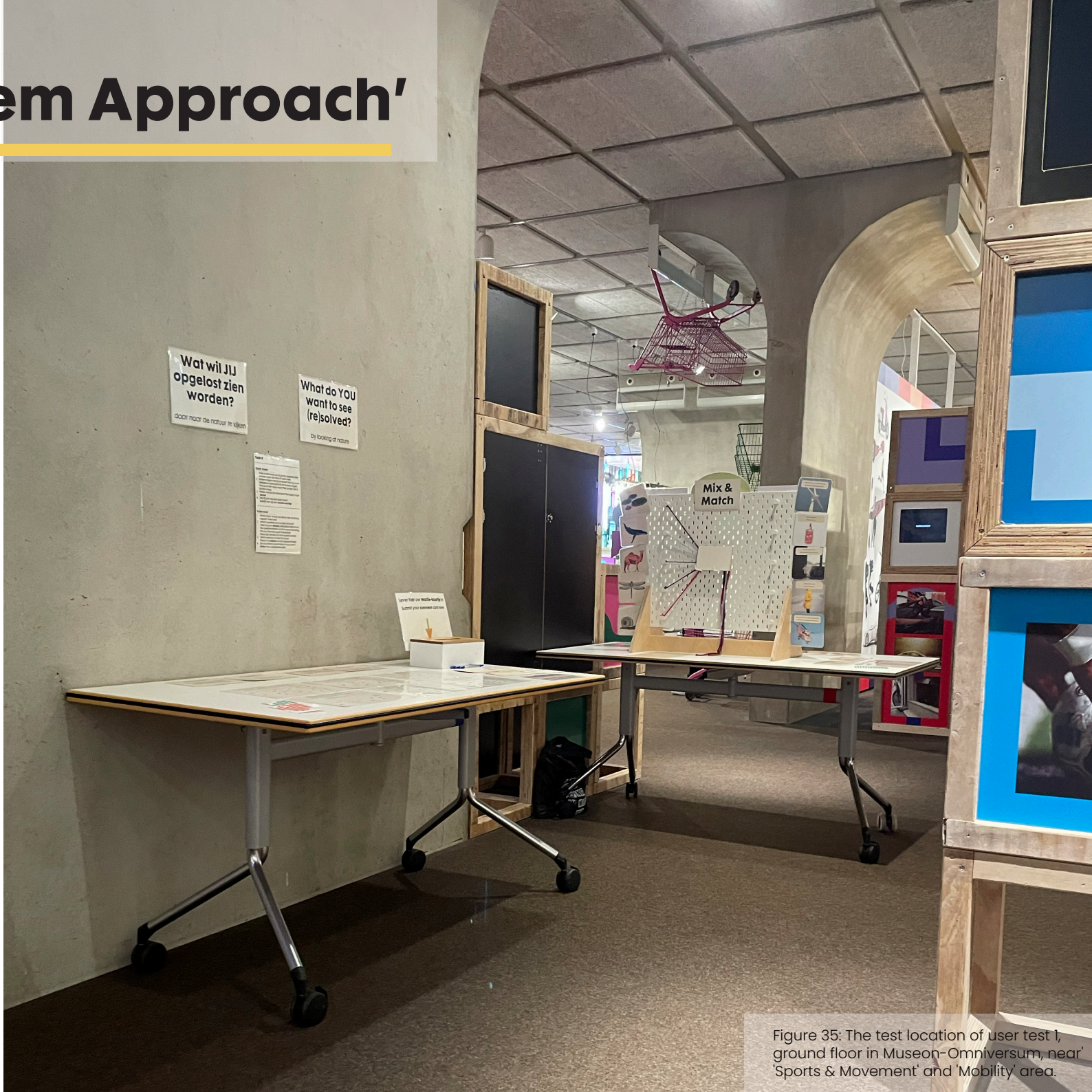


Figure 35: The test location of user test 1, ground floor in Museon-Omniversum, near 'Sports & Movement' and 'Mobility' area.

Findings

The findings are discussed per research question. The findings are based on conversations and observations with the visitor. Visitors who did not fit the target group were taken into account with observations as they still had to understand the meaning. In the end, the exhibition should address young and old visitors. The findings from the conversations should reflect an even balance between younger perspectives and older perspectives on the settings.

One thing that stood out and applies to every setting, is that visitors often do not read the instructions. They start interacting right away with the setting exhibit. This often led to confusion of the setting, especially in setting C. Therefore, the intended goal of this setting was not clear enough and often misunderstood.

Another aspect that does not work in a museum setting is having a part where visitors are asked to write down or draw their views on the subject. Children are often distracted from the goal of the user test as they want to draw, bypassing the intention of the user-test.

1. What do visitors (already) know about biomimicry?

Findings to the first research question were found by conversation.

However, setting A – Mix & Match proved to be helpful to discover if visitors had prior knowledge. The visitors could first explore the setting by themselves. The examples used in the test were new to most visitors but could often be matched to the right innovation by logical reasoning. When children were young (<10 years), parent(s) would often help during the process (see Figure 36). When the visitors still experienced some troubles or doubts, the researcher jumped in and started providing hints that nudged them to think in the right direction. These hints were moment-specific as they fitted into the conversation of that time. When the visitors were done, they would check for answers. It soon came to light that people did not read the back of the cards, so the researcher answered any remaining questions about the biological strategy used.

The data showed that one in twenty visitors has had heard of biomimicry before. However, many visitors knew examples that would be considered biomimicry, e.g. the Shinkansen or Velcro. A final question was asked after the visitor had interacted with the prototype: 'Would you be interested in learning more about biomimicry?' This led to a positive 'yes' by all visitors.

It was observed that this setting led to the most visitors to engage with the content. The goal of this setting was directly understood.

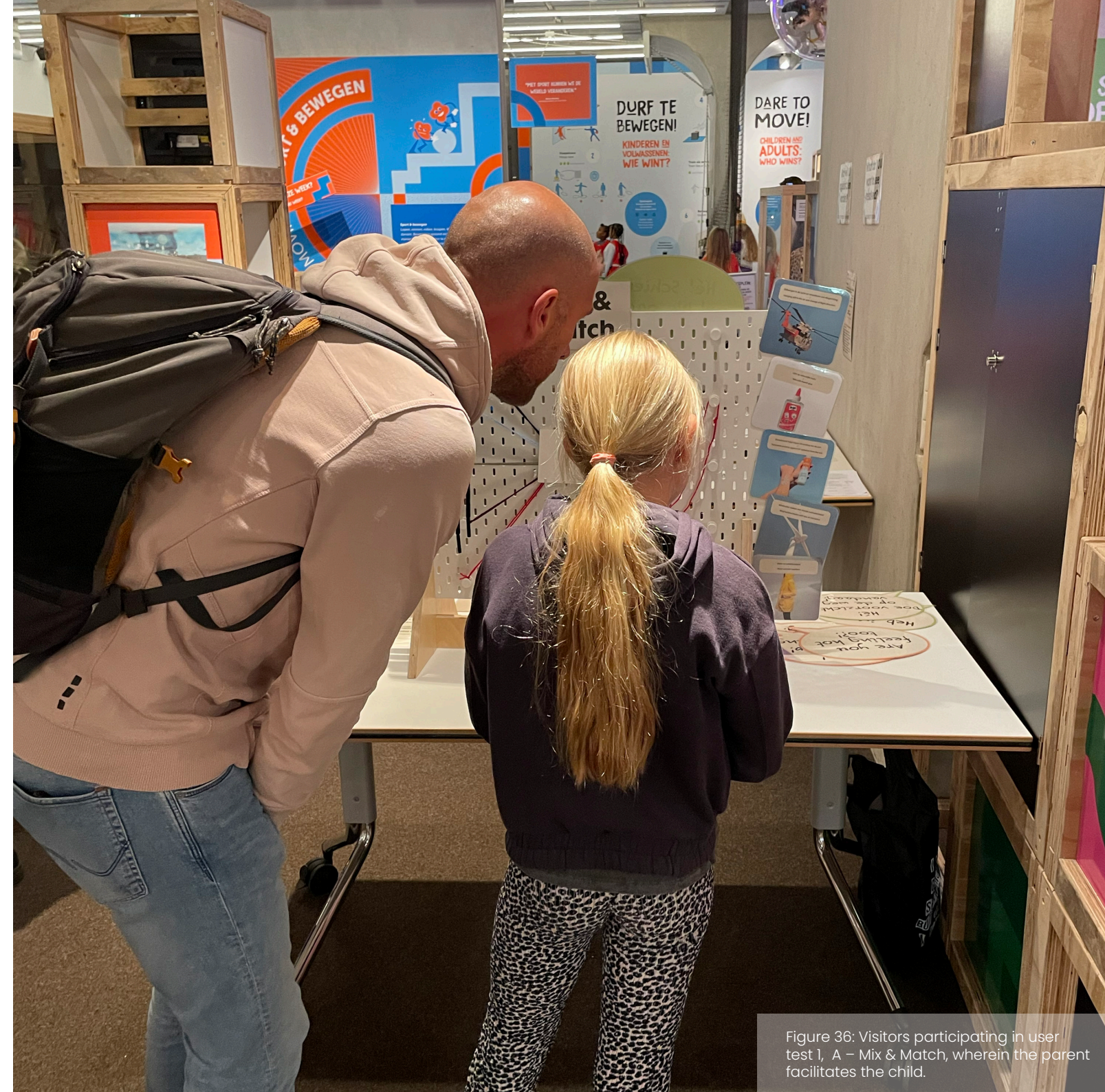


Figure 36: Visitors participating in user test 1, A – Mix & Match, wherein the parent facilitates the child.

2. What ingenuity are visitors using (in finding biomimetic aspects)?

Findings to the second research question were found by conversation and observation. Conversation with visitors showed that children quickly come up with characteristics that can help solve the problem (see Figure 37), while parents have more trouble connecting characteristics that help. However, some parents were thinking alike with their children. For example, in the situation: Hey! Tidy your room already!

“ Child 3 - “The toucan can help me as he can fly everything to its place.”
Parent 3 - “ I would take the ant's ability, as he is strong and can take everything to its nest.”
(Translated from Dutch) ”

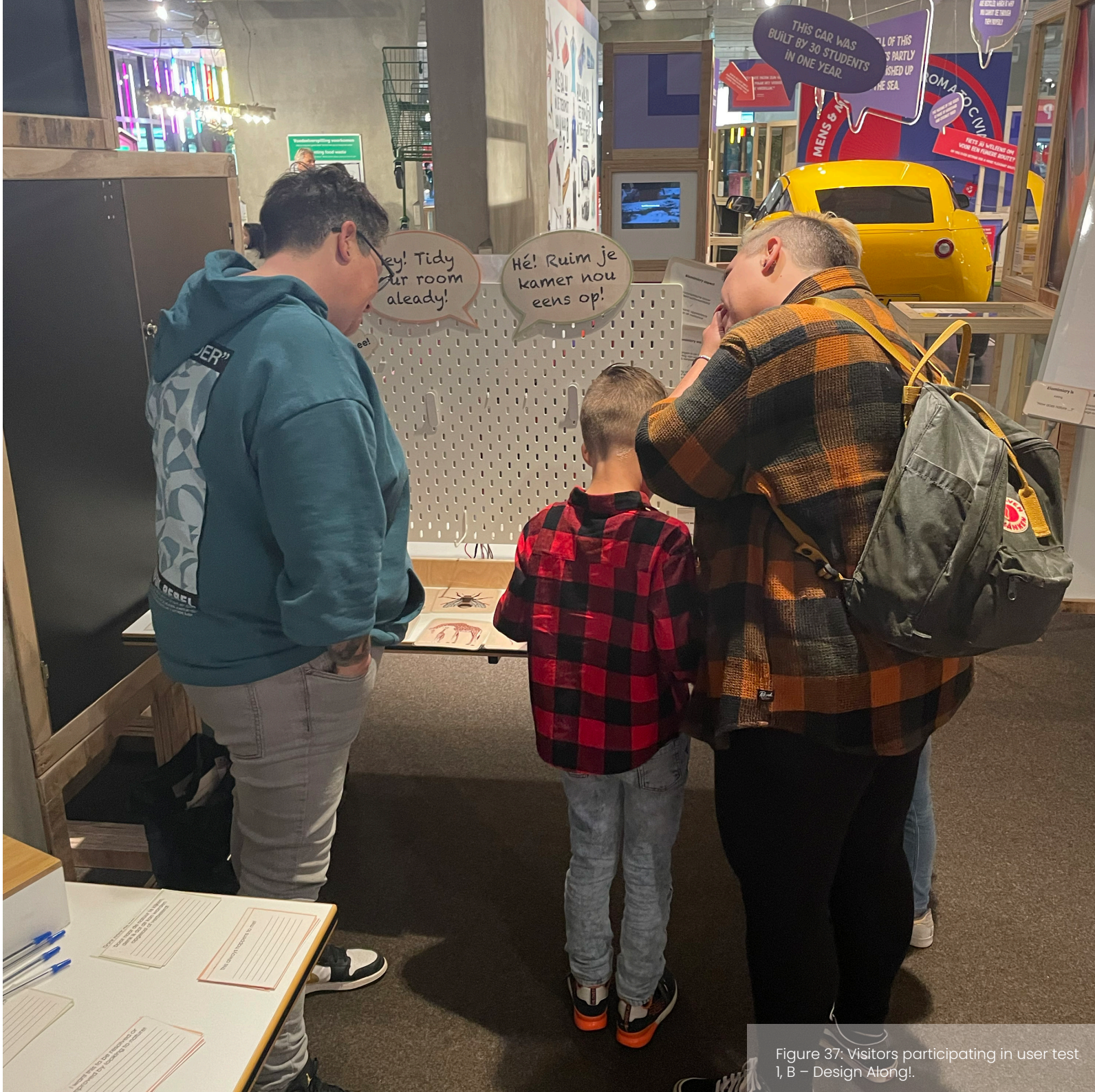


Figure 37: Visitors participating in user test 1, B – Design Along!.

3. How would they want to engage with the content (problem approach vs. example approach)?

Findings to the third research question were found mainly by passive data collection and observations.

If the visitors had tried setting A – Mix & Match as well as setting B – Desing Along!, the researcher would end the conversation with the question ‘Which setting do you like most?’; this was always followed by them answering: setting A – Mix & Match.

Observation showed that many visitors needed to figure out what to do with the interaction if the researcher was absent. This was followed by visitors directly moving on to another exhibit if the researcher did not jump in to help. The following quotes were overheard during observation:

“Why is this so difficult?”
(Translated from Dutch)

“Mom, what do we need to do here?”
(Translated from Dutch)

Furthermore, the exhibit did not start a dialogue between families/visitors. Dialogue only took off when the researcher was present.

Observation showed that setting ‘C – Vote’ was regularly visited. Visitors that were passing by would stop and bring out their vote (Figure 38 shows a grandparent and child filling in a card with their input). The complete score can be seen in Table 2.

The results show a considerable favour towards solving the question ‘How can I save the Earth?’, followed by ‘How can I tidy up my room faster?’.

Table 2: Final voting score per question in setting C – Vote!.

Voting score per question	Green	Red
How do I stay active or healthy?	45	12
How do I (or my house) stay cool?	28	23
How can I safely cycle through the city?	33	18
How can I save the Earth?	64	10
How can I tidy up my room faster?	59	23
How do I plan?	22	31

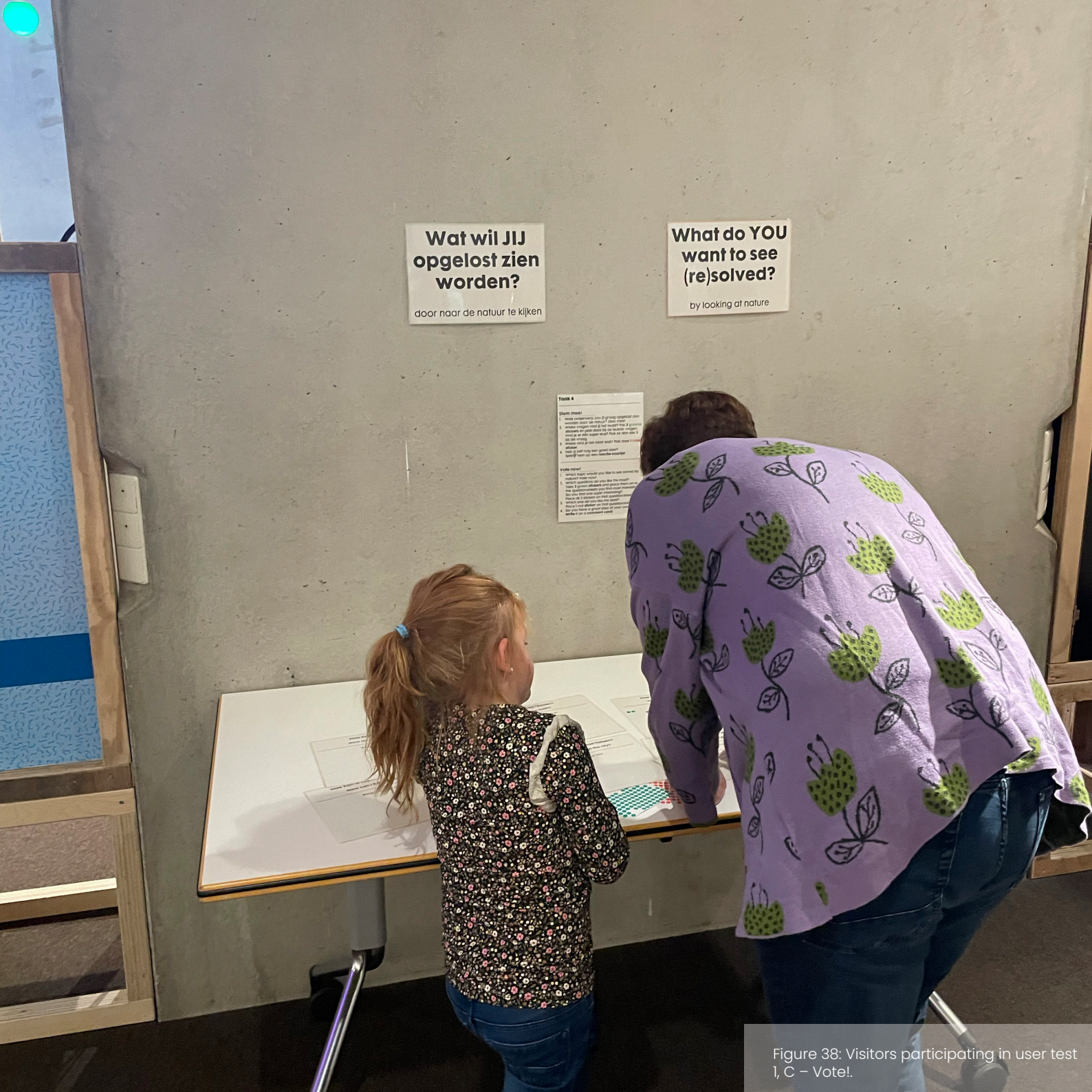


Figure 38: Visitors participating in user test 1, C – Vote!.

Discussion

The findings presented in the previous sub-section will be discussed per setting to find or discover recommendations which can be written as action points for future user tests in the project.

A Mix & Match worked best in this user test. Visitors directly understood what to do. This led to the assumption that a clear interaction that provides direct feedback (in this case, the answers) is preferred. However, the word 'biomimicry' is new too many visitors and should be explained clearly at a level everyone understands.

B Design Along! was experienced as difficult by the visitor if the researcher was not present. During observations, dialogue did not take off between families. This can be caused by one of the following reasons:

- Assumption 1: The assignment was experienced as unclear by some.
- Assumption 2: The setting is not engaging enough.
- Assumption 3: They did not like the interaction of this setting.
- Assumption 4: The absence of a 'fun' factor.

C Vote! used passive data collection without interference of the researcher or collected data through observations. The data only shows the final result and misses the reasoning behind. In addition, there is a possibility that the distribution adult/child is not even as the test was passive. Furthermore, there is a possibility that visitors placed more stickers than were asked, interfering with the data. Although the results show (Table 2) a considerable favour towards solving the question 'How can I save the Earth?', followed by 'How can I tidy up my room faster?', a great part also dislikes this question. This can mean that the question:

- Assumption 1: The question is undesirable by the visitor.
- Assumption 2: The question is provocative and leads to discussion.

This means that no clear direction can be based on the result of this setting. Further research has to be performed into the reasoning behind 'why' visitors want to see 'question X' solved.

3.4 Evaluating the Process

Looking back on the test, it may have started too soon into the project. The test may have been force-fitted into the project as it was bound to a specific time when Museon-Omniversum had the most visitors. The research part had not been concluded yet, so not all insights were put together. As there was no definite clear direction to pursue yet, due to the overwhelming world of biomimicry (there are too many examples to start from). Thus, additional research into the visitor, especially children's perspectives, is needed to be explored.

Additional exploration into the 'Problem' approach

To define a design direction that would be comprehensive to the target group, insights were gathered during an interactive lesson held in front of a class at a primary school (Groep 7 & 8). The findings of the responses received during the lesson will be clustered and used to choose a project direction.

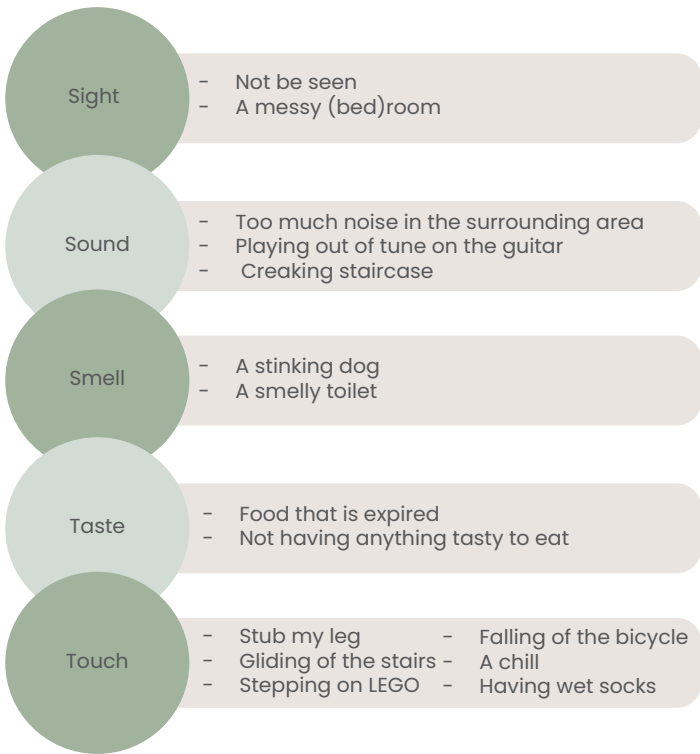


Figure 39: The events to be explored, categorised per sense.

Discover relevant 'Problems' by children

Additional research was carried out to identify problems that children face in their daily lives. With the help of Museon-Omniversum, a short workshop-like lesson was given at a primary school. The lesson was held twice, once in group 7 (pupils from 10 to 11 years) and once in group 8 (pupils from 11 to 12 years). The lesson started with explaining the goal of this lesson, to gather their input to ensure that the yet-to-be-designed exhibition would fit and address problems they recognise and relate to. Next, the term 'biomimicry' was introduced with examples such as the shinkansen. The first part of the lesson varied between information and discussion. The pupils were asked about personal knowledge and experiences. All to get them adjusted to the term 'biomimicry'. After the introduction, they were asked to write or draw things they find important in their life. To start them off with a positive feeling. When finished, they could turn the sheet and fill in the things they find frustrating or annoying.

The responses were analysed, and the answers clustered in themes. These frequently named irritations were often linked to the five senses or behaviour. Some clusters were of such magnitude that they were difficult to solve by biomimicry, let alone be approachable to children. Think of world problems such as climate change or current wars. A complete overview of the clusters is shown in Appendix F.

A design direction that was pursued in the 'problem approach', was to start from irritations linked to the five senses. As found in the literature research, the five senses are essential to playful design and transformative learning experiences. In addition, situations that visitors can recall and relate to have a higher chance of being remembered over time. Therefore, the decision to pursue the design direction 'Problems and irritations linked to the five senses' (as shown in Figure 39) is the starting point for subsequent ideations.

3.5 Overview of insight

Figure 40 depicts the takeaways based on the findings from user test 1. A list of all findings can be seen in Appendix G. These takeaways and guidelines will be taken along in the design process for future reference.

Takeaways and guidelines based on User Test 1 - overview

Knowledge	Characteristic of the visitor	Observations	Product
<div>Takeaways<ul style="list-style-type: none">- The term is unknown by most, but many know a few examples.- All visitors (who were interviewed) were excited to learn (more) about biomimicry.- Some (but few) visitors are interested in the information why the animal are connected to the innovation.</div> <div>Guidelines<ul style="list-style-type: none">- Information needs to be present (however, many do not read it).- Few look beyond the exhibit. Everything should be concentrated.- The term 'biomimicry' is too difficult to understand en sich. Rephrasing or synonyms are needed.</div>	<div>Takeaways<ul style="list-style-type: none">- (Grand)parents are open to talk.- (Grand)parents let their child discover and help when needed (facilitator).- Children are more difficult to approach as they may be shy.- Children are more creative in finding answers.- Parents help guide the children to find answers to questions during interviews.</div> <div>Guidelines<ul style="list-style-type: none">- (Grand)Parents often first read the assignment.- Children start interacting with the exhibit right away.</div>	<div>Takeaways<ul style="list-style-type: none">- Children run around the museum (explorer), the parent trotting behind (facilitator). Some are only busy with keeping their children close.- Visitors are curious about what is presented, but at the same time, if the prototype is not 'catching' enough, other exhibits in the museum draw the attention away.- No clear direct walking route can be determined on the ground floor (this differs too much per visitor).</div> <div>Guidelines<ul style="list-style-type: none">- Do not put information on the back of cards. Nobody reads them.- Drawing or writing does not work in museum-context.- Clear instruction is needed. If people do not understand the function/goal of the exhibition, they will walk on.- Make the exhibit attractive.- Do not number different tasks within the prototype. This leads to confusion, as there is no clear walking route.</div>	<div>Takeaways<ul style="list-style-type: none">- 'Voting' setup is a well-working way of passive testing.- Consent forms do not work in a museum context.</div> <div>Guidelines<ul style="list-style-type: none">- 'Doing' over 'Reading'. The first works best, let them experience. Interactive products work best (Mix & Match > Design Along!)- Make information more understandable (A2 niveau).- The text should be simple and short. Easy to understand.- Feedback at the end of the interaction is needed to verify if the visitor did it correctly.</div>

Figure 40: Takeaways and guidelines based on user test 1.

Conclusion

This chapter depicted the first user test (1) conducted to define a design direction to explore., plus the additional exploration about ‘problems and frustrations’ by children. The tests elicited many relevant insights about designing a exhibit in museum context.

The conversations held with visitors showed that many people did not know many biomimicry examples, except for the most well-known such as the Shinkansen or Velcro. However, it proved to be a challenging concept to understand, especially for children.

Visitors liked Mix & Match the most, as it had an interactive part. However, it was noticed that they need help to discover the (deepening) information.

Setting Design along! was most crucial for this project to discover if visitors liked to learn about biomimicry through a situation they recognised. However, the desired answers were hard to discover. This setting underwent some iterations during the week but with little result. During observations, visitors needed to figure out what to do with this setup, and therefore, it did not lead to any conversation between them. The researcher needed to be present to create the intended interaction. Therefore, no clear answer to this research question could be found during user test 1.

This Setting D – Vote! worked surprisingly, even though it was a passive activity. The best two questions that visitors would like to see answered are: ‘How can I save the earth?’ & ‘How can I tidy up my room faster?’. The first one aligns with the main focus of (the exhibitions in) Museon-Omniversum, thus not challenging a new direction. However, biomimicry can be used as a new perspective in line with their focus. Both questions are also disliked by few. In hindsight, the reasoning behind ‘why’ visitors liked this question should have been asked. Additional research was performed among pupils from a primary school. The responses were analysed and showed that ‘problems and frustrations’ linked to the five senses were mentioned most. This will be the starting point for the following design phases.

Overall, it did not fully provide the needed answers to answer the research questions, but much is learned about what does and does not work in the museum context. One aspect of change that is of importance for the project is that the target group, stated in the design goal, can be defined differently. The yet-to-be-designed exhibit should be designed for families with children (8 years and up).

Focus points

The most important guidelines derived from the user tests of the prototype are translated into actionable points (Figure 41) that can be implemented in subsequent user tests.

1. Knowledge about biomimicry is present, though not always under the term ‘biomimicry’. Examples given do easily impress visitors as they are unknown to them now. Visitors are curious to learn more about this subject, however the information should be presented shortly. How can you address multiple biomimetic examples to the visitor?
2. The interaction should be clear from the start. The things the visitor should do in the user test should be understood by visitors who do not read the instructions. How can you design an interactive exhibit that is intuitive?
3. The test should leave the visitor with a positive feeling towards their contribution to a better world. How can you positively influence the visitors towards biomimicry?
4. Social interaction should be pursued. Although this test was not successful in achieving to ‘start a dialogue between families’, it is crucial to the transformative learning experience. How can you stimulate conversations between families?
5. The current settings lack an interactive component, except for setting B – Mix & Match. To let the visitor engage with the subject of biomimicry, what can be done? What form should it take?

Figure 41: Actionable points derived from the user test.

Refined Design Goal

The insights from user test 2 are used to refine the design goal. The findings are converged and will help in the final phase. The design goal is structured to fit each of the phases of a transformative learning experience.

New design goal

Design a playful and interactive exhibition suited for families with children (8 years and up) to explore biomimicry and let them understand the usefulness of biomimicry for future problem-solving for the coming 'biomimicry zone' at Museon-Omniversum.

The four phases of transformative learning experience are addressed through

- 1. Make the visitor aware of what biomimicry is and can do.
- 2. Encourage dialogue between families to stimulate self-reflection and deeper understanding of biomimicry.
- 3. Interacts playfully with the concept 'biomimicry' through solving 'problems and irritations'
- 4. Plant a seed for future problem-solving (to use biomimicry).

A close-up photograph of a mushroom gill, showing a series of parallel ridges and grooves. The colors transition from bright yellow at the top to deep red in the center, and then to a dark purple at the bottom. The lighting creates a strong sense of depth and texture.

4.

Develop

The following chapter will build on the findings of previous chapters. The new design goal is the start of the second diamond (Double Diamond method), wherein the first step will be diverging. A list of design criteria will guide the ideation phase. Next, the prototype is evaluated through a user test, and this leads to new insights and action points for the final design of the exhibit.

This chapter aims to define an answer to the redefined design goal stated in chapter 3 through a new prototype. The prototype used proved to be a step in the right direction and will be the basis for the next chapter.

- 4.1 Design Approach
- 4.2 Concept 'Explore Biomimicry'
- 4.3 Evaluating Concept 'Explore Biomimicry'

4.1 Design Approach

This section briefly outlines the steps taken to come to the design which is presented and evaluated in this chapter.

Ideation

The approach of using relatable ‘problems and irritations’, as defined in the previous chapter, is further developed in this design cycle. The problems and irritations related to the five senses stood out from the others and were used as a starting point for design ideation. The three phases of the transformative learning experience (Awareness, Deeper Understanding and Exploration) were kept in mind. From now on, the ‘problems and irritations’ will be referred to as the ‘event’. The idea is to let the visitor solve an event that is linked to the five senses, using biomimicry.

The exhibit

The design objective is that the exhibit should be playful and interactive. At the same time it should encourage reflection on the concept of biomimicry (or an example of it) (Chapter 1.1). How can the exhibit be a stimulus for discussion? This question was used as part of the brainstorming phase.

Methods

An idea generation session was conducted with students of the Industrial Design Engineering (IDE) program at the TU Delft. Creative brainstorming techniques (How 2s, absurd questioning and SCAMPER (Heijne & Van der Meer, 2019)) were used to generate ideas. This idea was discussed with designers and stakeholders. This was followed by two ideation sessions with IDE alumni. To arrive at a concept to be tested in the second week of the Christmas break, different creative brainstorming techniques were used (Brainwriting 6-3-5, a brainstorm and roleplay (Heijne & Van der Meer, 2019)) (see Appendix H for the outcomes of the brainstorming techniques). Roleplay showed that approaching the concept by starting with an organism was harder to link to an event than linking an event to an organism. However, to confirm the phenomenon that emerged in the role play, both approaches are used in the user test.

Concept ‘Explore Biomimicry’ 4.2

The following section explains the list of requirements used to define the content of the concept, followed by the design of the concept-prototype. How would the visitor approach the prototype? What does the visitor have to do?

Explanation of the concept ‘Explore Biomimicry’

Visitors can interact with biomimicry through the ‘Explore Biomimicry’ concept. The concept consists of scanning an ‘event’ or ‘organism’ to activate the corresponding video. This is followed by a series of options. These options have an impact on the outcome of the final video. One flow of the decision tree of each approach is depicted in Figure 44 & 45. An overview of the complete decision tree for each approach can be found in Appendix I. All of the clips are supported by more in-depth information on the biological strategy. The concept is explained in more detail in Figure 43.

A short *glossary* for understanding this section

Biological strategy	A characteristic of an organism that meets a function
Superpower	This refers to a biological strategy of an organism
Event	An relatable situation that visitors (daily) encounter
Activation-block	The two starting blocks (Octopus & Slipping on the Stairs) which can be ‘scanned’. The visitor have to place them in the designated area (Plaats Hier)

The design tested in User Test 2

1. The visitor has to choose between an event and an organism. In this example the event is 'Slipping of the stairs' and the organism is 'the Octopus'.



2. The second step is to place the event or organism in the correct place (Scan Hier). The first clip will start to play when done correctly. In the picture one can see the opening screen of the octopus approach.



3. The third step is where the visitor is asked to make a choice. What superpower or event would they like to explore? They are presented with option to choose from. Each clip contains deepening information about the biological strategy. The complete sequence can be seen in Figure 44 & 45.



4. This is an information sign to explain the subject of the exhibit to the visitor. The signpost is a simplified version of what biomimicry entails.

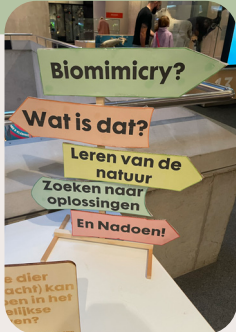


Figure 43: Complete setting of User test 2 with allocating numbers for explanations. The different numbers represent the steps the visitors need to take to complete the prototype exhibit.

Step-to-step guide to screens used in user test 2

Figure 44 shows the step-by-step screens of the organism-approach. The example shows the octopus’s ‘Grow bigger or smaller’ superpower option. This is followed by a short explanation of biomimicry. Next, the visitor has to choose which event can best be solved with this superpower (in this case, catching the wind on the bike). The visitor can then choose to apply biomimicry to solve a problem around the house or to discover an existing innovation based on the octopus.

Organism Approach

In short, the approach of an organism is first of all focused on the superpowers of the animal being scanned. Superpowers refer to biological strategies. However, they are called ‘superpowers’ to make the concept more accessible to children. Visitors are asked to discover one superpower. They are then asked to use that superpower to solve an event. Once they have done this, they have the option of exploring an existing innovation about the organism. Alternatively, they can try to apply biomimicry themselves.

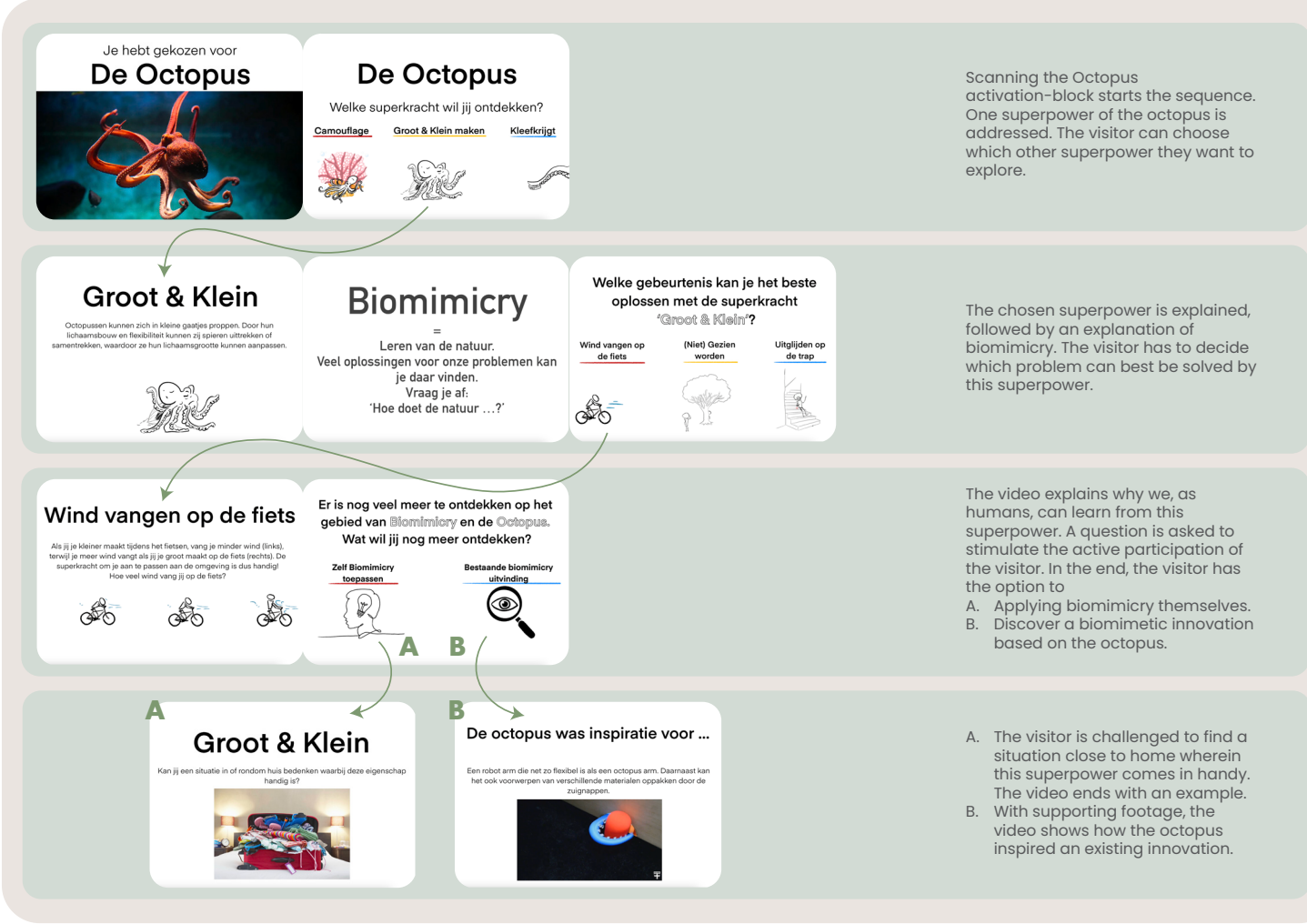


Figure 44: Step-by-step guide to the screens of the organism-approach used in the prototype with allocating explanations. The path is shown with the superpower ‘Growing bigger or Smaller’ and the corresponding event ‘Catching wind on the bike’.

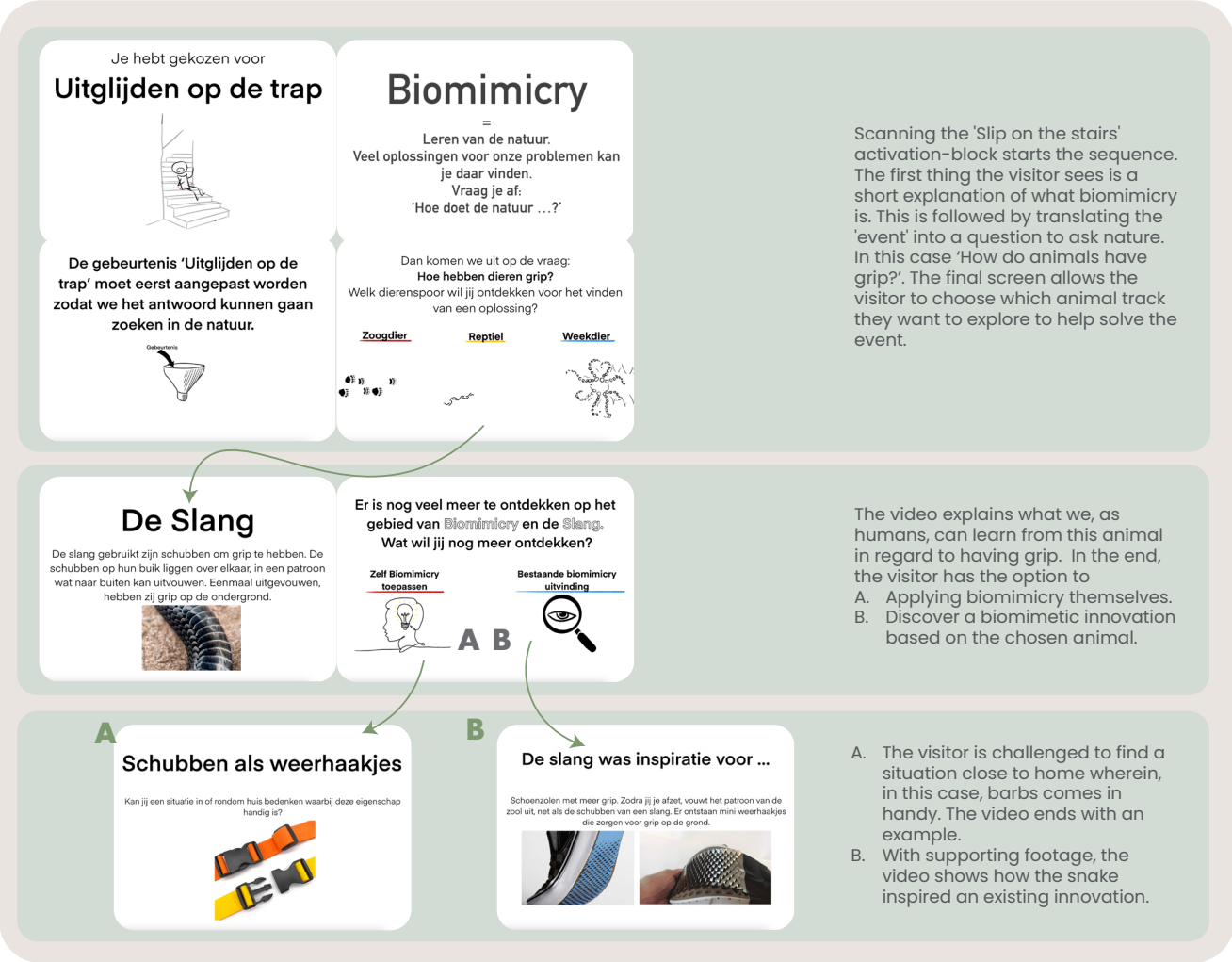


Figure 45: Step-by-step guide to the screens of the event-approach used in the prototype with allocating explanations. The path is shown of the option 'The snake'.

Figure 45 shows the step-by-step screens of the event-approach. The example starts with a short explanation about biomimicry, followed by the transformation of the event into a question to be asked to nature (How does nature have grip?). The visitor can then choose which animal to study to answer this question. The example depicts the option of the snake. The snake can use its scales as barbs to grip. The visitor then has the option of using biomimicry to solve a problem around the house, or discovering an existing innovation based on the snake.

Event Approach

In brief, the approach of the event focuses on finding an organism that could help solve or prevent the event by using a biological strategy of the animal. Visitors then have the option of exploring an existing innovation about the organism. Alternatively, they can try to apply biomimicry themselves.

Meaning behind the concept

For this concept, the learning method of Biomimicry Thinking (Chapter 2.2) was adapted for this research project, to make it more accessible to children. This alteration made it more fit for a museum environment (see Figure 46). The aim was to make the visitors (families) aware of the wide range of solutions that nature has to offer. Through stimulating discussions within the families, they begin to understand the method of biomimicry thinking and, ideally, would use this method in solving problems in the future. The difficult concept of biomimicry can be approached at a low level through relatable events.

The adapted method consists of 3 phases with a total of five steps.

Phase 1: Scope

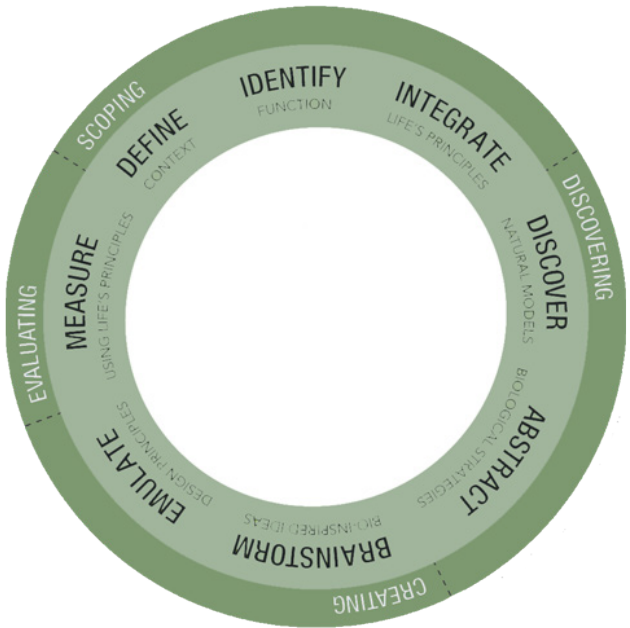
- 1. Define the problem
- 2. Identify what you want to achieve with the problem

Phase 2: Discover

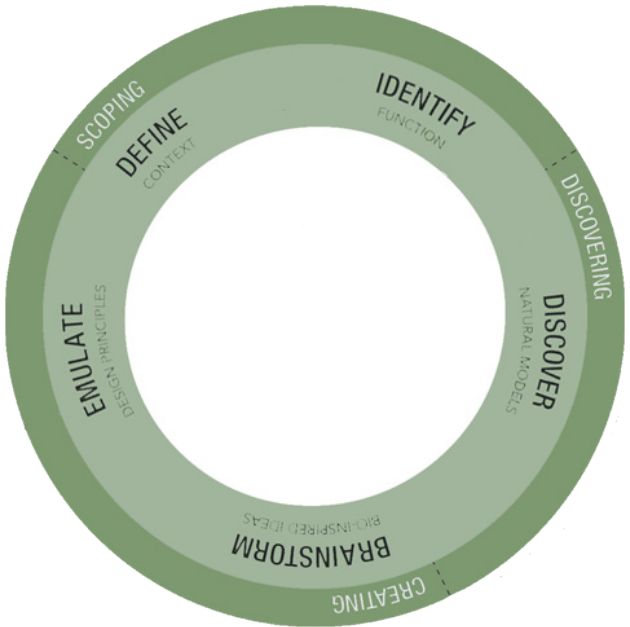
- 3. Discover what nature already has. Which question could you ask to nature?

Phase 3: Create

- 4. Brainstorm: Play around with the solutions. Which one can help you best?
- 5. Emulate: Decide on a final solution. Does it solve the problem?



The original four phases, consisting of eight steps, of biomimicry thinking (Biomimicry, 2023).



The simplified version of biomimicry thinking method, consisting of three phases and five steps.

Figure 46:
[Top] The original steps in the Biomimicry Thinking method.
[Bottom] Simplified steps of the Biomimicry Thinking method used in the concept of user test 2.

Diving into the exhibit content

This section describes the content used for this approach and the requirements used to determine the correct event and organism. They were explored at random and were further explored if they had promising results in accordance with the requirements.

Events per senses

The events, which are linked to the five senses, are depicted in Figure 47. This Figure was also shown in chapter 3.4. These events were to be used for exploration in the design content for user test 2.

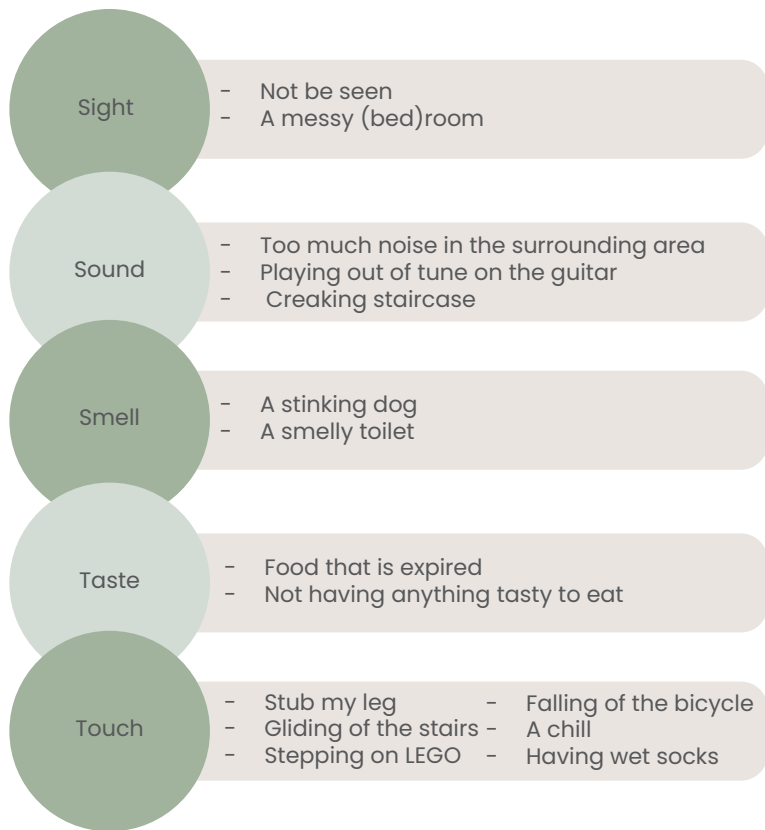


Figure 47: The events to be explored, categorised per sense.

Requirements for each Approach

Further desk research has been carried out to link the events to the organisms. As there are two approaches in the prototype, based on the simplified method of Biomimicry Thinking, two different sets of requirements are used. One for the starting point of the ‘event’ and one for the starting point of the ‘organism’ (Figure 48).

Event: The needs and requirements

- The event should be translated into nature-related questions. This translation should be understandable for children (from 8 years).
- The organism should address an ‘event’ that has emerged from research and is linked to the five senses.
- The organism should have at least two innovations based on its biological strategies.
- The organism should be available as figurines from toy companies (only for this prototype).
- Preferably solved by an organism, currently in the collection of Museon-Omniversum.
- Preferably cross-referenced to organisms used in the organism approach.

Organism: The need and requirements

- The animal should have multiple superpowers (at least two).
- The animal should have multiple innovations, per superpower one innovation.
- The superpowers should address an event as mentioned in the previous paragraph.
- The organism should be available as figurines by toy companies (only applicable for this prototype).
- Preferably addressing an organism that is in the collection of Museon-Omniversum.
- Preferable cross-reference to the organisms used in the event approach.

Figure 48: [Left] Event requirements, [Left] Organism requirements.

In short about the requirements, the organism should already have biomimicry innovations based on its biological strategies. To find a suitable organism, the event had to be translated into a question that could be answered by looking at nature. In addition, as the Museon-Omniversum wanted to combine collection and exhibition, it would be preferable if the organism could be found in the Museon-Omniversum collection.

A number of events have been explored, such as ‘A stinky dog’. This event was translated into the question ‘How does nature reduce odours?’. The event ‘Too much noise in the neighbourhood’ was translated to the question ‘How does nature reduce noise? These two events proved to be difficult to solve while meeting the above requirements. The event ‘Sliding down the stairs’ proved to be suitable for this prototype. This event was translated into the question ‘How does nature have grip?’ Several organisms (see Figure 49) had superpowers related to grip, and at the same time innovations based on these superpowers.

Building the prototype

Some coding in Arduino and Python was required to create the interactive components (‘scanning’ and ‘making choices’). The code was quickly up and running. The wooden signs are laser cut and the centre block (with the buttons) is hand built from 5mm plywood. The digital clips are created in Premiere Pro and uploaded to Resolume, the programme used to play the clips in the correct order.



Figure 49: Organisms that have an biomimetic innovation based on grip.

4.3 Evaluating the Concept 'Explore Biomimicry'

This section is an evaluation of the 'Explore Biomimicry' concept that was tested as a prototype in user test 2. The summary of the test is supported by the findings, which are discussed in the conclusion. This led to a redefined design goal and focus for the next design iteration.

Summary of user test

The data from this user test will further refine the design goal and form the basis for the next design iteration. Table 3 provides a summary of User Test 2. The full test plan and list of findings can be found in Appendix I & J. This user test was conducted on the first floor of the Museon-Omniversum, near SDG 13 – Climate Action, SDG 14 – Life below Water and SDG 15 – Life on Land (see Figure 50).

Table 3: Summary of user test 2.

Set-up user test 2

Who 40 families observed & qualitative interview

What Validate the design with respect to the design goal through the research questions. Discover existing knowledge of biomimicry in the visitor.

When 2 to 8 January, the Christmas break

Where First floor, between SDG 13 – Climate action, 14 – Life below water & 15 – Life on land in the One Planet exhibit.

Why To discover if visitors can recall the subject just explored and if the flow of the prototype works in a museum setting.

How Through observation and interviews, data is gathered which is used to answer the research questions.

Role of Researcher

The researcher was present at all times, as the prototype could not function on its own. Families could approach in their own time and discover the exhibit. Interview questions were asked afterwards.

Research question

1. How do visitors perceive the interactive experience of the prototype?
2. How do visitors reflect on biomimicry through their own participation and discussions among families?
3. To what extent do visitors recall what they have learned (about biomimicry) after interacting with the prototype?

Reflection

On the first test day, 25 families were observed and interviewed. On the second day, 15 families were observed and interviewed. A museum professional also participated in the user test on the second day. Between the test days, small iterations were made to improve the clarity of the interaction. These included:

- 1) Adding arrows to show where the blocks should be scanned.
- 2) Adding text above the buttons to explain that they are used for voting.
- 3) The addition of a signpost to repeat the main message of the content as presented in the video clips.



Figure 50: The test location of user test 2, first floor in Museon-Omniversum, near SDG 13 – Climate Action, SDG 14 – Life below Water and SDG 15 – Life on Land.

Findings

The findings are discussed by research question. They are based on observations and short interviews with visitors after the user test. Some overarching observations are discussed first.

Overarching observations

The use of the word ‘superpower’ was less effective with children than expected. It had little impact on the distribution event/organism. By observation, 16 out of 40 families (roughly 40%) would choose to start with the ‘event approach’, while 24 out of 40 families (roughly 60%) would choose to start with the ‘organism approach’. This suggests that both approaches were inviting to explore.

In addition, the observations showed that some of the visitors were drawn directly to the screen and did not look any further around the exhibit. Some visitors therefore missed the signpost altogether as they focused on the activation-blocks or buttons.

1. How do visitors perceive the interactive experience of the prototype?

Most visitors did not understand the initial interaction. They would often stare and look confused. When the researcher was present, the first question asked was: ‘Do you understand what you need to do?’ This was often followed by a ‘no’. After an explanation by the researcher, each visitor understood and completed the flow of the prototype. They engaged with the content until the last clip in their decision tree. Some younger participants looked away halfway through a clip. However, they stayed until the end. There were also occasions when visitors pressed the button too early. This caused Resolume to play two videos at once, resulting in sound pollution in the video (when the prototype was still working on its own). This was quickly remedied by the researcher’s intervention.

As in user test 1, this user test again showed that visitors hardly read the signs. The signs about what each block represented (Figure 43, number 1) were often not read, resulting in visitors not knowing what to do with the prototype.

Interviews showed that visitors liked having the ability to direct videos. Three out of forty found the videos a little too long. One participant mentioned that the videos could have more colour to make them more appealing to visitors.

“ Parent of a child: ‘The information is playfully conveyed. It takes the time to explain everything clearly in a calm tempo. I liked the interaction enough to explore all information.’
 (Translated from Dutch) ”

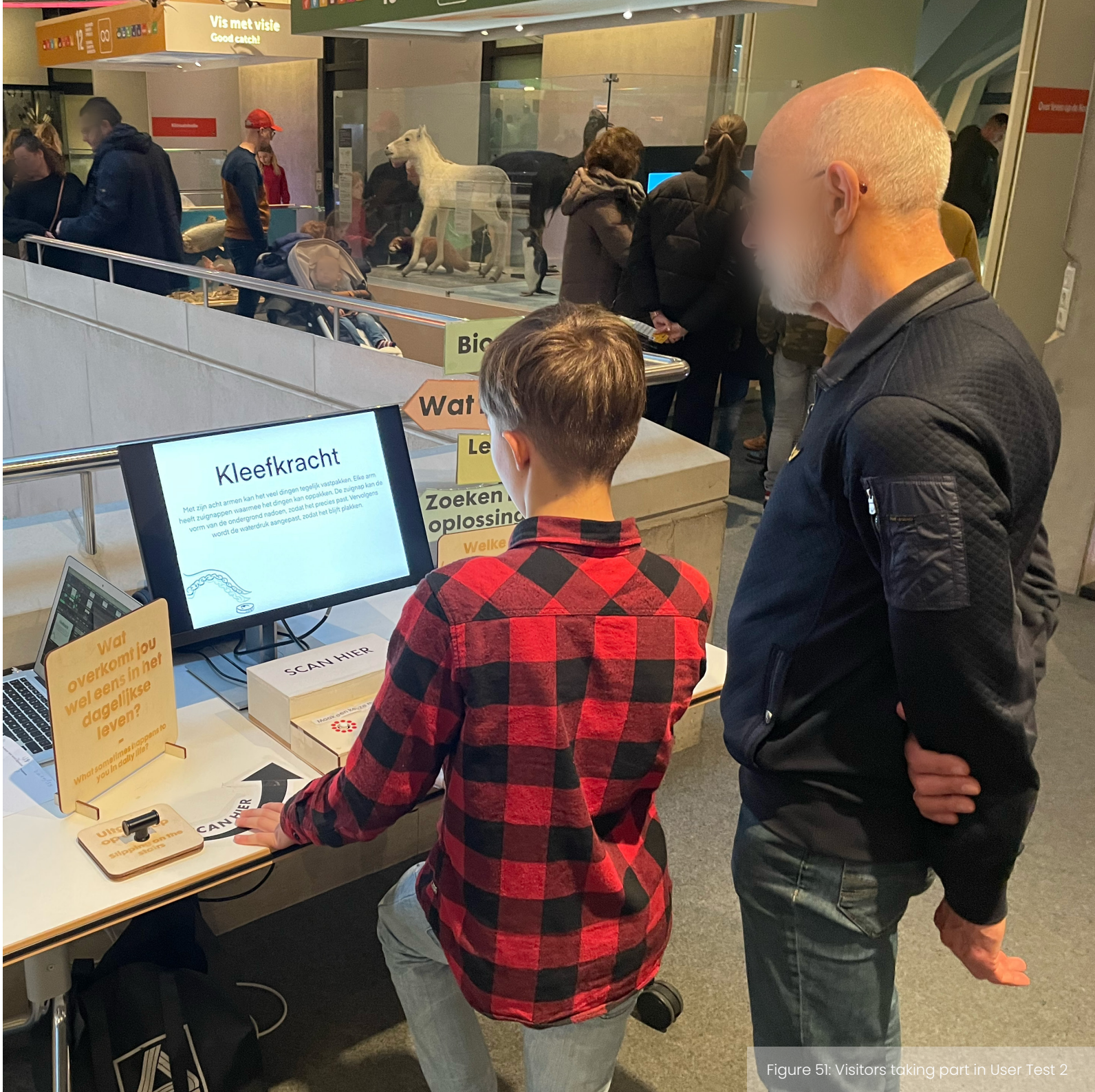


Figure 51: Visitors taking part in User Test 2

2. How do visitors reflect on biomimicry through their own participation and discussions among families?

(Grand)parents often helped their children during the interaction. They often leaned down to be at eye level with their children. Although the first test day showed that only 27% of the visitors would discuss the topic, this increased to 53% on the second test day. No clear reason could be found to explain why this increased.

Observations showed that many participants chose the option to try to solve an event around the house by using biomimicry, in comparison to discovering an existing innovation based on the biological strategy. This was actively tracked on the second day and showed that 73% of participants chose the option to try to apply biomimicry themselves.

The family chose to discover the event of 'slipping on the stairs' with the ability of the octopus. They ended with them trying to apply biomimicry themselves.

“ Child: 'This could be handy in the shower with a shower mat.'
Parent: 'Ooh, yes. Did not even think about that.'
(Translated from Dutch) ”

“ Child: 'Adhesion would be handy to remove spiderwebs at high places. I would not need a ladder to reach the spot.'
(Translated from Dutch) ”

← The family chose to explore the characteristic 'adhesion' by scanning the organism (Octopus). They ended with them trying to apply biomimicry themselves.

3. To what extent do visitors recall what they have learned (about biomimicry) after interacting with the prototype?

Although many visitors could rephrase the meaning of biomimicry after the interaction, few could repeat the word itself. This shows that the use of the prototype was effective in conveying the intention of biomimicry. The younger participants (< 10 years old) were able to remember the super power of the animal, while the older participants (> 10 years old) were able to grasp the intention of biomimicry itself.

On the second test day, a signpost with simplified steps of biomimicry was added to the set-up. This led to an increase in memorization of the word 'Biomimicry'.

“ Researcher to Younger Child: 'Do you still remember what biomimicry is?'
Younger Child: 'No.'
Researcher: 'What did you just learn?'
Younger Child: 'About the octopus. How it uses its suction cups and how it can change colour'
(Translated from Dutch) ”

“ Child: 'Yes, that difficult word. (Looks at the signpost) Bio...mimicry.'
(Translated from Dutch) ”

“ Child: 'I have learned that I can learn from nature by copying.'
Researcher: 'That is exactly what biomimicry is about!'
Parent to child: 'Do you know the English word for 'nadoen'?'
Child: 'Yes, mimic.'
The realization was clearly visible on the childs face
(translated from Dutch) ”

Discussion

The first thing to mention is that the presence of the researcher may have influenced the outcome of the questions asked afterwards. Visitors may have been nervous about giving their real opinions. Secondly, due to malfunctions of the prototype, visitors could have left the ‘flow’. During malfunctions, videos played over each other or the wrong video would started. However, when it was mentioned that it was a prototype for a graudation project, all visitors were patient and waited until the researcher played the correct video. Still completing the ‘flow’ of the test.

The next section discusses the findings for each research question. The results showed that each approach was valued by the visitor. No clear preference emerged. The museum expert who did a full run-through of both approaches saw potential in both. However, the ‘event’ approach was more understandable from a biomimicry point of view; it represented a coherent path. This also emerged during the brainstorming sessions with the IDE alumni.

1. How do visitors perceive the interactive experience of the prototype?
Most visitors did not know what to do when they approached the prototype. This may be due to too much text on the signs (Figure overview user test 2 setting: number 1) or misuse of the word ‘scan’. Participants may associate this with scanning, e.g. a QR code. Many picked up the animal block and started looking at the blocks for something to scan. Future tests will need to use different wording or clear use-cues.

In addition, observations showed that young visitors sometimes pressed the buttons too early (five out of forty). The (grand)parents often started to help the child when this happened. However, due to the failure of the prototype, the buttons were disabled and the choices had to be entered manually by the researcher by pressing the correct key on the keyboard. This prevented videos from playing over each other. The use of buttons in the prototype is playful and useful for making choices, but should be thought through to prevent misuse.

2. How do visitors reflect on biomimicry through their own participation and discussions among families?
Between the two test days, there was a significant increase in the number of visitors participating in discussions with each other. This may be due to several reasons:

- 1) the nature of the visitor
- 2) the busyness of the museum
- 3) the attitude of the researcher

Whatever the reason, it remains difficult to stimulate discussion. In future ideas, more open-ended questions can be used in the content. Provided that the visitor has time to respond. In this user test, some clips moved on too quickly, leaving no room for the visitor to respond.

3. To what extent do visitors recall what they have learned (about biomimicry) after interacting with the prototype?
Placing information next to the prototype (the signpost) showed an increase in the number of visitors who remembered the word ‘biomimicry’. Repetition of information therefore proved to be a useful learning factor.

Overview of insights

The findings from User Test 2 are shown in Figure 52. The complete list of findings from User Test 2 can be found in Appendix J. These findings will be used in the next design iteration.

Overview of Insights	
Observations	Interviews
<ul style="list-style-type: none">- Most visitors do not know how to start the prototype.- Some young visitors are too eager and press too soon on the buttons.- Starting discussions proves to be difficult. Most visitors stay silent and wait until the example shows.- Extra time is needed after a question is asked to provide the visitor to respond.- No visitor chose to discover both approaches.- Most parents take the role of facilitator.	<ul style="list-style-type: none">- Visitors can repeat the meaning of biomimicry. Placing extra information next to the prototype increases the learning factor.- Visitors like to have the option to steer the direction of videos.

Table 52: Key takeaways from user test 2.

Conclusion

This section brings together and summarises all the findings from User Test 2 and addresses it per research question.

1.

How do visitors perceive the interactive experience of the prototype?

This design was not intuitive for most visitors; they did not know where to start when they approached the prototype. In the next iteration, the visitor needs to be guided in the right direction through the use of words and clear (use) cues. After a short explanation by the researcher, each visitor completed the flow and stayed engaged. The voting option was appreciated by the visitors as an interaction of the prototype. It kept them engaged.
2.

How do visitors reflect on biomimicry through their own participation and discussions among families?

Encouraging discussion proved difficult. The results showed that many participants chose the option to apply biomimicry themselves. However, this option did not always lead to discussion. Some visitors would wait until an example was shown. Although there was an increase in the number of participatory discussions between the families on the second day, no clear reason for this could be identified. This should be explored further in the next iteration cycle.
3.

To what extent do visitors recall what they have learned (about biomimicry) after interacting with the prototype?

The tests generated many relevant insights. Conversations with visitors showed that many could grasp the meaning of biomimicry and rephrase it after using the test. The number of visitors who were able to repeat the word 'biomimicry', in addition to grasping its meaning, increased significantly when a signpost was included that briefly explained biomimicry.

Overall, the design of the prototype proved to be a step in the right direction in addressing biomimicry. Visitors were able to explore the concept of biomimicry in a playful way through voting, which kept them engaged. This design can be further developed and refined in the next design iteration.

Focus points

The most important guidelines derived from the user tests of the prototype are translated into actionable points (Figure 52) that can be implemented in subsequent user tests.

1.

The interaction should be clear from the start. The things the visitor should do in the user test should be understood by visitors who do not read the instructions. Visitors did not know what or how to scan. How can you alter the interactive exhibit in such a way that it is intuitive?
2.

Social interaction should be pursued. Although this was partly successful in this user test, more visitors could 'start a dialogue between families' about biomimicry as it is crucial to the transformative learning experience. How can you stimulate conversations between families to an even higher level?
3.

All visitors only did the 'flow' once. Much more is to explore about other animals. How can you stimulate visitors to discover other animals as well?

Stayed the same from previous test but is still relevant.
4.

The test should leave the visitor with a positive feeling towards their contribution to a better world. How can you positively influence the visitors towards biomimicry?

Figure 52: Actionable points derived from the user test 2.

Refined Design Goal

The insights from user test 2 are used to refine the design goal. The findings are converged and will help in the final phase. The design goal is structured to fit each of the phases of a transformative learning experience.

New design goal

Design a playful and interactive exhibition suited for families with children (8 years and up) to explore biomimicry and let them understand the usefulness of biomimicry for future problem-solving for the coming 'biomimicry zone' at Museon-Omniversum.

This consist of

1. Make the visitor aware of what biomimicry is and can do.
2. Encourage dialogue between families to stimulate self-reflection and deeper understanding of biomimicry by presenting information invitingly.
3. Let the visitor interact with the concept of 'biomimicry' in a playful way by solving 'events' through simplified steps taken from Biomimicry Thinking.
4. Plant a seed for future problem-solving (to use biomimicry).



5.

Deliver

The following chapter will build on the findings of previous chapters. The new design goal is the start of the second diamond (Double Diamond method, Chapter 2.1), in which the first step will be diverging. A list of design criteria will guide the ideation phase. Next, the prototype is evaluated through a user test, and this leads to new insights and action points for the final design of the exhibit.

This chapter aims to define an answer to the redefined design goal stated in chapter 3 through a new prototype. The prototype used proved to be a step in the right direction and will be the basis for the next chapter.

- 5.1 Design Approach
- 5.2 Concept 'Superpowers of Nature'
- 5.3 Evaluating the Concept 'Superpowers of Nature'

5.1 Design Approach

This section briefly outlines the steps taken to come to the final design which is presented and evaluated in this chapter.

Ideation

Overall, visitors were able to recall the meaning of biomimicry, based on the previous user test. This iteration will build on the setup of user test 2, with a focus on improving the interaction, as a museum exhibit should be clear from the start. In the previous design, visitors did not know what they had to do in order to start the exhibit. Next, the focus would be on improving social interaction within families by using provoking questions to stimulate awareness and deeper understanding (phases of transformative learning experience). Furthermore, it would be recommended if the visitors would try out more than one option, to discover the possibilities of biomimicry themselves. Last but not least, the test should leave the visitor with a positive feeling after interacting with the prototype.

These focus points were taken to heart in the iteration sessions that followed to create the final prototype.

Methods

Open-end discussions and brainstorming were held with IDE students. How could the previous concept be improved to reach the design goal? Generated ideas were inspiration for the final design, which was proposed to the stakeholder.



Figure 54: The design set-up of user test 3 in Museon-Omniversum.

Concept 'Superpowers of Nature' 5.2

The following section explains the final design of this project. How does it work? What are its components?

Explanation of the concept 'Explore Biomimicry'

The interaction where the visitor can choose the direction of exploration, is central in the concept of 'Superpowers of Nature'. Each option displays different information about the organism, followed by its biomimetic innovation. One option the visitor could choose is depicted in Appendix K, Figure K1. However, the complete decision tree can be seen in Appendix K. All clips are substantiated with deepening information about the organism or innovation.

This concept would start with the approach of events as experts mentioned that this approach was most straightforward and easier to follow. Originally, three events were worked out in detail. The visitor could solve these events through biomimicry. See Appendix K, Figure K1 for the concept set-up in Museon-Omniversum.

However, during this user test (3) in Museon-Omniversum, no data could be collected as the prototype started faltering. Furthermore, the visitors on the test day were below the age of 8, therefore not suited for data collection. The main takeaway from this user test was that visitors would like to actively explore, which causes a reaction, e.g. buttons or placing the organism-blocks. The current set-up of the user test (as in Figure 54) would therefore not be suited for in a museum context. Additional testing in a controlled setting should be performed.

User test 3 at primary school

A simplified prototype was designed and tested on the same primary school as was mentioned before. The 'flow' or decision tree was adjusted to start with the organism-blocks, instead of starting with an event, as the user test 3 in Museon-Omniversum showed that visitors started with placing the organism-blocks.

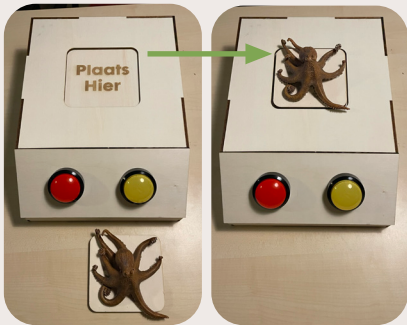
The setting was controlled and participants were explicitly asked to perform the complete 'flow' of the test and provide feedback by filling in the evaluation form. This change in set-up helped to answer the unanswered research questions. The complete set-up and explanation of the user test held at the primary school can be seen in Figure 55.

The design tested in user test 3 at the primary school

1. In order to start the interaction the pupils have to press a button. As an reaction a videoclip will start to play.



2. After starting the 'flow', the pupils were asked to discover superpowers of one of the organism-blocks. They have to place one of the organism-block in the designated area (Plaats Hier). For this test, the Octopus-approach was the only one that worked.



3. These are probs, presented around the exhibit to draw the attention of the pupils. These probs are addressed in the video clip. After completing the flow, the probs make sense.

4. This is an information sign to convey the subject of the exhibit to the visitor. It depicts a simplified version of what biomimicry entails.



Figure 55: Complete setting of User test 3 at a primary school with allocating numbers for explanations. The different numbers represent the parts included in the design. Step 1 and 2 are the ones the visitors need to take to complete the prototype exhibit.

Step-to-step guide to screens used in user test 3 at a primary school

Figure 56 depicts the step-by-step screens of the Octopus-approach. The visitor has two su-perpowers to discover. This example shows the octopus’s superpower of ‘adhesion’. After the explanation, the biomimetic innovation is presented. After the example, the visitor is chal-lenged to think of examples that use the same principle in day-to-day products. To see an ex-ample, they have to press any button. An event, as came forward in research, is addressed and solved.



Figure 56: Step-by-step guide to the screens of the (simplified) organism-approach used in user test 3 at the primary school, with allocating explanations.

Meaning behind the concept

The video clips guide the visitor through the simplified steps of method Biomimicry Thinking as shown in Chatper 4.2. This concept makes use of the ‘Challenge to biology approach’. The prototype allows the visitor to come into contact with biomimicry at an easy level, to explore the wonders of biomimicry and be challenged to think about what it can mean to them. This set-up of the user test let the visitor (re-frame) the concept biomimicry as something useful, a thing that can help them find solutions in life. By displaying close-to-home situations, the visitor can (re-see) the benefit in daily events. Ideally, they will start looking for answers in nature in future scenarios (re-enact). These three phases are based on Chapter 2.4.

Building the prototype

The backend of the prototype is made with Arduino (Figure 57). The program converts a ‘press of a button’ to a keyboard output. The decision tree is recreated in Figma and can be controlled through keyboard output. Each screen represents a video, which was made in Premiere Pro. The casing and signpost are printed by laser cutting in 5 mm plywood and put together with wood glue. To make the signpost stand out more, each sign is painted (Figure 58).

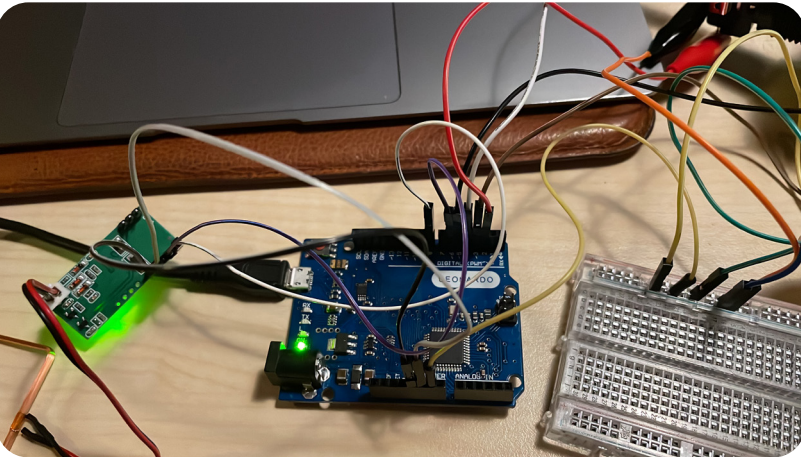


Figure 57: Building the backend of the prototype with Arduino components.

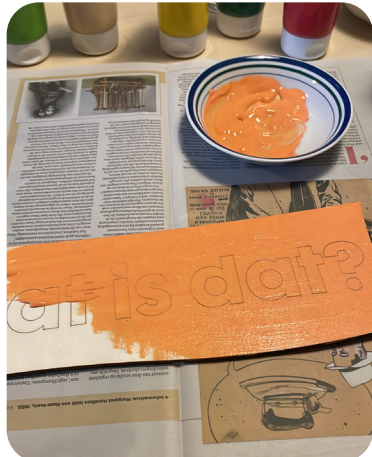


Figure 58: Painting the signpost signs in bright colours to stand out in Museon-Omniversum.

5.3 Evaluating the Concept 'Superpowers of Nature'

This section is an evaluation of the first 'Superpowers in Nature' concept that was tested at a primary school (Groep 7 & Groep 8). The summary of the test is supported by the findings, which are discussed and concluded. This test led to a simplified version to be tested on pupils of a primary school.

Summary of user test

The data from this test will be used to see if the design goal of this project is achieved. Based on this final user test, recommendations will be proposed to Museon-Omniversum. The list with all findings can be found in Appendix L. A summary of user test 3 at the primary school can be seen in Table 4.

Table 4: Summary of user test 3 at the primary school.

Set-up user test 3 at primary school

Who 8 groups of 2 pupils, 16 participants in total. They were between 10 and 12 years old.

What Validate the design with respect to the design goal through the research questions.

When January 13th

Where Primary school near Museon-Omniversum

Why To **evaluate** if the concept exhibit **fulfils** the **design goal**

How Data is gathered through observations and an evaluation form, which are used to answer the research questions.

Role of Researcher

The researcher was present at all times. The pupils had to approach the exhibit without explanation. Afterwards, they were asked some final questions and were handed a evaluation form.

Research question

Knowledge exploration

1. What do visitors recall about biomimicry after interacting with the prototype?
2. Are visitors stimulated to discover multiple animals/solutions?

Intention

3. What kind of social interaction does the exhibit evoke?
- 3A. To what extent do visitors reflect on biomimicry through their own participation and discussions among families?
- 3B. To what extent do they expect to refer to biomimicry in future scenarios?

Usability

4. How do visitors perceive the interactive experience of the prototype?
- 4A. Do the visitors understand the flow of the prototype?



Figure 59: User test 3 at primary school with participants.

Findings

The findings are addressed per heading of the research question.

Knowledge Exploration

Many pupils do recall the superpower of the organism chosen, in this case, the octopus. They could repeat the ability of camouflage or suction cups. Two participants could repeat the meaning of biomimicry and did remember the innovation based on the octopus. Four out of sixteen participants missed or did not remember the meaning of biomimicry after interacting with the prototype. In these cases, the researcher had to step in and explained the word through the signpost. However, all probs addressed and dispersed around the exhibit were known by the pupils. They had made the link to these probs after completing the flow.

Furthermore, every participant wanted to discover multiple biomimicry examples at the end of the flow. However, for this user test only the octopus worked. They could discover the other superpower of the octopus. Twelve out sixteen participants chose to discover the other option. The evaluation form showed that they are willing to discover other solutions based on nature (4.5 out of 5).

Intention

The participants started to discuss which button (red or yellow) they would press when the option presented itself to choose. Even when both buttons would lead to the same clip, they discussed which to press anyway. More discussion arose when they had to choose the animal-block to place in the designated area, but it was still limited, e.g. no personal preferences were shared. They all came quickly to an agreement. Observation showed that they were passively observing the content of the prototype.

The screen designed to invite the participant to discuss was invalid and led to no discussion or self-reflection. Every participant duo determinedly pressed the button to see an example without answering the question asked in the video

'How can any of these superpowers help you? Can you think of anything?'

In the end, an evaluation form was handed out. The answers showed they are curious to discover other solutions found in nature (4.5 out of 5) and that they started thinking about (new) solutions that can be found in nature (3.6 out of 5), after interacting with this design.

Usability

Observation showed that they were a bit hesitant to approach the test set-up. However, everyone quickly was drawn into the 'flow' of the prototype. Through follow-up questions at the end and the evaluation form, the participants liked the 'placing the animal-blocks' approach. They unanimously prefer the physical approach over digital (buttons). The form showed that they liked the interaction needed in the prototype (4.5 out of 5).

'... otherwise everything will be or will remains digital'
(Translated from Dutch)

'... voting keeps me engaged with the content of the product'
(Translated from Dutch)

As said, the participants approached the set-up hesitantly, but this was quickly lifted. They knew what to 'scan' or how to vote. The option to press the buttons too soon was turned off to prevent misuse. Observations showed that in this set-up, the participants already made a choice and pressed the button to 'vote'. However, this option was temporarily turned off, and the participant did not understand why. Additional support from the researcher was needed to tell them when the buttons could be pressed.



Figure 60: User test 3 at primary school with participants.

Discussion

The presence of the researcher may have influenced the outcome of the questions asked afterwards as visitors may have been nervous about giving their real opinions. The answers are discussed per heading of the research question.

Knowledge Exploration

The findings show that the word ‘biomimicry’ and the meaning behind the concept are still difficult to grasp for children in the target group. Even if the concept is simplified, the superpower of an organism is remembered over biomimicry. The signpost helped to explain the word, but there is a gut-feeling that they did not read it before (e.g. when they approached the prototype). However, the day-to-day examples were known to every participant and worked as attractive factor (when they approached the set-up). To make the content suited for the target group, relevant and recognizable examples should be used. This will create awareness that we can (really) learn from nature, as they can make the connection between organism characteristics and day-to-day objects.

Interest was present in all participants. A factor that could have influenced the data is:

The participants wanted to stay out of normal lessons longer and therefore wanting to discover multiple options.

However, according to evaluation form, they wanted to discover more solutions (4.5 out of 5), but this can never be confirmed completely.

Intention

Although the participants discussed which button to press or which organism-block to place, no dialogue between participants occurred when they were asked if they knew any examples of biomimicry themselves. This is because dialogue is an important part of a transformative learning experience. This set-up does not meet the design objective in this respect. This should be addressed more clearly in future design cycles as it is important to stimulate dialogue. Knowledge will then be retained for a longer period of time.

However, they were curious to discover other innovations based on biomimicry (according to the evaluation form 4.5 out of 5). This clearly indicates interest is present among them. Showing examples of biomimicry has a positive effect on them learning something new as they stated that (3.5 out of 5) started thinking about (new) solutions that can be found in nature. Creating a new section on biomimicry will therefore be effective and interesting for the visitors of Museon-Omniversum.

Usability

The prototype was designed so that the visitor could not press the button ‘too early’, in which case a video would be skipped. However, in this design, they pressed and nothing happened as the function was still off. The ‘right’ time to activate the buttons should be explored more in future design cycles. Overall, the design used in this test is effective. It was well received. The interaction itself would work in a museum context. It combines education and playful experiences into an interactive exhibitio, while leaving the autonomy to the visitor.



6.

Conclusion

The next chapter concludes this project. The final evaluation shows that the final design is a promising concept to address biomimicry through a transformative learning experience. This chapter presents the key findings and checks if the design complies with the literature research and the design goal. It ends with proposing recommendations for Museon-Omniversum.

- 6.1 Outcomes
- 6.2 Limitations
- 6.3 Recommendations

Figure 61: Bird of paradise, flower background (Wilcox, 2021)

6.1 Outcomes

This section compares the final design concept with the literature research and user tests carried out during the project. The conclusion is divided into four parts: Research outcomes, Design outcomes, Future vision and the Design goal.

Research Outcomes

The final project aimed to explore and design an exhibit for Museon-Omniversum on the world of Biomimicry. Multiple research activities contributed to the final concept design, e.g. interviews, observations, and literature study. Biomimicry proved to be a difficult concept to present in museum context. The core message that will be presented, focusses on the method Biomimicry Thinking. This method is simplified to be used in the design. (Chapter 4.2). The research showed that many factors do play a role in exhibit design. An exhibit should combine education with entertainment, presenting the content playfully (Chapter 2).

Design Outcomes

Three different user tests were performed to verify the effectiveness of the design in museum context. Each subsequent user test building on the outcomes of the previous one. The last design provided outcomes that can be implemented in the new area (biomimicry) in One Planet NOW! for Museon-Omniversum. The primary focus of the design is to make the visitor aware that many answers can be found in nature, to the problems we encounter as species. The research showed that biomimicry is quite difficult to present to children. Therefore, the path was chosen to explore biomimicry through events that children and adults (may) encountered on daily basis. Biological strategies (Superpowers) are used to solve these events. The content re-frames the concept biomimicry as something useful, a thing that can help them find solutions in life. By displaying close-to-home situations, the visitor can (re-)see the benefit of biomimicry in daily life. Ideally, they will start looking for answers in nature in future scenarios (re-enact).

This includes presenting the information clearly and comprehensible for visitors from the age of 8 years and up. Supporting footage is needed to bring the message across. The visitor (unknowingly) goes through a simplified process of Biomimicry Thinking.

The outcomes of user test 1 & 2 are used to come to a final concept design (Chapter 5). The design of the prototype unifies the two approaches of user test 2 (Chapter 4) into one. Each activation-block represents one organism, with their own decision tree. Each decision tree addresses two superpowers, their correlating innovations of the organism, and an event that came forward in (Chapter 3). The final test was surrounded by existing products that could be linked to these superpowers. They lay scattered around the central interaction. These products should intentionally spark interest by visitors that walk by. In addition, a signpost about biomimicry is placed near the exhibit, as this contributed to visitors recalling the word 'biomimicry' more easily.

The exhibit introduces the visitor to the wonders of biomimicry in a playful way. The information is presented through videos that stimulate the visitors to discuss the content together. The final design concept therefore fulfils the target area as discovered in Chapter 2.5 (Being playful, and informative, which can be done with multiple people).

Future vision

Biomimicry is a concept that is useful to know about at any age. The sooner the better. We as a species have to drastically change our way of treating the world. Biomimicry can be seen as a means to reach this goal. Museums are a perfect place for introducing this concept. Playful interactive interactions can be one way to present the concept of biomimicry at an easy-to-approach level. The main message that should come across is that we should start looking at nature for solutions. Solving the problems we encounter sustainably. The thesis provides an example of how to address biomimicry playfully in a museum context. The final design is one way to approach one of the many sides of biomimicry. The design has the potential to transform visitors' perspectives, by stimulating dialogue. This also increases the chance of the content being remembered by visitors (Chapter 2).

Design Goal

This section presents a reflection on the design goal (Figure 62). Each part of the design goal is addressed separately.

New design goal

Design a playful and interactive exhibition suited for families with children (8 years and up) to explore biomimicry and let them understand the usefulness of biomimicry for future problem-solving for the coming ‘biomimicry zone’ at Museon-Omniversum.

This consist of

- 1. Make the visitor aware of what biomimicry is and can do.
- 2. Encourage dialogue between families to stimulate self-reflection and deeper understanding of biomimicry by presenting information invitingly.
- 3. Let the visitor interact with the concept of ‘biomimicry’ in a playful way by solving ‘events’ through simplified steps taken from Biomimicry Thinking.
- 4. Plant a seed for future problem-solving (to use biomimicry).

1. *Make the visitor aware of biomimicry*

Although no ‘direct’ dilemma is used in the content of the design, the visitor is made aware of the usefulness of biomimicry. The examples show that problems close-to-home can be solved by looking at nature, connecting their personal lives to the concept of biomimicry.

2. *Encourage dialogue to stimulate deeper understanding*

The visitor reflects on biomimicry through open ended question that are included in the content. By stimulating dialogue, they start thinking about possible (biomimetic) solutions, creating a line-of-thought (Biomimicry Thinking Method) that is useful in later similar situations. The evaluation showed positive outcomes in encouraging dialogue and stimulate deeper understanding. Although dialogue was present during testing, this can be improved. More research and testing is required to elevate the design to a higher level that stimulates dialogue within most visitors.

3. *A playful interactive exhibit*

‘Superpowers of Nature’ is a design concept that lets the visitors explore biomimicry in a playful way. The ability to steer the direction of videos through choosing is preferred and keeps the visitor engaged with the content. Furthermore, placing an activation-block in the designated area made the interaction even more appealing to the visitors.

4. *Plant a seed for future problem-solving*

In the ideal situation, the visitor has learned a new approach in solving problems. In turn, they will fall back on this approach in future scenarios and find sustainable solutions to problems they encounter. However, this is not tested in this project and should be investigated further by reaching out to visitors after their visit through communication, e.g. mail.

Figure 62: Reflection on the four phases of a transformative experience addressed, based on the design goal.

6.2 Limitations

In carrying out this study, certain limitations could have affected the results of the project. These limitations are explained in this section.

Visitors

The attitude of visitors differed greatly between testing days. No clear reason could be found for this phenomenon. The nature of visitors should be taken into account in future testing. Furthermore, all visitors that participated in the user tests spoke Dutch. Visitors with different backgrounds may respond differently to the content.

Pupils of primary school

The behaviour of the pupils towards testing the final prototype may influence the outcome. There is a possibility that they are afraid to tell the researcher what they really think, not fully giving their opinion. In addition, the testing was not done in a museum context, which may influence the outcome as well.

The timeframe of the project

Due to the limited time in this project, no data is available if this design will help visitors recall biomimicry in future scenarios. In order to discover if visitors transformed their perspective, additional effort has to be made in reaching out to them after their visit.

Qualitative research

Engaging in qualitative research deepens empathy for the target group and sparks creative inspiration, yet its findings may lack statistical representativeness.

6.3 Recommendations

This graduation project was done for Museon-Omniversum. All research and user tests lead to a final concept that may be used in the new area of biomimicry for One Planet NOW!. in Museon-Omniversum. However, a handful of recommendations are proposed to take the concept to the next step; to transform the concept into an exhibit that can be implemented in the exhibition space.

The recommendations are categorized in 4 sections: Design, Video Content, Technical and Target Group.

Design

These adjustments or additions are proposed to connect the concept design to integrate into the house style of Museon-Omniversum, their collection, or to increase the interaction.

– First of all, the design is not static and open to change. The design can be integrated in the style Museon-Omniversum currently uses in One Planet NOW!, to create unity between the different themes exhibited. Figure 63 depicts a quickly made example of integration in the wooden blocks they currently use in displays.

Some aspects should be present to ensure visitors know what to do:

- The use of physical organism-blocks.
- The use-cue of where to place the ‘organism-block’
- The physical option to vote to steer the video content (e.g. buttons).

– Create placeholders for the different organism-blocks to stimulate visitors to put them back in place after interacting with the exhibit (as seen in Figure 63).

– Next, during the final user test, some products were scattered around the user test. This led to curiosity among the participants. They were wondering why those products were placed there. A suggestion is to create a wall with products to attract attention. The link to these products is made by interacting with the exhibit.

– The data also showed that there was a significant increase in the number of visitors who were able to recall the meaning of ‘biomimicry’ after the sign was installed. It is therefore recommended that this be incorporated into the final design.

– At last, additional links towards biomimicry can be made through placing signs throughout the museum that depicts information about a biomimetic innovation, based on the stuffed animal. See Figure 64 for an example of the polar bear.



Figure 63: Proposition of the final concept integrated in the wooden blocks style of Museon-Omniversum.



Figure 64: Idea: Extra information about biomimetic innovations placed by stuffed animals throughout Museon-Omniversum

Video Content

- The video content of the prototype should be relevant and be presented in such way that children will understand. The final design provided one way to present the information, which proved to be successful. However, there are still some recommendations.
- To stimulate a transformative learning experience, more open-ended question can be incorporated into the content, to stimulate discussion among families.
 - The content should be extended, providing the visitor with more options to explore. The content should be run by an expert in the field of biomimicry to ensure the information is correct as some examples used in the final design do not line up perfectly.
 - The timing of releasing the buttons should be tested more. Visitors often press the button too soon, skipping videos that are crucial for understanding the content (User Test 2). This was resolved in User Test 3. However, during this test, they already made a choice when the video was not finished, and the buttons were still disabled. The participants did not understand why ‘pressing the button’ did not work. Therefore, future content should be perfectly timed to prevent confusion.
 - The effectiveness of ‘relatable events’ that came forward in Chapter 3.4, has not been proven. Further research should enclose if using day-to-day products related to the addressed biological strategy is sufficient enough to create a transformative (learning) experience.

- The current decision tree is effective, an extra iteration cycle is recommended to ensure a smooth transition between the content.
- The biomimetic examples used in the video content can be linked to the SDGs, to create even more connection between the current expositions in Museon-Omniversum.
- The content should also be translated to include all visitors of Museon-Omniversum.
- An additional requirement will be that the videos have to be made in the house style of Museon-Omniversum.

Technical

- The final concept design could not work on its own. The researcher made it work through ‘Wizarding of Oz’ method. The part of the interaction wherein an organism-block is ‘scanned’ by the visitor, was not working on its own. The Arduino code would not work in combination with the NFC-tags. Even the test code provided would not work. The code used in this test can be seen in Appendix K. Furthermore, there were some troubles with loading or playing the videos in the right order by using Figma. No clear reason could be found for this phenomenon, but the most logical reason is that it runs on a public internet connection. The busier the museum, the less stable the internet connection.
- Therefore, to elevate the design to the next level, a few programs are recommended for making the concept suitable for the museum.
- The use of different hardware and software is advised to create a (stable) working exhibit. Either program is known with the employees of Museon-Omniversum.

Software:
This can be programmed in Unity or in Brightsign. Both programs are suited to resolve the problems with loading the videos and ‘scanning’ the organism-blocks. Brightsign being the fastest solution as the decision tree is quite simple to recreate in its program. In addition, it can recall external hardware quite easily through the Brightsign hardware product.

Hardware:
Either Unity or Brightsign can be used to control the hardware used in this design. Brightsign has its own hardware product which can run independently, in combination with third-party parts, while Unity needs to use third-party parts to run the software.

Visitors (Target Group)

The final design is tested on children 10 years and older outside a museum context. The design proved to be effective for children this age. As the visitors of the Museon-Omniversum are diverse, the design should also be tested on visitors of 8 or 9 years old in a museum context. In addition, all participants spoke Dutch during the final user test. The final concept is not tested on English-speaking participants. Although I assume that a translation of the content would not cause confusion for English-speaking participants, future tests should exclude this.

Epilogue

This final section describes my personal reflection on the thesis. Full courage, I started this journey about seven months ago. I wanted to explore biomimicry, as this was a totally new concept for me. It intrigued me from the start. Furthermore, I got the wonderful opportunity to experience the life of ‘working in a museum’. This was a possible future direction I wanted to explore. And I can finally say: “Yes, the world of museums is something for me.”

In the following sections I will discuss some of the lessons learned from this project.

The challenge

The challenge of designing an exhibit for a museum was a daunting and challenging task. There were many times when I was overwhelmed by the many factors to consider in the design process. I gained a lot of respect for programme makers. The museum provided a lot of freedom to explore all sides of designing an (interactive) exhibit. All in all, I think I have managed to combine all these factors into a design concept that is appropriate for Museon-Omniversum.

Learning as designer

I learned much as a designer in this final project. The most important learnings are captured in three main takeaways.

Firstly, as a designer you have to put yourself in uncomfortable situations. As a rather introverted person, it takes courage to put yourself out there. But during every user test, the participants were so open and happy to help. They really enjoy helping you. So, future me, you have nothing to worry about. Just put yourself out there.

Secondly, this project made me realise how difficult it can be to design on your own. Most of the projects done during the Masters are group projects. Now I fully understand why design is a group effort. Sparring with partners really helps you get to the final design. It was quite challenging to do it alone, but luckily I had lovely friends to help me through those ‘challenging’ moments. So I can say that I prefer to work in teams. Something I will definitely look for in my future job.

Finally, designing is making choices, which you not always can explain. Sometimes, you have to go with your gut feeling. However, substantiating this for this project proved not always to be that easy. Often, later in the process, you could critically refer back and substantiate the choice. Thus, stick with your gut feeling, even when it is not (always) grounded yet.

Personal Learnings

One of my personal learning goals was to use rapid prototyping in my project. I found it quite difficult to incorporate this into the process when there was so much going on (research, documentation, analysis). Although I prefer this design approach, it did not fully come to light in the project.

Another thing I wanted to train was questioning. I have had many opportunities, some provided by the museum, and I can definitely say that I have grown in this aspect, but there is still a (long) way to go before I am really confident.

During this project, I tried to enhance my ability to substantiate my arguments. Most of the time, it was all clear in my head, but putting it on paper is a totally different story. With the help of my supervisors I managed to create a coherent story that depicted my final design.

The last goal I set for myself: Have fun. Although I had many ups and downs during this project, my loving friends really helped me through the process. Now that the end of my graduation project is near, I can happily say that those feelings are gone. I hereby can say that I enjoyed the process and am proud of the final design. As I wrap up this concluding epilogue, my chapter as a student draws to a close, marking the beginning of a new one as a designer.

Thank you for coming along on this journey.

Sven

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