The Great Kenya Eco Challenge

A play-based exhibit on sustainable awareness for the Green Kids' Museum

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A play-based exhibit on sustainable awareness for the Green Kids' Museum

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Summary

The aim of this graduation project was to design a play-based exhibit piece for the Green Kids' Museum in Kenya with the objective to raise awareness of biodiversity and ecosystems in a playful manner.

Global climate is changing at rapid speed, resulting in a loss of biodiversity and the breakdown of ecosystems (Damiens, 2021). It is important that people are made aware of the dramatic consequences if these ecosystems would be lost forever. Yet, children in Kenya are not fully aware of the richness of the ecosystems within their own country, hence there is a clear need for inspiring education. The Green Kids' Museum will be built with the objective to raise children's awareness of the different aspects of sustainability, with one room dedicated to biodiversity and ecosystems in Kenya.

This research project has explored different ways to transfer knowledge in a playful way about biodiversity and ecosystems fitting children in the 9 to 11 year old age range. The outcome of this exploration resulted in a game that serves as an interactive exhibit piece helping children recognize the different ecosystems in Kenya.

In the initial phase of this project research was done in three different Dutch museums to understand what type of museum installation attracts children. This showed that children are mostly attracted to large striking installations that are interactive and require little to no instructions and installations where they can build something or win a prize. These aspects were taken into account during the ideation phase; each design needed to have at least one of the previously mentioned aspects to make it attract to children. The chosen design had the first three aspects incorporated and resulted in a first iteration that was tested with the target group. The evaluation with the target group was split into a physical test and an online test. The results of this test showed that the children enjoyed the game, but expressed the wish to play the game for a longer amount of time and at an increased level of complexity. A number of unfamiliar animals were added to the game increasing the complexity and duration of the game. The design was evaluated with manufacturers in Kenya to validate that the product could be fully manufactured in Kenya. Based on their feedback some alterations were applied to the design making it ready for manufacturing. Manufacturers were selected based on their efforts to produce sustainably. This selection was done based on the manufacturing techniques catalogue, created by the researcher for this project, providing a comparison of different manufacturers in Kenya that execute that same technique. Based on these results a final design has been created.

The final concept, "The Great Kenya Eco Challenge", is an interactive exhibit piece teaching Kenyan children how to recognize the different ecosystems in Kenya. This is done by matching different animals to the ecosystem they live in using a button system. The exhibit piece enables children to learn about ecosystems in a playful and fun way.

Glossary

Biodiversity
Biodiversity refers to the variety of life on Earth on all levels and includes all evolutionary, ecological, and cultural processes that bolster life (American Museum of National History, n.d.)

BOM
A bill of materials is a list of all necessary parts and materials to create a product

Ecosystem
An ecosystem is a certain geographical area where weather, landscapes and organisms interact with one another to form one system of life (National Geographic Society, n.d.)

Food chain
A food chain describes which organism eats whom in the wild

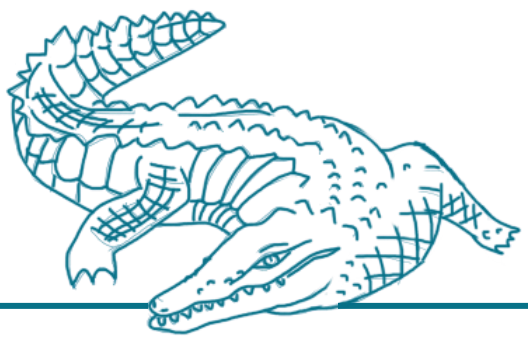
Food pyramid
A food pyramid is a way of displaying a food chain where the predator is above the pray

Flow chart
A flow chart shows the steps in a process in a sequential order

Harris Profile
A Harris Profile is a technique that helps rate different concepts according to previously set requirements

MPI
MPI stands for plus, minus, interesting. It is a technique that helps rate different ideas according to their positive and negative aspects

Play-based exhibit
A play-based exhibit is an interactive installation that brings knowledge in a playful way



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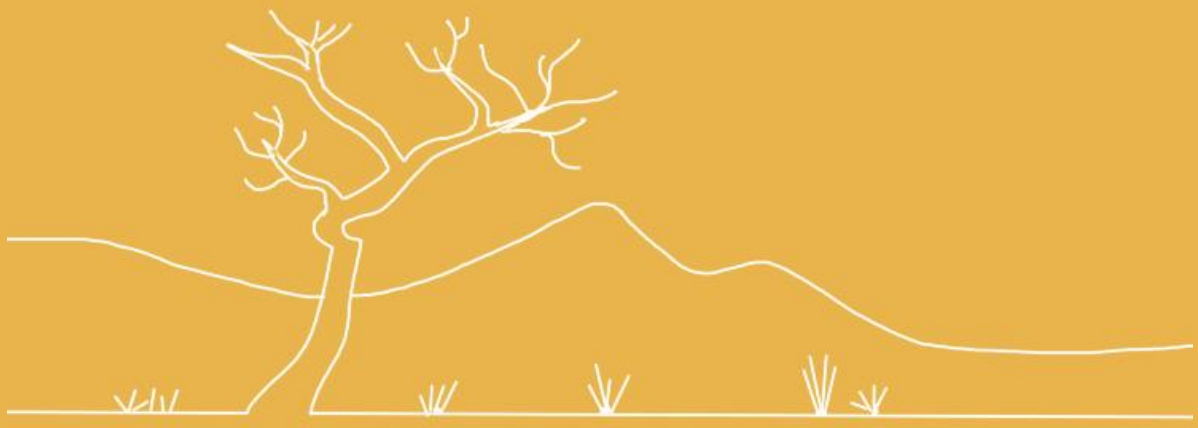


Chapter 1: Project context

Problem definition

Our climate is continuously changing, with loss in biodiversity and breakdown of ecosystems as a result (Damiens, 2021). Yet, children in Kenya are not sufficiently taught in class about how (their) behaviour and actions have an impact on the environment and are neither encouraged to protect their planet (Green Kids' Museum, 2021). Therefore there is a need for inspiring education about sustainability in Kenya. The Green Kids' Museum will be built to help solve this need. One of the rooms will bring children awareness about biodiversity and ecosystems via interactive play-based exhibits, which will form the focus point of this graduation project, as it can be seen as the more positive theme of the six and best fits the interest of the designer. During this project it is important to find out in what ways Kenyan children can learn about biodiversity and ecosystems in a playful and inspiring way that sticks with them.

This project aims at designing a play-based exhibit piece for the Green Kids' Museum in Kenya with the objective to raise awareness of biodiversity and ecosystems in a playful manner. The play-based exhibit will be targeted at Kenyan schoolchildren aged 9 to 11. The goal of this installation concept is to visualise with a concrete example how the museum will shape its aims in interactive installations, which could support in generating funds.
The product solution should allow for being manufactured in Kenya, with local materials and production techniques. These materials and techniques might differ from what is available in the Netherlands, so a thorough research is needed to see what is available in Kenya. The client has expressed the wish to make use of as much local knowledge, customs and facilities as possible, however the client lacks the expertise on implementing these aspects into a fitting exhibit piece. Therefore, these will form one of the main focus points of this project.

Green Kids' Museum

Evy van Weezendonk is the founder of the Green Kids' Museum which will be situated in Ngong Forest. The goal of the Green Kids' Museum is to raise Kenyan children's awareness of sustainability by actively interacting with different installations throughout the museum. The museum is created for primary school children in Nairobi, aged 6-14 years old and focuses on all aspects of sustainability, including the building and installations itself, by using local sustainable materials and production techniques. The build is planned to start in 2022 and will be the first interactive museum in Kenya. The museum will have various spaces covering different themes around sustainability:

- Biodiversity and ecosystems
- Consumption and waste
- Energy and resources
- Climate change
- Power of one

The Green Kids' Museum will be open for schools on weekdays and for families and tourists in the weekend. The museum will work with different entrance fee categories for each group:

Outreach schools	Free
Schools	€
Citizen children	€€
Citizen adults	€€€
Resident children	€€€€
Resident adults	€€€€€
Non-residents	€€€€€€

In this way the museum can generate the necessary funds to provide free visits and transportation for outreach schools that do not have financial means for such trips.

Approach

The goal of this project is to design a play-based exhibit piece for the Green Kids' Museum in Kenya with the objective to raise awareness of biodiversity and ecosystems. This goal will be reached by following 5 phases (see Figure 1):

1. Research phase: during this phase knowledge and insights are gained on biodiversity and ecosystems worldwide and specifically in Kenya, and how these topics are currently taught to Kenyan children. During this phase research is done on interactive museums in the Netherlands to find inspiration and insights on suitable play-based exhibits for children. Finally, research is done on available manufacturing techniques in Kenya and how sustainable these are. All results together create design criteria, which can be used to assess concept ideas. The research can be found in chapter 2, 3, 4 and 5.
2. Ideation phase: here, ideas are created and selected using methods from the Delft Design Guide, after which the final concept design is detailed by selecting fitting materials and production techniques. See chapter 6 for the results.
3. Concept validation & iteration phase: during this phase both Dutch and Kenyan children are interviewed to validate the concept and see if it fits the target group. Kenyan manufacturers are subsequently interviewed about the play-based exhibit concept to validate the feasibility of producing the concept with the suggested materials and production techniques. Once concluded, necessary alterations are made. See chapter 7 for the results.
4. Concept development phase: at this stage, details such as the size, material and cost of the play-based exhibit are established. Chapter 8 shows the final concept.
5. Product presentation phase: during this final phase adequate visual and textual representations of the product are made for the purpose of generating funding for the Green Kids' Museum. The final results can be found in chapter 8.

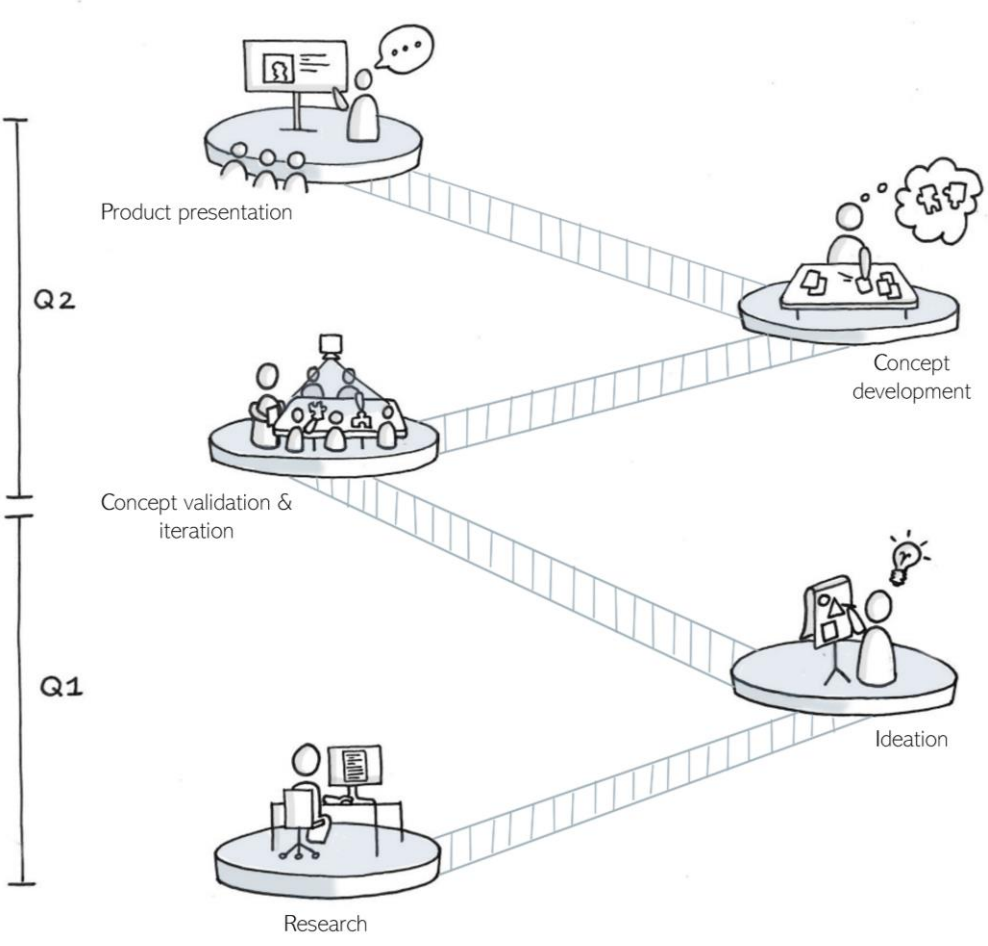


Figure 1. Approach

Stakeholders

Figure 2 shows the stakeholders that will have a stake in (part of) the life cycle of the product, which includes development of the product, marketing, sales, use of the product and disposal. These stakeholders are all parties that have a direct or indirect influence on the play-based exhibit piece.

The figure shows the direct stakeholders that have a direct influence on the product, such as the designer and manufacturer. They determine, together with the core group, the product outcome. If the manufacturer, for instance, states that it is not possible to manufacture the current product design, the design needs to be adjusted so that it can be manufactured. Therefore, the manufacturer has a direct influence on the design of the product. The wide network consist of indirect stakeholders and do not have a direct influence on the product. However, they can alter the image of the product, meaning these stakeholders can have an influence on the way people look at the play-based exhibit. Social media can, for example, display the play-based exhibit as a product that can have a positive influence on Kenyan children, which creates a positive image of the play-based exhibit. However, they could also have negative comments about the play-based exhibit and say it has a negative impact on children, creating a negative image of the play-based exhibit. The core group consist of the client, who is fully engaged and essential for the design process.

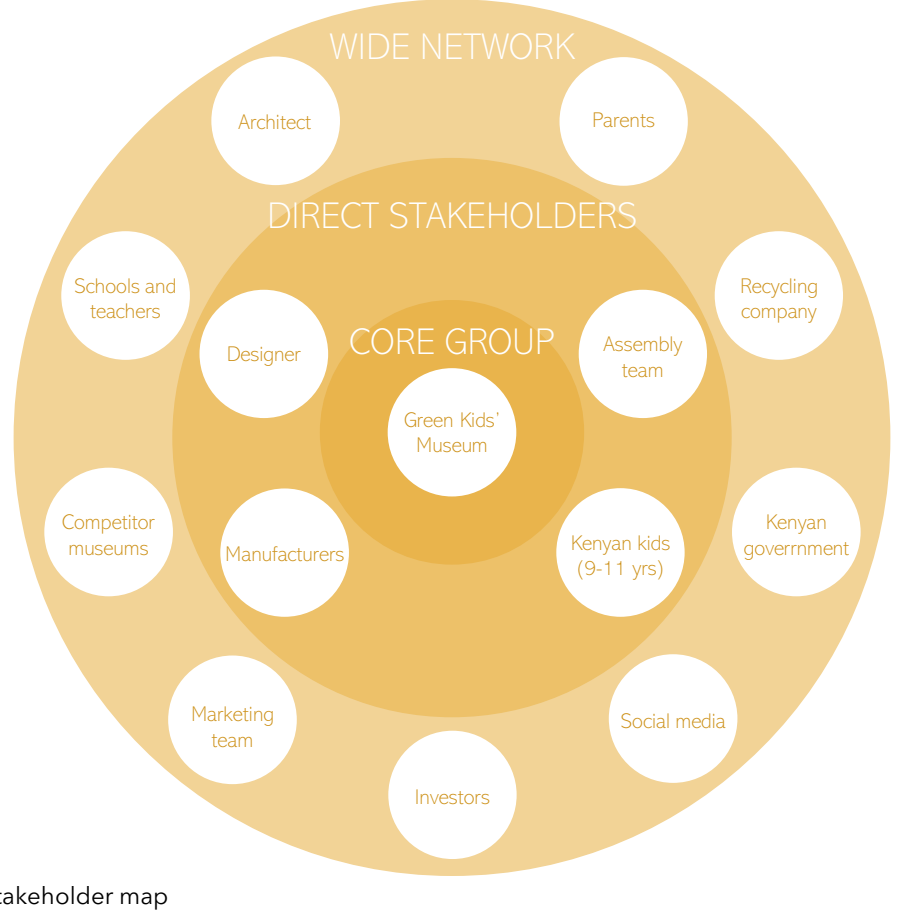
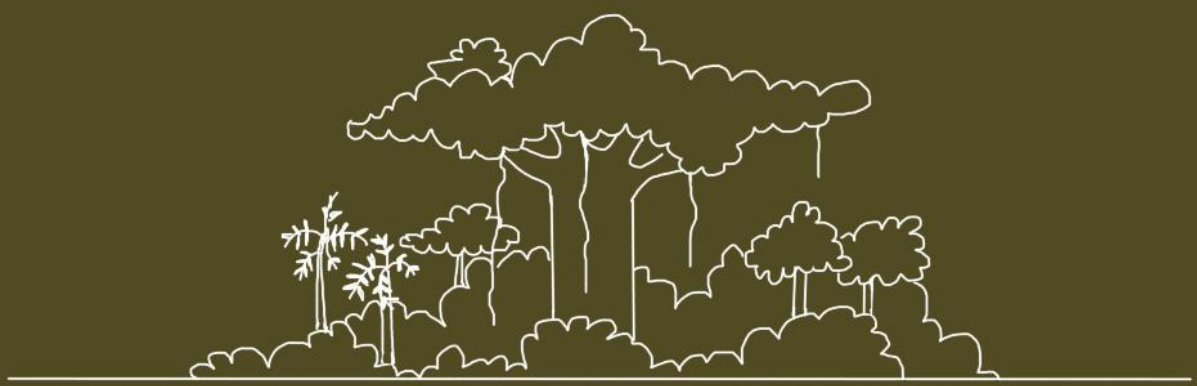


Figure 2. Stakeholder map



Chapter 2: Biodiversity & ecosystems

The goal of this graduation project is to design a play-based exhibit piece that raises children's awareness of biodiversity and ecosystems. The first step to reaching this result is gaining an understanding of the meaning of biodiversity and ecosystems as well as the current state of our planet's and Kenya's biodiversity. This will subsequently help in gaining inspiration on what kinds of information to deliver to children. For this, it is also necessary to understand how Kenya currently teaches children about biodiversity and ecosystems to be able to create a play-based exhibit piece that matches their knowledge.

What is an ecosystem

An ecosystem is a certain geographical area where weather, landscapes and organisms interact with one another to form one system of life (National Geographic Society, n.d.).

There are many different ecosystems in the world. Each ecosystem has their own weather type, landscape, plants and animals living in it. The grasslands in Kenya, for example, form one of the types of ecosystems in Kenya and has one of the most abundant biodiversities in Africa (Ominde, 2021). It has a diverse range of plants and animals on top of a vast number of rivers and lakes. This ecosystem provides essential ecosystem services, such as mitigating droughts and floods, and cycling and moving nutrients (Dakota Prairie Grasslands, n.d.)

What is biodiversity

Biodiversity (biological diversity) refers to the variety of life on Earth on all levels and includes all evolutionary, ecological, and cultural processes that bolster life (American Museum of National History, n.d.).

There are three factors that determine the level of biodiversity:
1. The diversity of species
2. The diversity of genes within these species
3. The diversity of ecosystems

Biodiversity is important, because it provides the basic conditions needed for human survival (BPL, n.d.). It provides us with food, health, clean air and water. Currently, we experience a loss in biodiversity. This means that the diversity in species is decreasing and that the abundance of some individual species also decreases. There is a continuation of loss in world's forests, essential ecosystem services such as the provision of clean water and soil for farming continue to degenerate, and there is still no progress in the reduction of pollution, climate change and loss of habitat (Oliver, 2020).

The Convention on Biological Diversity (CBD) created a plan where every participating government in the world agreed to reach 20 sustainable goals before 2020, however the CBD's Global Biodiversity Outlook 5 report revealed that none of these targets were met in 2020 (Kukreti, 2020). This shows that sustainability, and therefore biodiversity, is not yet taken seriously. The CBD report warns that "biodiversity is declining at an unprecedented rate and the pressures driving this decline are intensifying" (Kukreti, 2020). Action needs to be taken now to preserve the biodiversity and ecosystems within.

Due to the diversity and abundance of species in the country's varied ecosystems, Kenya is considered one of the most biodiverse countries in the world (National Environment Management, n.d.). This is mostly because of the diversity in landscapes, ecosystems and habitats (NEMA, 2005). Kenya is for example inhabited with the Big 5, lion, leopard, elephant, black rhinoceros and African buffalo, which most Kenyan kids will be familiar with.

Education

Because there is a decline in the use of sustainable traditional land and because indigenous and local knowledge is fading away, societies see and associate less with biodiversity (UNESCO, n.d.). This therefore forms a threat on biodiversity and ecosystem services. It is therefore of high importance to include biodiversity and ecosystems into the education and learning programmes (UNESCO, n.d.).

Promoting the conservation of biodiversity should play an important role in worldwide education, because "environmental problems tend to be based on lack of knowledge and education" (Ramírez, 2019). The UN Conference of Environment and Development, established in 1992, proposed to set up a program on education for sustainable development. "Educators were urged to include environmental education in their curricula, not only in biology and natural science classes, but across the spectrum, as a topic to be discussed in social sciences, and other school subjects" (Ramírez, 2019).

Kenya has recently integrated environmental studies into their school curriculum for lower primary and pre-primary (Mueni, 2018). They believe that teaching children desirable behaviour in their early years help them retain the taught behaviour and attitude as they grow up. "Equipping these future leaders with the necessary environmental knowledge and skills will help in mitigating the effects of climate change through environmental restoration and conservation" (Mueni, 2018).

The Green Kids' Museum has set up learning goals for each target group that fit the current educational curriculum in Kenya. The learning goals of the biodiversity and ecosystems theme for the target group that will be tackled during this graduation project (9-11 year olds) are:

- Children are able to summarize what an ecosystem is
- Children are able to recognize the different "roles" in an ecosystem
- Children are able to discuss the interconnectedness of an ecosystem
- Children are able to consider their own role in an ecosystem
- Children are able to give examples of human impact (good/bad) on ecosystems

To start the ideation process it is necessary to create a focussed direction, so proper ideas can be created that suit the Green Kids' Museum and the assignment criteria. From the above learning goals two new learning goals are formed, which have the most potential for ideation. Choosing only two learning goals will help narrow down the focus during the ideation phase and help create more useful ideas. Therefore the play-based exhibit has to have one of the following learning goals:

1. The learning goal of the play-based exhibit is to recognize the different ecosystems in Kenya.
2. The learning goal of the play-based exhibit is to understand the interconnectedness of a food chain within an ecosystem in Kenya.

Conclusion

What can be taken from this chapter is that the play-based exhibit piece needs to either teach children to recognize the different ecosystems in Kenya, or to understand the interconnectedness of a food chain within an ecosystem in Kenya. Both learning goals fit the Kenyan school curriculum for children between 9 and 11 years old, which will be the target group for the exhibit piece. Decision on which learning goal the exhibit will carry out will be made during the ideation phase. Here the idea is chosen that fits the product requirements best.

Chapter 3: Interactive museums

To get an understanding of what kind of interactive installations work for children and what not, three different interactive museums in the Netherlands were visited that have science and/or biodiversity as their main theme. During these visits children of different ages were observed to see which installations attracted the most interest, which is expressed in excitement and staying longer at the installation. The layout of the museum and quality of the installations were subsequently viewed to get an understanding of what would fit the Green Kids' Museum and what not.

Below shows an overview of the pros and cons of each museum and their installations, based on the museum visits. It is also good to note that there are not yet any interactive museums in Kenya, so Kenyan children are still unfamiliar with this concept. Therefore, during the ideation phase the results accumulated from Dutch children are used to create ideas which are subsequently tested with Kenyan children to validate these results and see if they still apply.

Visit Museon 02/03/2022

Museon is a museum that covers all the facets of our planet, from sustainability to war, etc. The museum is quite overwhelming with many signs, sounds and light everywhere. Lack of a clear path directing you through the museum makes it difficult to focus. What made part of the museum a bit more coherent was the stamp card system, which helped you lead from installation to installation (see Figure 3). This system was both interesting for the children, as it was very interactive, and the parents as they could give their own input on different topics. However, just less than half of the installations were connected to this stamp system.

Pros:

- Children seemed to love the expositions where they could build something, such as creating electronical circuits to make lights and sounds go off (see Figure 3) or building their own city out of building blocks.
- The installations were very diverse in topic, so there was something interesting for everyone.
- Children liked the stamp system, but did not always think about the questions. They just wanted to stamp the card.

Cons:

- Children skip reading the instructions and will not understand the installation if instructions are required (see Figure 4).
- Children were less interested in exhibitions which solely consisted of video and audio fragments.
- Some installations were too challenging for children so parental help was required, which children did not always want.

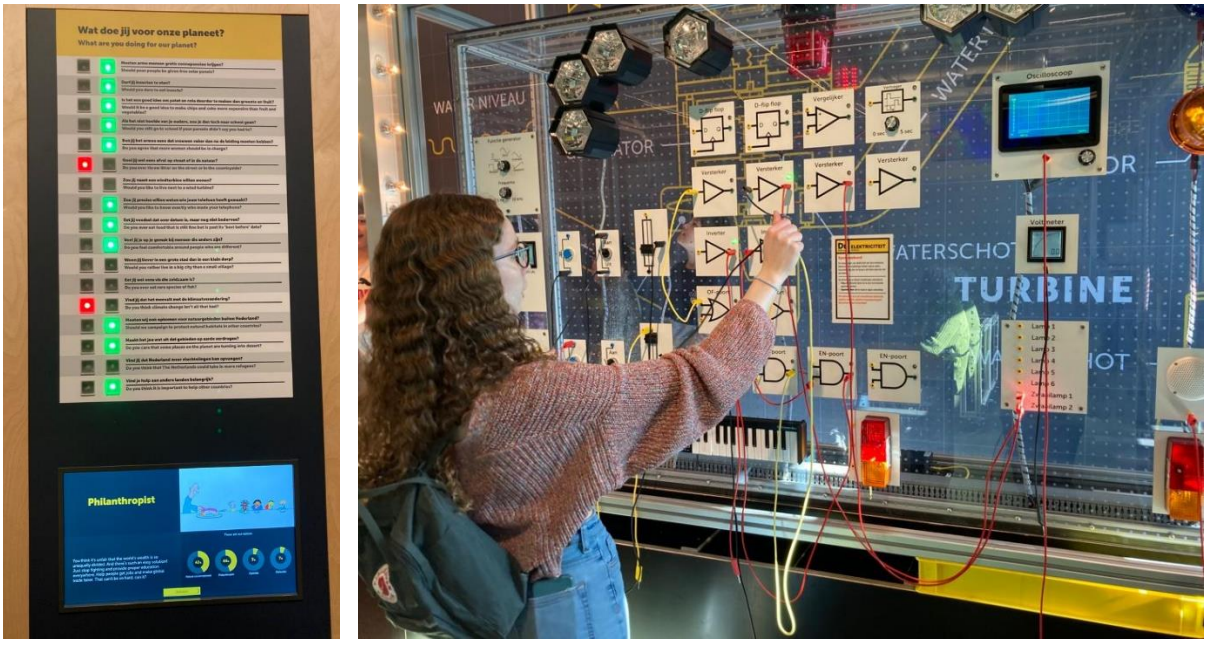


Figure 3. Museon. Stamp card results (left) and an interactive electronic board (right)

Figure 4. Museon. A game about water pollutants (left) and one about the sustainability of different big capitals in the world (right)

Visit Nemo 08/03/2022

Nemo is a science museum and covers both physical science and mental science. The rooms were quite overwhelming, with many sounds and lights coming towards you at once. There is also no clear path to follow throughout the rooms, which makes it quite unorganised. The open space, however, did make it easy for children to run around in.

Pros:

- The big, elaborate installations attracted the most children and kept their attention the longest as there was much to look at and interact with (see Figure 5).
- All senses were used throughout the museum.
- The museum has a lot of installations with layered challenge levels, which means that they have a simple message for the younger target group and a more complex message for the older target group.
- Children did not mind playing together with children they did not know (see Figure 5).

Cons:
- The installations that needed explanation were not interesting for children
- A lot of robotic installations were out of use.
- Children were less interested in installations without any moving parts. They seemed to just look over them.

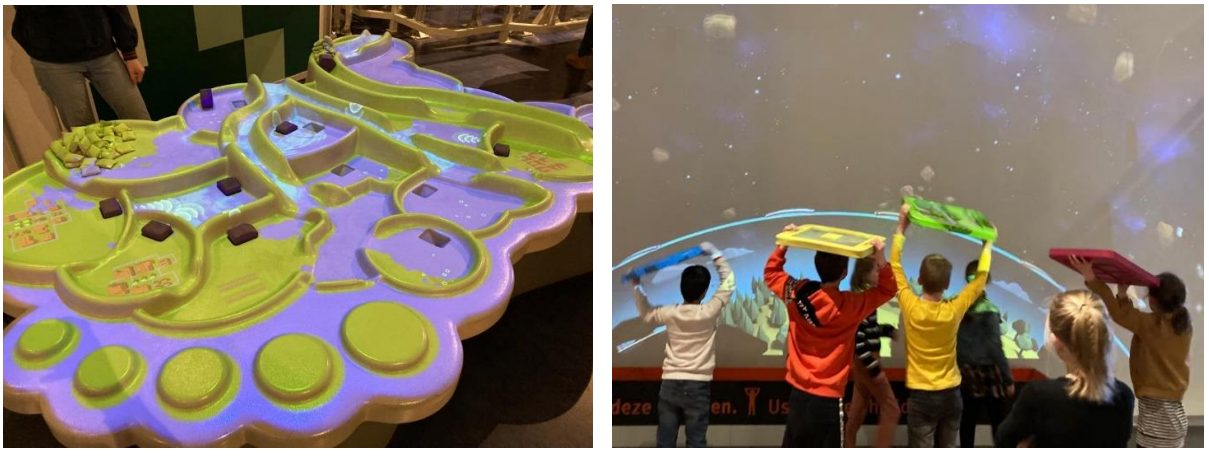


Figure 5. Nemo. Interactive beamers used to manage waterways (left) and to protect the planet from meteors (right)

Visit Naturalis 22/03/2022

Naturalis has been rebuilt and is now located in a new building. The museum itself is made of natural stones with minerals in them and layers of imitation fossils to connect the building to nature. The museum has many windows allowing for much natural light inside the building. Naturalis is very organised with separate rooms per theme and a very clear path to follow. It is compact in its information and every room has a couple installations, making it more organised. The museum is interesting for both children and adults and the museum has a mix of interactive and non-interactive installations.

Pros:
- The installations were very clear and most required no instructions. Children immediately understood how to use them (see Figure 6).
- Children were most interested in the big installations, such as a big dinosaur skeleton which had moving projections of the living dinosaur supported by loud roaring sounds behind it. Children seemed to be amazed by the size of the installation in combination with the realistic-looking projections.
- Children loved a particular installation with binoculars, each binocular displaying a different scene in nature. They seemed to find this amazing and wanted to watch all the videos on the different binoculars and were even talking about the videos to one another. The videos were short and intense. Figure 6 shows the installation with binoculars.
- Children found a mineral exhibition in a cave interesting, because it was situated in the dark which they found exciting.

Cons:
- Children do not read the small text at the installations and if they do not immediately understand the installation they lose their interest.
- Children cared less for static objects and installations, such as stuffed animals (see Figure 7).


Figure 6. Naturalis. Children have to guess what animal belongs to which fur (left) and the installation with binoculars (right)


Figure 7. Naturalis. A child feeding the birds as fast as possible (left) and a display of stuffed animals (right)

Conclusion

This museum research has shown the following pointers for good design:

- Large installations gain the attention of children faster than smaller installations
- Building something appeals to children
- Make sure the exhibit is interactive. Only playing video or audio fragments is not attractive enough
- Do not rely on children reading instructions
- Be cautious with relying on parents having to explain something before children can use it. Children do not want that.
- A reward at the end of the game can elongate the child's interest
- Do not make robotic types of installations

Whether children learned something from the installations cannot be concluded as this is not tested in the museum. This will only become clear outside of the museum once they apply the learned information. It was noticeable when they understood the working of the installation, but not if they actually understood the information that the installation tried to convey. Therefore, no conclusions can be drawn regarding learning objectives or knowledge transfer.

Chapter 4: Manufacturing techniques in Kenya

To be able to design a product which can be manufactured in Kenya, it is important to know what kind of manufacturing techniques are available in this country. Therefore, a catalogue is created which serves as a living document for both the designer, client and future designers. The catalogue has the following purpose:

- *To have an overview of a range of available production techniques in Kenya.*
- *To have quick access to contact details of available manufacturers in Kenya.*
- *To get an understanding of how sustainable each technique is and how sustainable the company is when it comes to practicing this technique.*
- *To assess whether the technique is suitable for the Green Kids' Museum.*

Figure 8 shows a wireframe of the catalogue containing all the above mentioned segments.

Figure 8. Wireframe catalogue

The complete catalogue can be found in Appendix B. Figure 9 shows 8 example pages from the catalogue. The catalogue consists of a list of different manufacturing techniques that could be used to create a play-based exhibit piece, and some products that can be integrated into the new exhibit piece. Each manufacturing technique is covered by 4 pages, with the first 2 pages explaining the technique and the (sustainable) benefits for the museum and new exhibit piece. The other pages show three manufacturers in Kenia that apply this technique. These manufacturers are rated according to how sustainably they practice this technique, based on material sourcing, transportation of materials, production and end of life. This information was obtained through the internet by looking up information from their online platforms such as their website or Facebook page and are presumed to be correct and true. A colour coding system was applied. If no information could be found on a certain aspect it was rated as average, which resulted in a yellow colour. A red colour indicates the aspect is very non-sustainable and green highly sustainable. Figure 10 shows three examples of filled-in scales. The left shows a scale where all factors are rated as average, in the middle scale all factors are rated as very non-sustainable and on the right all factors are rated as very sustainable.

Figure 9. Example pages from the manufacturing technique catalogue

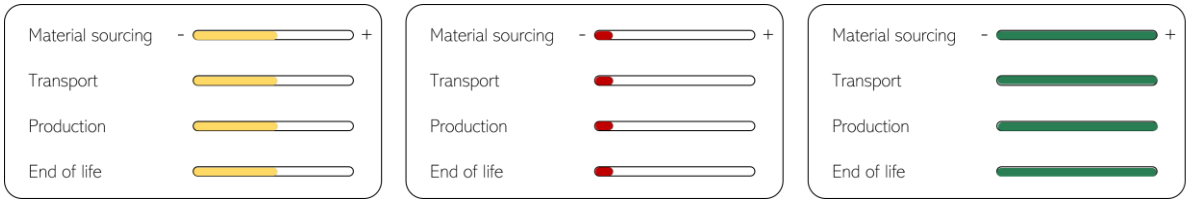


Figure 10. All factors rated as average (left), all factors rated as very non-sustainable (middle), all factors rated as very sustainable (right)

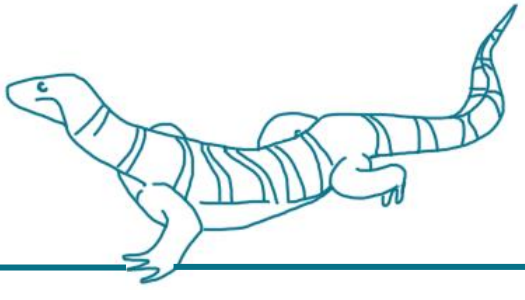
The different factors were rated accordingly:

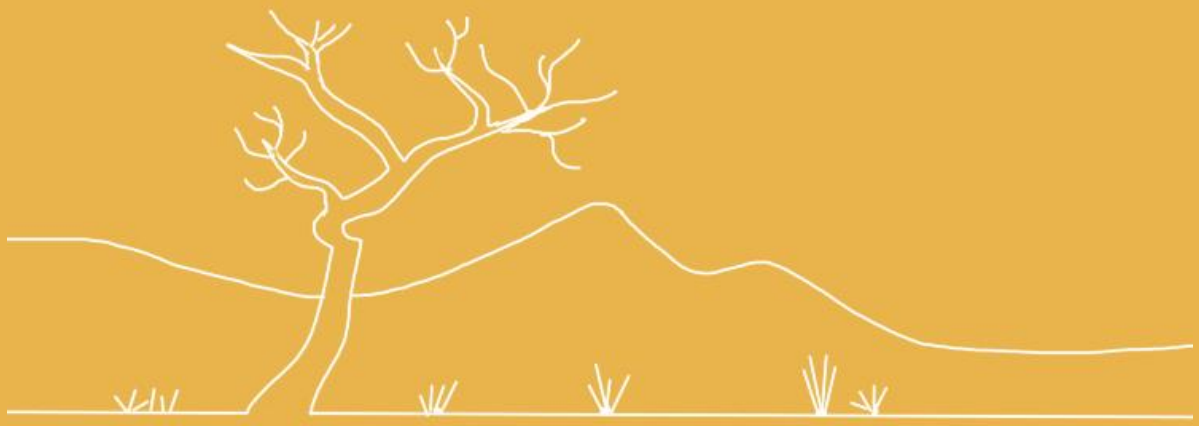
- Material sourcing: Is the material used for this technique sustainably sourced? For example, by sourcing from certified suppliers, using less energy or sourcing renewable materials? The more it implements any of these aspects, the higher the sustainability score.
- Transport: Does the material or product have to be transported into the country? The smaller the distance to Kenya, the higher the sustainability score.
- Production: Is the product sustainably produced? For example, by using less energy or generating minimum waste? The more it implements any of these aspects, the higher the sustainability score.
- End of life: Can the product after its use easily be reused or recycled? The better it can be reused or recycled, the higher the sustainability score.

The catalogue shows that manufacturers that practice the same manufacturing technique can score completely different when it comes to how sustainable they are. When looking at injection moulding for example, SILAFRICA states they reduce their energy usage during injection moulding and that they source their plastics locally. ADIX and Precision Plastics Limited do not state anything about their energy usage during production so were rated as average. When looking at the sustainability factors, transport is mostly rated as very unsustainable. For both woodworking and 3D printing, all 3 companies score very low on transport. They all obtain their materials from distant sources, such as China, Spain and Brazil. On the other hand, most manufacturing techniques create products that can easily be reused or recycled which is a positive sustainable factor. Finally, some of the products that can be used for the play-based exhibit have to be imported from another country. The interactive beamer Tover, for example, is produced from the Netherlands and would have to be transported to Kenya. However, as this is a small product that does not require much maintenance, it could outweigh the negative sustainability factor.

The catalogue was used and reviewed by an expert that also does research in this field. She suggested making it more clear that injection moulding is only more sustainable (and cost effective) when used on an industrial level and 3D printing when not used on an industrial level. She warned that users of the catalogue might incorrectly compare the two. This has been made more clear in the text of the two chapters.

In chapter 7 of this report the catalogue is used as a guide to select the most fitting manufacturers for producing the product by looking at which manufacturers take sustainability the most into account during production.





Chapter 5: Product requirements

Before starting the ideation phase it is necessary to get an understanding of the requirements for the new play-based exhibit piece. This will help create a product that fully fits the goal of the project. These requirements, together with wishes for the exhibit piece are summed up below and formed from research and acquired information. The Delft Design Guide is consulted for choosing the correct headings (2016). As project requirements are concrete and measurable it can be challenging to use these to rate the appropriateness of conceptual ideas that are not yet detailed. For that reason, next to the requirements, design criteria are created which are less concrete. The design criteria are used throughout this research to evaluate the appropriateness of first conceptual ideas and details of the design. Once the design is fully worked out the product can be evaluated according to the requirements to see if all of them are met.

Requirements

1. Performance
    - The product should not physically harm the user in any way
        - The user should not be able to get limbs stuck in the game
        - The user should not be able to get an electrical shock from the game
        - The user should not be able to get any cuts or splinters from using the game
        - The game should not be able to fall on the user
    - The product should not mentally harm the user in any way
    - The product should raise awareness about biodiversity and/or ecosystems via either understanding the interconnectedness of a food chain within an ecosystem in Kenya or recognizing the different ecosystems in Kenya
    - The product should be considered playful by 9 to 11 year old Kenyan children (Gray, 2013):
        - The process of playing the game and the outcome of the game are both as important
        - The game is guided by mental rules, but these leave room for creativity
        - The game is played in an alert, active, but relatively non-stressed frame of mind
    - The product should keep the attention of 9 to 11 year old Kenyan children for at least 5 minutes (Ward, 2020)
    - The product should be able to be used by both one child or two children at the same time
    - The product should be able to be used by all genders
    - The product should be able to be used by both left handed and right handed people
    - The product should be able to be understood by the user without reading the instructions
2. Life in service
    - The product should withstand an overall use of 6 days a week, 9 hours a day (Green Kids' Museum, 2022)
    - The product should withstand rough play
    - The product should withstand moisture and grease from human touch
3. Production
    - The product should be able to be fully produced, used and recycled in Kenya
    - The product should be produced by manufacturers that take sustainability into account when creating a product
4. End-of-life
    - The product should be able to be recycled or reused

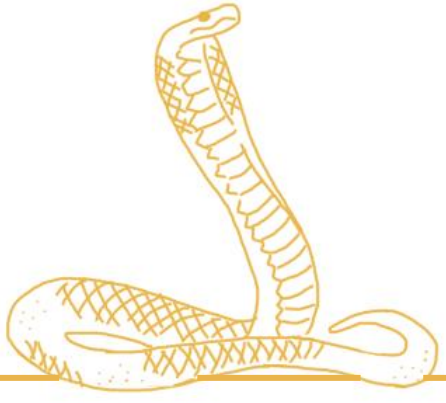
Wishes

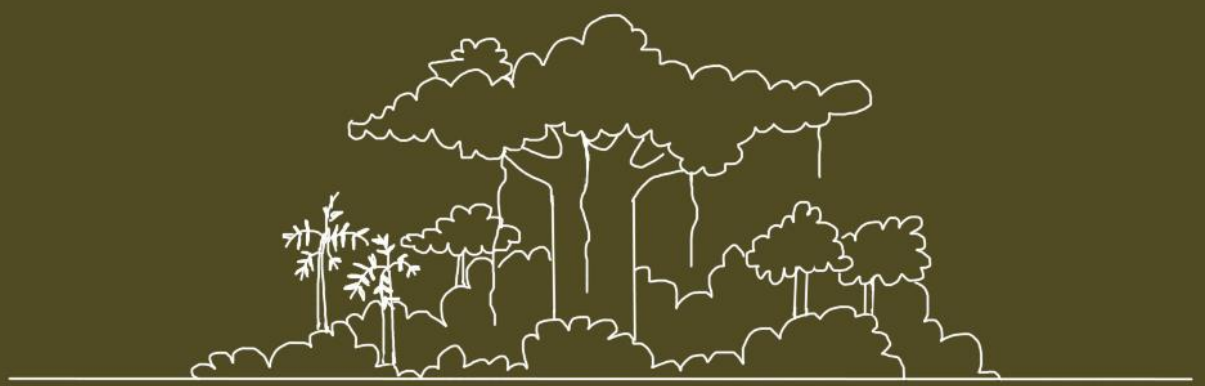
- The product should be made of as much recycled or biomaterial as possible
- The production cost should be as low as possible
- The product should be as easy to clean as possible

Below criteria are the general criteria for a product that fits the objectives of this project. Later on in the research more detailed criteria are created for every main part of the chosen design.

Design criteria overall

1. The product should help raise awareness about biodiversity and ecosystems to 9 to 11 year old Kenyan children in a playful manner.
    - The product should cover at least one of the following learning goals:
        - Children are able to recognize the different ecosystems in Kenya.
        - Children are able to understand the interconnectedness of a food chain within an ecosystem in Kenya.
    - The product should cover biodiversity and ecosystems in Kenya so Kenyan children can relate better as the examples are close to home.
    - The product should be playful and have the following characteristics of play:
        - The process of playing the game and the outcome of the game are both as important.
        - The game is guided by mental rules, but these leave room for creativity.
        - The game is played in an alert, active, but relatively non-stressed frame of mind.
2. The product should be perceived as fun by 9 to 11 year old Kenyan children.
    - The product should keep the attention of the child long enough for them to complete the game.
    - The product should be able to be used by one or more users at the same time.
3. The product should be able to be made in a sustainable way.
    - The product should be able to be fully produced, used and recycled in Kenya
    - The product should be produced by manufacturers that takes sustainability into account when creating a product.





Chapter 6: Concept design

During the ideation phase, a variety of ideas were created which were then rated according to the PMI (plus, minus, interesting) method (Delft Design Guide, 2020). For the plus and minus the design criteria were used. If an idea complied with the design criteria it was written down as a plus, if it did not comply it resulted in a minus. The ideas were sorted according to their learning goal. The first 4 ideas belong to the first learning goal, the second 4 ideas belong to the second learning goal. The ideas with the least (highly ranked) minuses were selected to continue with.

Learning goal: Understand the interconnectedness of a food chain within an ecosystem in Kenya.

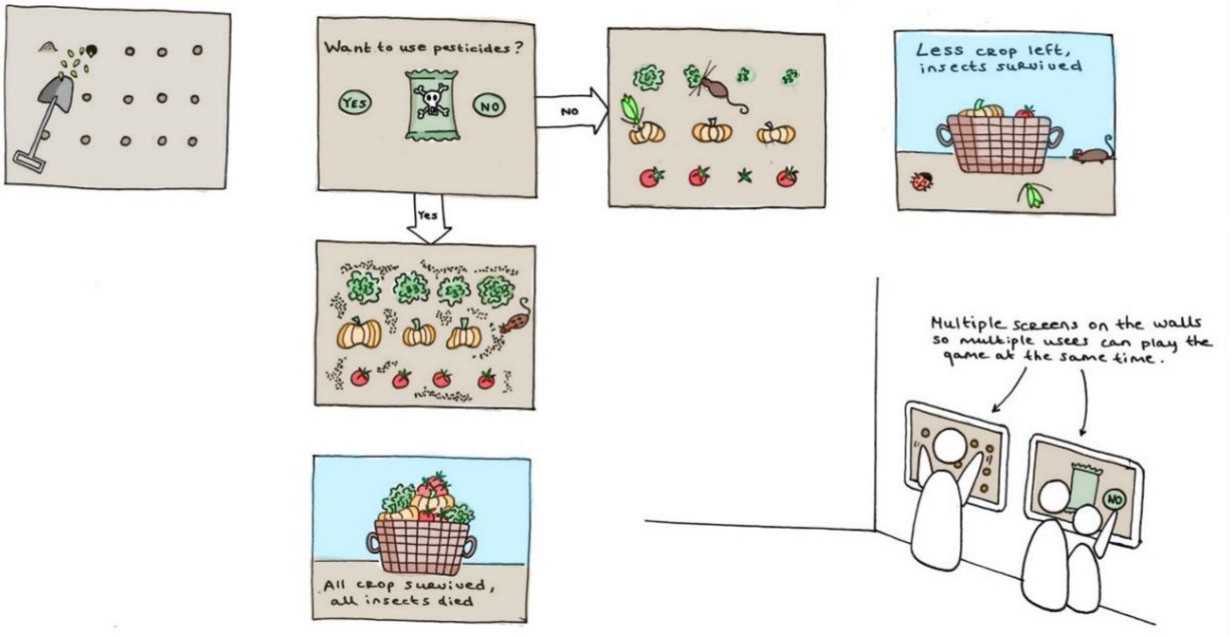


Figure 11. Idea 1: Grow your crop

Idea 1: Grow your own crop and make decisions along the way that will determine the biodiversity on your land. The game is played on large screens and can be played together with others.

Plus:
- The concept idea covers biodiversity and ecosystems in Kenya.
- The concept idea has characteristics of play, as the process of playing the game is as important as the outcome, the game can be played in multiple ways meaning the game leaves space for creativity, and the game is played with an alert and active, yet non-stressful mindset.
- The product keeps the user's attention for an extended period of time and the game can be played alone or together with multiple people.
- The concept idea can be made in a sustainable way, as the screens and visuals can be manufactured in Kenya (see catalogue in Appendix B), which reduces the CO2 emissions from transportation.

Minus:
- The concept idea does not fully cover the learning goal of understanding the interconnectedness of a food chain within an ecosystem. Not the complete food cycle is tackled in this game. It is not connected to other animals and humans and could therefore also make less of an impact on the child.

Figure 12. Idea 2: Food pyramid

Idea 2: Stack the blocks in the right way to create a food pyramid. Do this within the given time, otherwise the table will shake all the blocks down. If the blocks are stacked in the wrong order, the table will also shake the blocks down.

Plus:

- The concept idea covers the learning goal of understanding the interconnectedness of a food chain within an ecosystem.
- The concept idea covers biodiversity and ecosystems in Kenya.
- The concept idea has some characteristics of play, as the process of playing the game is as important as the outcome, and the game is played with an alert and active, yet non-stressful mindset.
- The concept idea can be made in a sustainable way, as the wooden pieces can be made locally from local wood sources (see catalogue in Appendix B).

Minus:

- The game cannot be played in multiple ways meaning the game does not leave much space for creativity.
- The concept idea might be too simple for 9-11 year old children, which could result in not keeping their attention and therefore will not be perceived as fun.

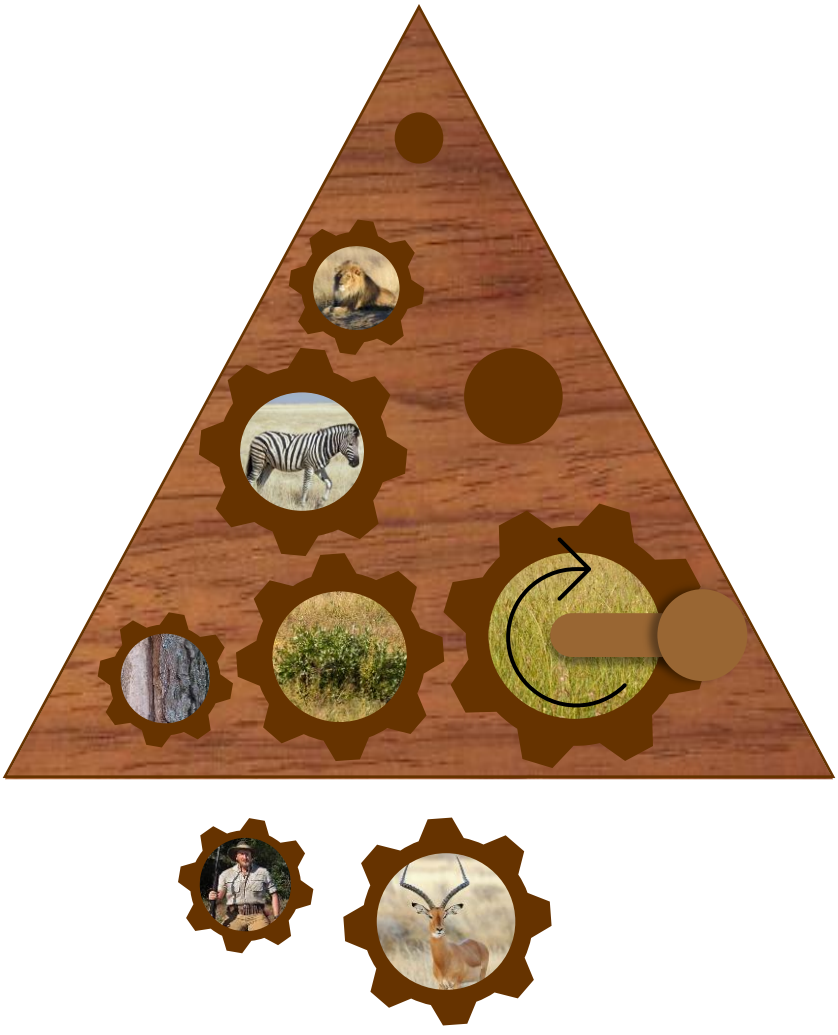


Figure 13. Idea 3: Food pyramid

Idea 3: Place the gears in the right order to create a working system, a.k.a a food pyramid.

Plus:

- The concept idea covers the learning goal of understanding the interconnectedness of a food chain within an ecosystem.
- The concept idea covers biodiversity and ecosystems in Kenya.
- The concept idea has some characteristics of play, as the process of playing the game is as important as the outcome, and the game is played with an alert and active, yet non-stressful mindset.
- The product keeps the user's attention for an extended period of time and the game can be played alone or together with multiple people.
- The concept idea can be made in a sustainable way, as the wooden pieces can be made locally from local wood sources (see catalogue in Appendix B).

Minus:

- The game cannot be played in multiple ways meaning the game does not leave much space for creativity.

Figure 14. Idea 4: Protect your crop

Idea 4: Protect the crop from pests. Move a plate above your head to bounce the pests away. If you don't the insect will eat your crop. The more users play the game simultaneously, the better the protection.

Plus:
- The concept idea covers biodiversity and ecosystems in Kenya.
- The concept idea has some characteristics of play, as the process of playing the game is as important as the outcome, and the game is played with an alert and active, yet non-stressful mindset.
- The game can be played by two or more players at once.

Minus:
- Not the full food cycle is tackled in this game. It is not connected to other animals and humans and could therefore make less of an impact on the child. Therefore, not the full learning goal is covered here.
- The game cannot be played in multiple ways meaning the game does not leave much space for creativity.
- The game might not be perceived as fun by 9 to 11 year old Kenyan children, as the game is very repetitive and can therefore cause the user to not keep their attention for an extended period of time.
- The concept idea makes use of an interactive beamer which has to be imported from outside of Africa. This therefore means the product cannot be fully manufactured in Kenya and is also less sustainable.

Learning goal: Recognize the different ecosystems in Kenya

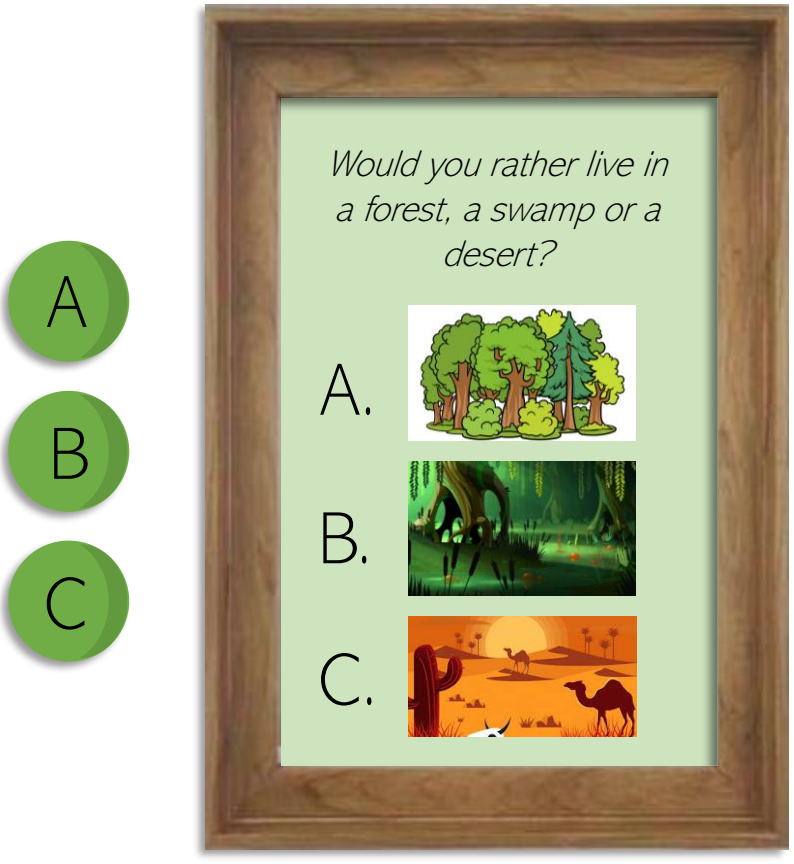


Figure 15. Idea 5: Spirit animal

Idea 5: Answer questions about ecosystems to find out what animal you are. The user will get to know more about the animal, the type of ecosystem they live in and what this ecosystem entails.

Plus:
- The concept idea covers biodiversity and ecosystems in Kenya.
- The concept idea has characteristics of play, as the process of playing the game is as important as the outcome, the game can be played in multiple ways meaning the game leaves space for creativity, and the game is played with an alert and active, yet non-stressful mindset.
- The game keeps the user's attention for an extended period of time.
- The concept idea can be made in a sustainable way, as the screens and visuals can be manufactured in Kenya (see catalogue in Appendix B), which reduces the CO2 emissions from transportation.

Minus:
- The concept idea does not fully tackle the learning goal of recognizing the different ecosystems in Kenya. The learning goal is reversed: the user does not recognize the different ecosystems during the game, but learns about them afterwards.
- The game cannot be played by two or more players at the same time.

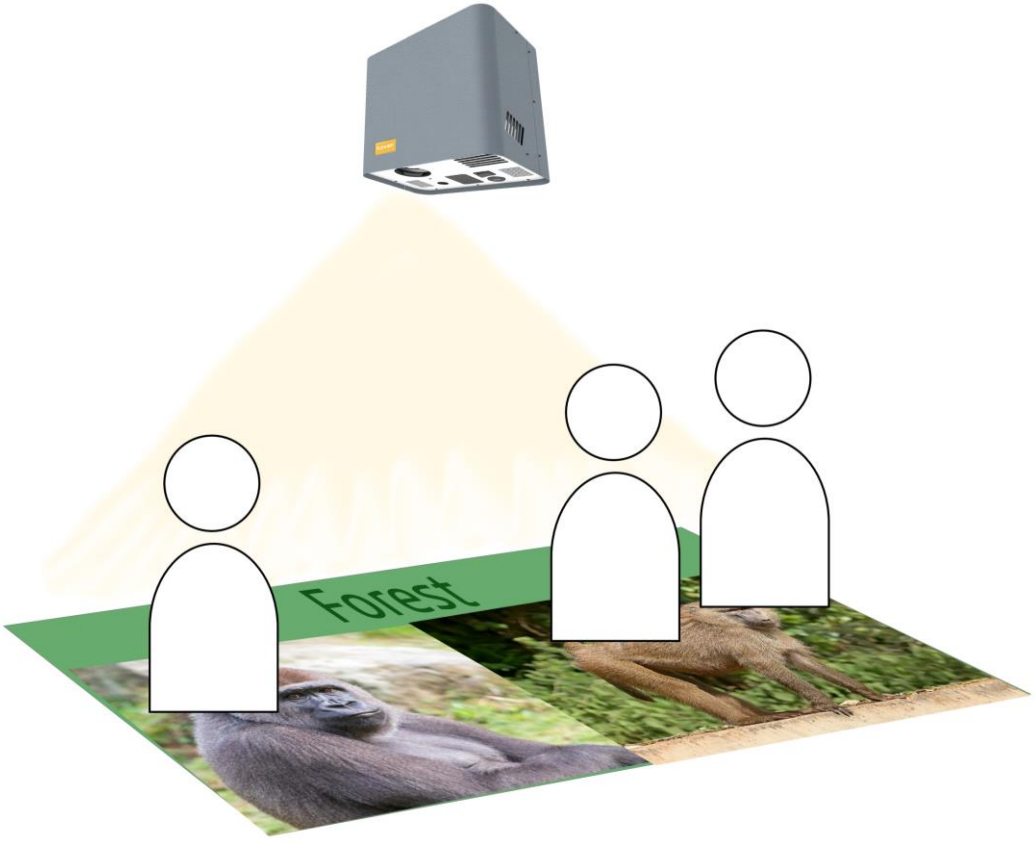


Figure 16. Idea 6: Find the match

Idea 6: Step on the correct animal that fits the ecosystem. Can be played with multiple people at the same time.

Plus:
- The concept idea covers the learning goal of recognizing the different ecosystems in Kenya.
- The concept idea covers biodiversity and ecosystems in Kenya.
- The concept idea has characteristics of play, as the process of playing the game is as important as the outcome, the game can be played in multiple ways meaning the game leaves space for creativity, and the game is played with an alert and active, yet non-stressful mindset.
- The game can be played alone or together with multiple people.

Minus:
- The concept idea makes use of an interactive beamer which has to be imported from outside of Africa. This means the product cannot be fully manufactured in Kenya and is therefore less sustainable.
- The game might be too simple and repetitive for 9-11 year old children and will therefore not keep the child's attention. The game therefore might not be perceived as fun.

Figure 17. Part 1 of idea 7: Match the ecosystem

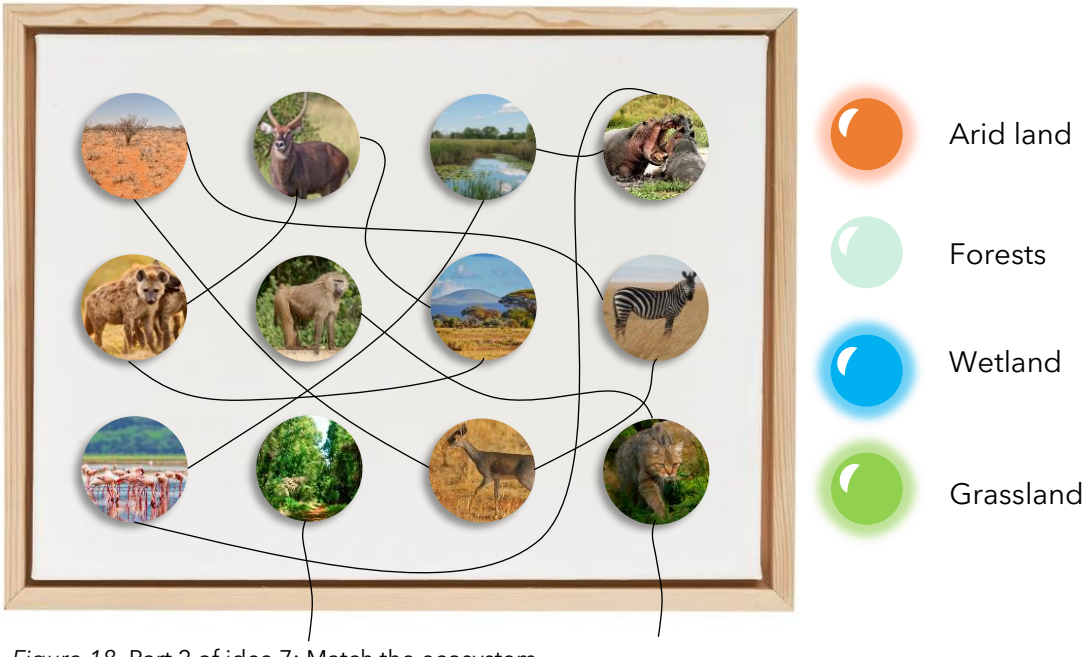


Figure 18. Part 2 of idea 7: Match the ecosystem

Idea 7: First look on the map to see which kinds of animals live in which ecosystem in Kenya. Then go to the game where you connect the different animals to the correct habitat to create one ecosystem. If an ecosystem is connected correctly, the corresponding light will turn on.

Plus:

- The concept idea covers the learning goal of recognizing the different ecosystems in Kenya.
- The concept idea covers biodiversity and ecosystems in Kenya.
- The concept idea has some characteristics of play, as the process of playing the game is as important as the outcome, and the game is played with an alert and active, yet non-stressful mindset.
- The product keeps the user's attention for an extended period of time and the game can be played alone or together with multiple people
- The concept idea can be made in a sustainable way, as the wood for the board and the electronics can be sourced in Kenya (see catalogue in Appendix B), which reduces the CO2 emissions from transportation.

Minus:

- The game cannot be played in multiple ways meaning the game does not leave much space for creativity.

Figure 19. Idea 8: Find the habitants

Idea 8: Quickly choose which animal belongs in the ecosystem by pressing the right button. The buttons are screens, so the animals will change after every ecosystem. Play alone or together with a friend to see who is the fastest.

Plus:

- The concept idea covers the learning goal of recognizing the different ecosystems in Kenya.
- The concept idea covers biodiversity and ecosystems in Kenya.
- The concept idea has characteristics of play, as the process of playing the game is as important as the outcome, the game can be played in multiple ways meaning the game leaves space for creativity, and the game is played with an alert and active, yet non-stressful mindset
- The product keeps the user's attention for an extended period of time and the game can be played alone or together with multiple people.
- The concept idea can be made in a sustainable way.
- The concept idea can be made in a sustainable way, as the wood for the board, the screens, and the electronics can be sourced in Kenya (see catalogue in Appendix B), which reduces the CO2 emissions from transportation.

Concept directions

Figure 20 shows an overview of the previously rated ideas.

Because the first design criteria "the product should help raise awareness about biodiversity and ecosystems to 9 to 11 year old Kenyan children in a playful manner" is quite broad, this criteria has been split into its three sub-criteria (see Figure 20). This makes it easier to rate the criteria and create more useful insights.

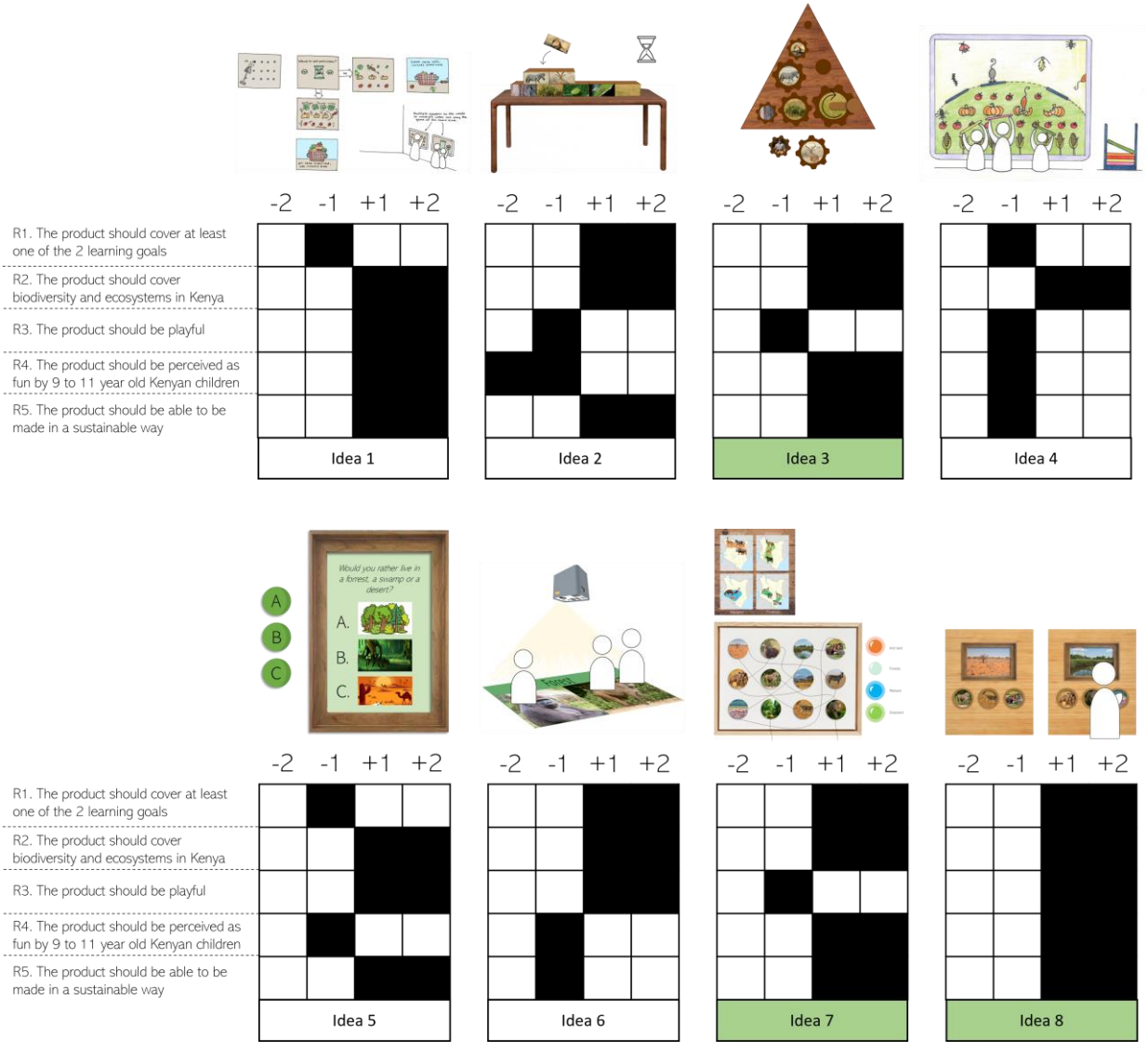


Figure 20. The ideas rated according to the design criteria

The ideas that do not (fully) cover one of the learning goals are dismissed, such as idea 1, 4 and 5, as this is the most important design criterium. Idea 2 is dismissed as the game is not suitable enough for the target group. Idea 6 is also dismissed as the concept idea cannot be fully produced in Kenya and is less suitable for the target group. The games of 3 and 7 cannot be played in multiple ways, but this is only a sub-sub criterium, which does not weigh up to the plusses of the game. Idea 8 complies with all design criteria. Therefore, idea 3, 7 and 8 are the most suitable design directions and fit for further assessment.

Chosen concept

Idea 3, 7 and 8 all comply to the design criteria and thus all fit the goal of this project. Therefore, selecting the final concept to continue this project with will be done according to intuition. Idea 8 is the least original idea of all three. The concept idea already exists in many forms and it is likely that this exact game is already played somewhere in the world. Children also move the least during this game, and the interactive museum research had shown that children like to be energetic and move around a lot in an installation. In addition, children play against each other rather than with each other, which could make it less playful. Therefore, this concept idea is not a perfect fit for this project. Idea 3 might be too easy for the target group as the user could also solve the game by not looking at the pictures and playing it as it were a regular gear game. There also might be the problem of gears fitting in different places resulting in wrong solutions. And besides that, the current idea has loose parts which can get lost. Therefore idea 3 is neither the best idea to continue with. Idea 7 has the right challenge level for 9-11 year old children, makes children move a lot, can be played together with people from different ages and sparks the interest of the designer most. Therefore idea 7 (Match the Ecosystem) is chosen as the concept to continue this project with. This means that "recognizing the different ecosystems in Kenya" is the chosen learning goal of this project. The game will be altered to fit this learning goal even better.

First iteration

Now that a concept idea is chosen it is important to eliminate the design flaws by redesigning it. The first iteration of the concept idea looks as follows:

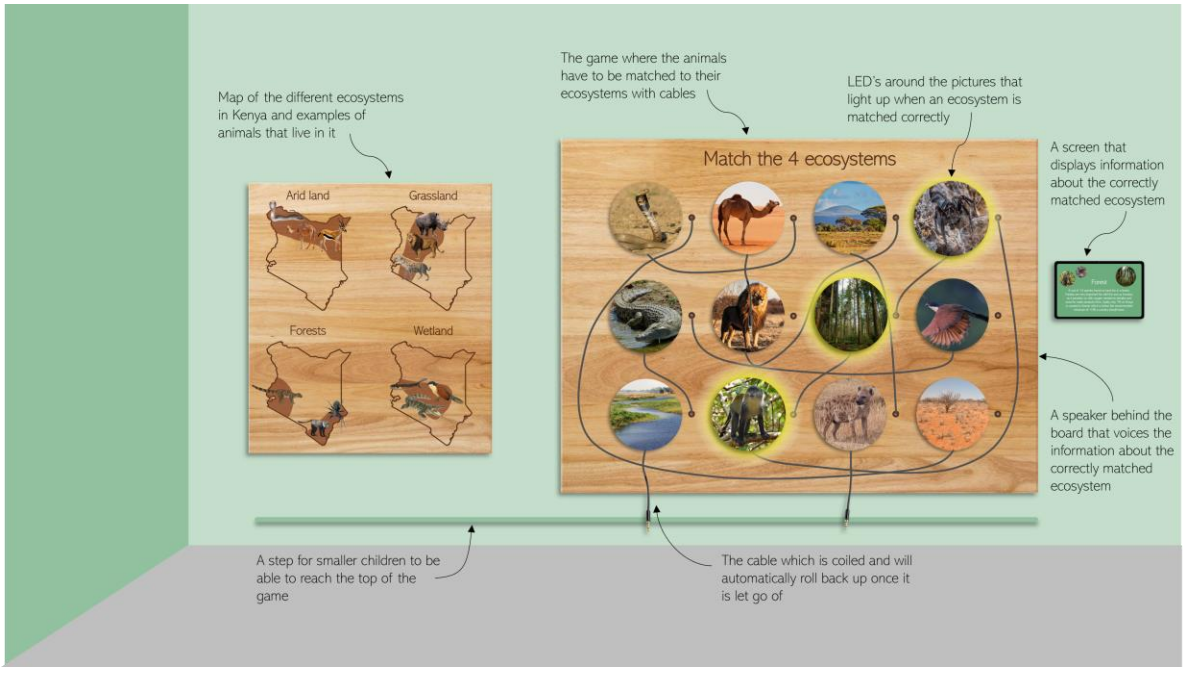


Figure 21. First iteration of the chosen concept idea

In this concept idea the animals still have to be connected to their ecosystems via cables. The cable is pulled from under the picture and connected to a different picture by putting it in the contact point next to it. Two animals have to be connected to one ecosystem. If the two animals are correctly matched to their ecosystem all three pictures will light up via an LED strip that is attached to the outside edge of the pictures. A sound will be played from the speaker behind the game which voices information about the correctly matched ecosystem. This information can also be read on the screen next to the game. A map next to the game shows where each ecosystem is located in Kenya and shows some examples of animals that live in each ecosystem.

What lacked in this design was:

- The map gave away some of the answers of the game which might make the game too easy.
- Children might pull the cables out too far which could break them. The game should withstand rough handling, so this solution is not the best option.
- The game was not able to automatically reset itself as the cables first all needed to be pulled out before someone else could play the game.
- It was unclear how to match the two animals to their ecosystem as they needed to be connected in a triangle (from animal to animal to ecosystem to animal), which did not feel intuitive.

Second iteration

A second iteration is applied allowing the start of the validation phase. This design looks as follows:

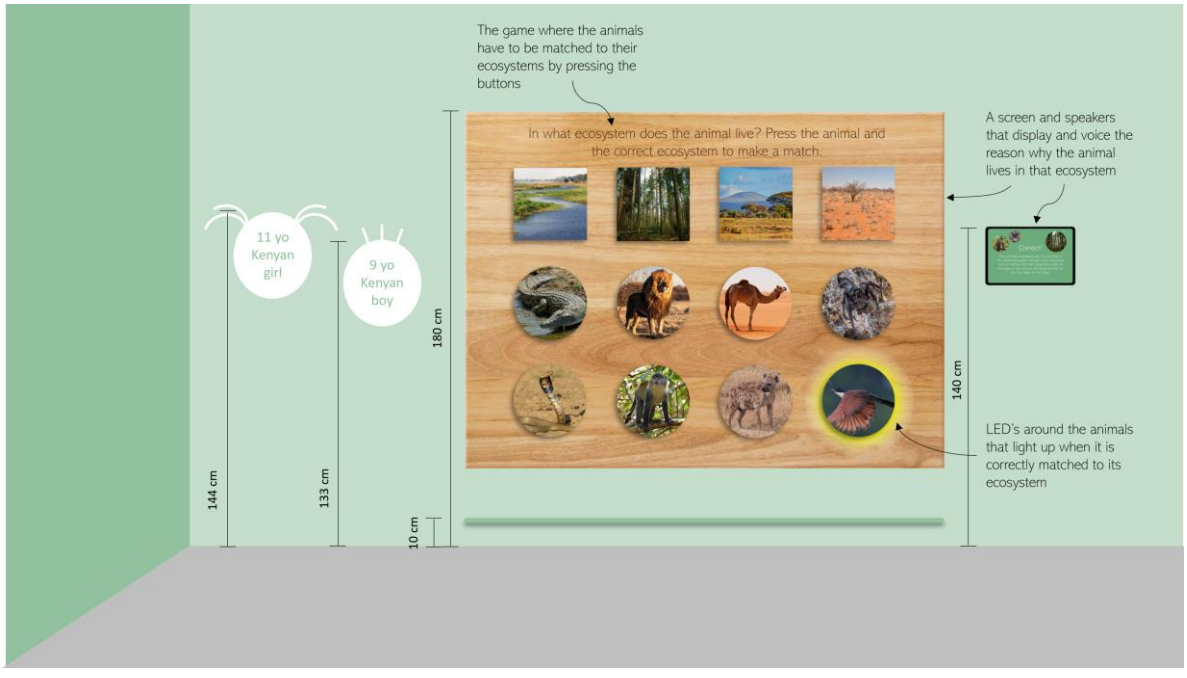
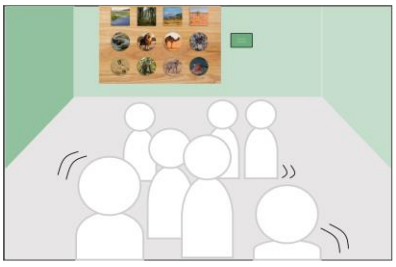
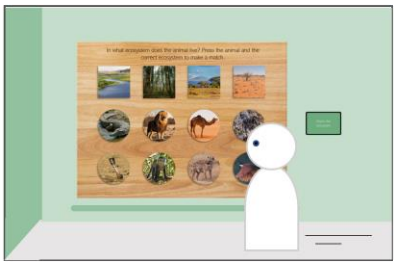


Figure 22. Second iteration of the chosen concept idea

In this concept idea the animals are connected to their ecosystem via buttons. The circles and squares on the board are buttons that can be pressed. First button to be pressed is an animal (circle). The button will stay pressed. Then an ecosystem (square) should be pressed. This button will also stay pressed for less than a second after which both buttons pop up. If the match is correct the animal will light up via the LED strip around the complete outer edge of the button. The speakers behind the game will voice the reason why this animal lives in this ecosystem and the same information can be read on the screen next to the game. If all LED's are lit up the game will automatically reset by turning all LED's off and returning the screen to its home screen. A complete user scenario can be seen in Figure 23.



A group of Kenyan school children enters the Biodiversity & Ecosystems room.

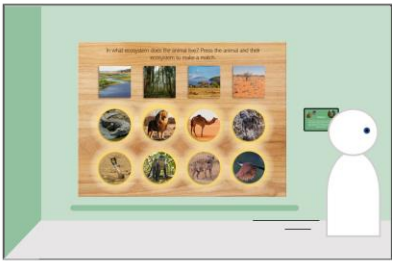


One of the children walks towards the Match The Ecosystem game.

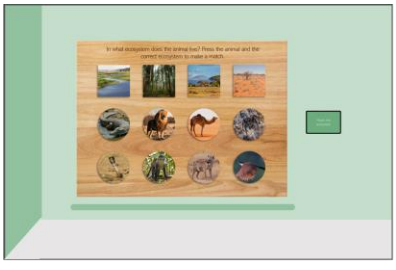
The child presses one of the animals. The button remains pressed.

The child presses one of the ecosystems. This button will also remain pressed.

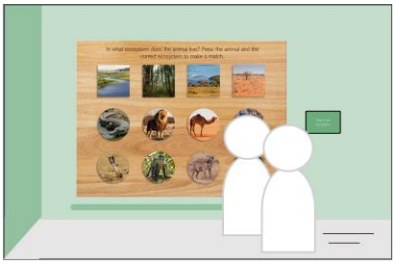
The combination is correct. The buttons pop out and the light around the animal starts to shine. You can hear a fact about the animal, which can also be seen on the screen. The animal button cannot be pressed again.



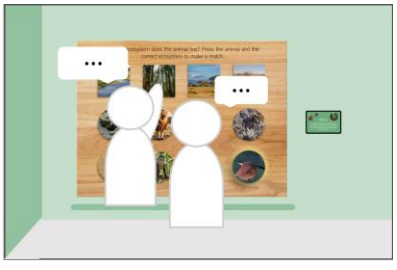
The child matched all the animals to their correct ecosystem, so all the lights are on. The child finished the game and walks towards the next exhibit piece.



After 30 seconds of being untouched or by pressing any button on the board the game will reset. The lights will go out and the screen returns to its home screen.



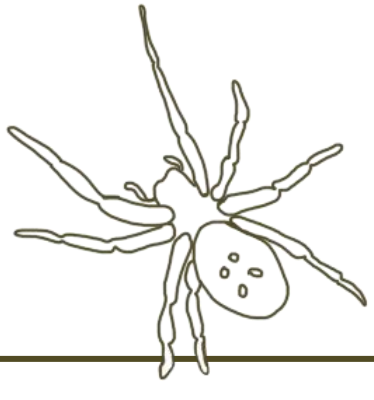
Two children walk up to the game and decide to play it together.



Together they discuss what combinations to make.

The children incorrectly match an animal to an ecosystem. The buttons will pop out and no lights will turn on. They now hear a voice that tells them to try again.

Figure 23. User scenario



Below show the envisioned materials and measurements of the concept idea.

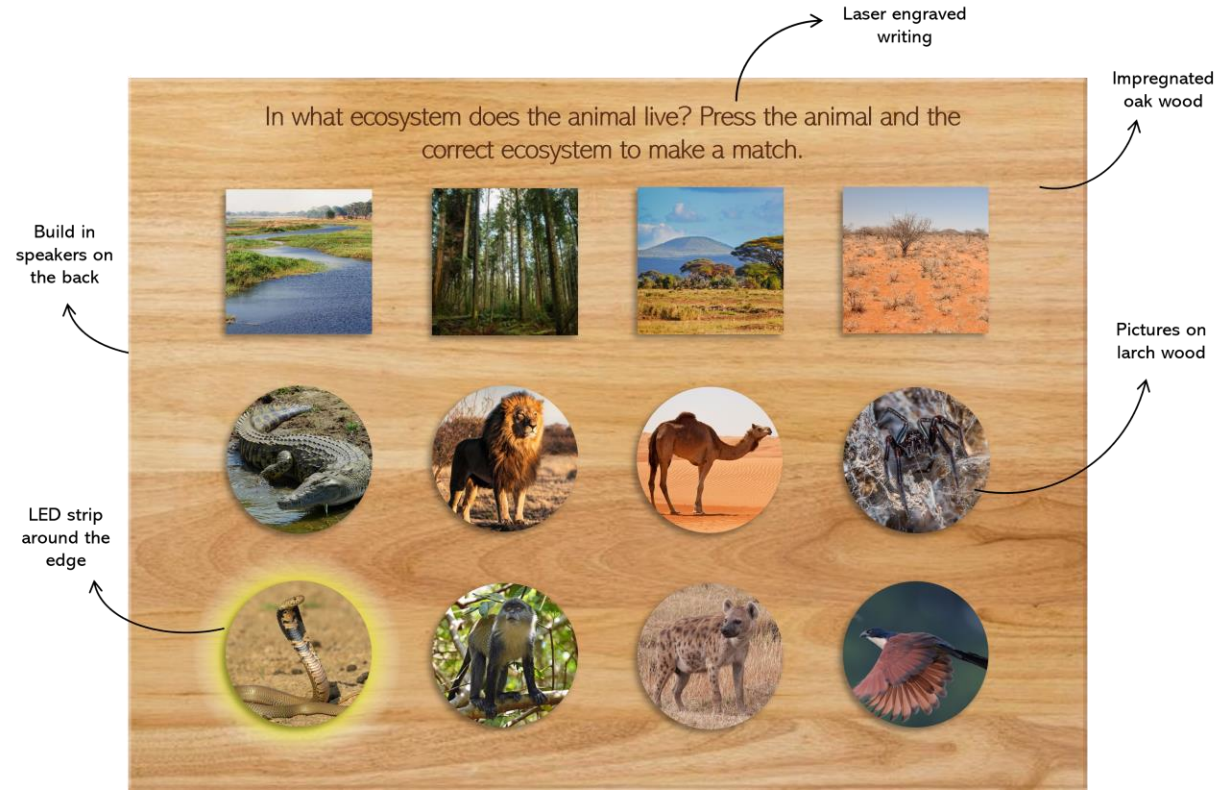


Figure 24. Envisioned material for the concept idea

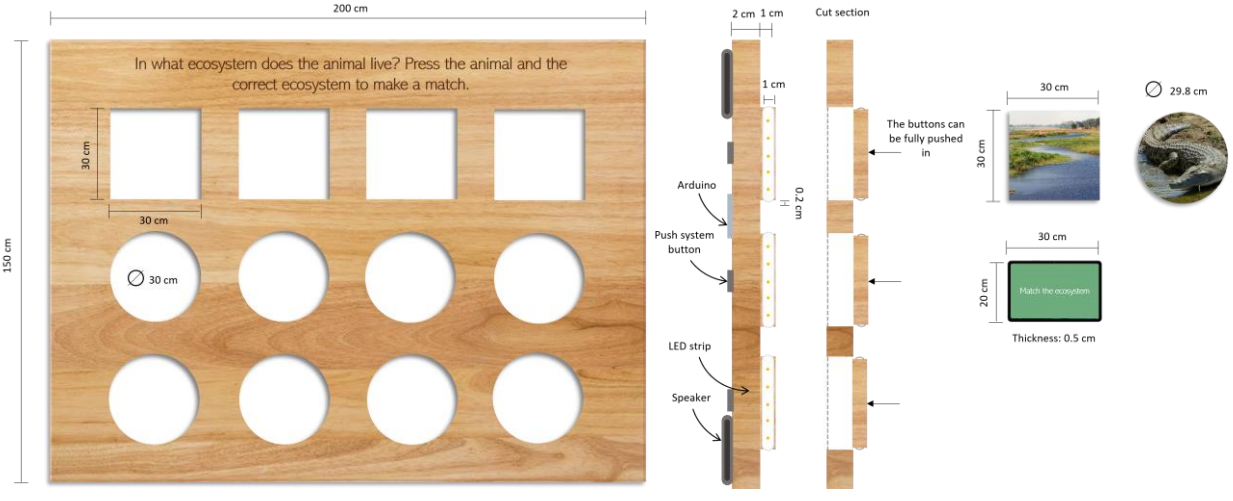


Figure 25. Measurements of both the front and side view of the concept design

Chapter 7: Product validation

The chapter on museum visits in the Netherlands has shown that the concept design in theory might fit the objective, as it is:

- *Large and stands out*
- *Interactive*
- *Consists of lights and sounds that work together with the interactions of the game and enhance the learning experience*
- *Does not need much instruction*

This chapter will validate if it indeed fits the target group by having the target group test the design and asking them questions about what they learned and liked, and what improvements there could be. On top of that, the concept design will also be validated with the manufacturers. Here the question will be answered about the production feasibility of the design.

Manufacturers

The concept idea consists of the following parts:

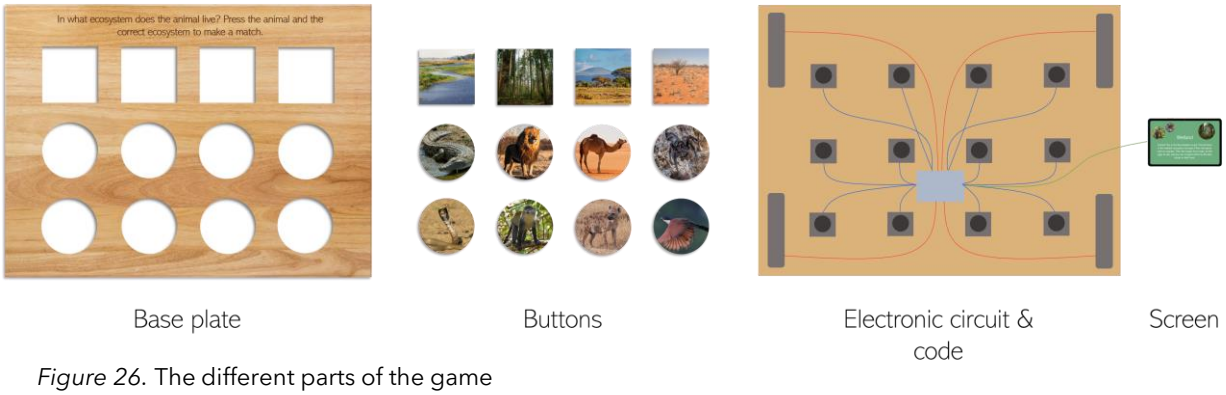


Figure 26. The different parts of the game

For each of the 4 product elements the most suitable manufacturer will be selected. Selection is done by consulting the Manufacturing Technique Catalogue, which can be viewed in Appendix B. Here the required production techniques are looked up and from the suggestions the manufacturers that produce their products in the most sustainable way are sought out. The selected manufacturers are:

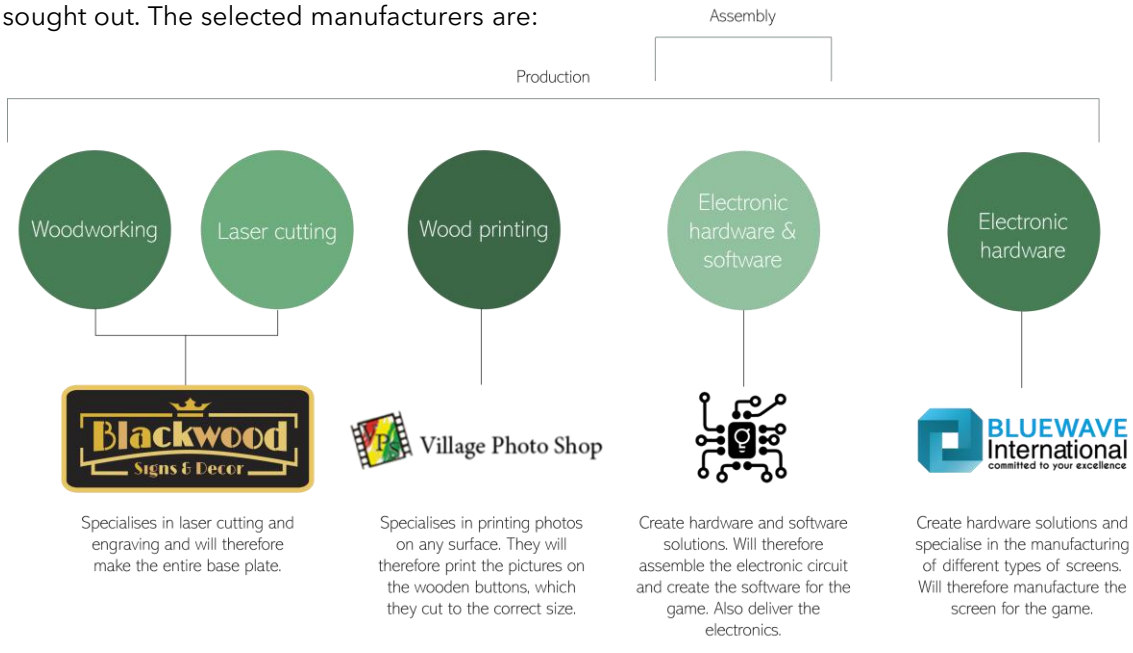


Figure 27. The 4 manufacturers of the product and the production techniques they execute

Figure 27 shows the manufacturers and the production techniques they will use for their part of the game. To create the base plate, for example, Blackwood Signs & Decor needs to cut the wood to size and cut shapes out of the wood, and they also need to laser engrave the text onto the wood. Therefore both production techniques are named in the Figure.

Validation of manufacturers

Method

To know if it possible to manufacture the concept design with the assigned production techniques and materials, it was necessary to talk to manufacturers from Kenya that are specialised in these production techniques. For this, research has been done on manufacturers that practice these production techniques and how sustainably they execute the techniques (see chapter 4). The most fitting and sustainable manufacturers have been selected to work with during this project. The manufacturers were interviewed via online meetings. Production of the product element, estimated cost price, lead times and how the manufacturer takes sustainability into account during their production process were discussed in detail.

Research question

Are the selected manufacturers able to produce their respective part of the product and can they do this in a sustainable way?

Participants

The following companies have been selected to work with:

- Blackwood Signs & Decor
- Village Photo Shop
- Geviton
- Bluewave

One person of each company was interviewed. The participants were recruited via email.

Apparatus

The equipment needed for the test:

- Laptop with questions
- Phone

Procedure

1. The participants were first informed about the cause and goal of the interview via email.
2. The participants were then later called and the concept design was explained to the participants.
3. Finally the interview started where the following format was used:
    a) Is it possible to use this material (combination)?
    b) Is it possible to use this technique? Are you able to manufacture it this way?
    c) How much will it cost to manufacture this?
    d) How long will it take to manufacture this?
    e) Do you consider sustainability? How do you incorporate this in your work?

The questions were tweaked according to each company and served more as a guide during the interviews.

Data collection

The data was collected, written down and processed in Word on a private laptop to which only the researcher has access. The participants were made anonymous and are only linked to the company they work for.

Results

Below shows a summary of the interview results per manufacturer. The complete interview results can be found in Appendix C.
NOTE: all prices provided by manufacturers are in Kenyan Shilling (KES) or United States Dollars (USD) and converted to Euro (EUR) based on the average 2021 Rate of Exchange KES to EUR and USD to EUR (Exchange Rates, n.d.).

Blackwood Signs & Decor:
Patrick, spokesman for the company, suggested the following regarding the base plate:

- Make the base plate out of FSC certified African mahogany, as this is a native wood type and can therefore be sourced locally.
- Make the base plate at least 2.2 centimetres thick to prevent warping. Also add a wooden frame to the back of the plate to make it more steady and to be able to hang the game to the wall.
- Manufacture the base plate in 4 quarter pieces as the size is too large to make it out of one piece of wood and will result in much higher costs.
- Use CNC machining to write the lettering on the base plate, as the lettering is too large for laser engraving.
- After cutting and engraving the base plate can best be sand stained and fully cured so it is water and scratchproof.

Patrick also provided the following about manufacturing the piece, the cost and how the company deals with sustainability in their practice:

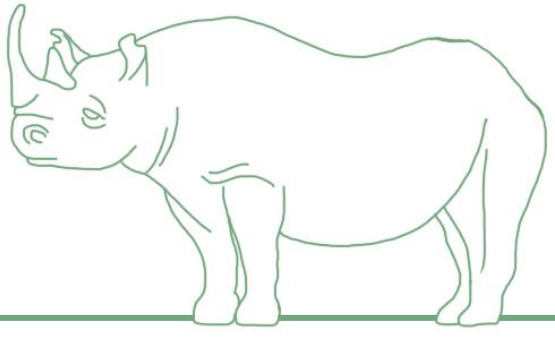
- The wood will be retrieved from a local wood source called Chirag Builders and is FSC certified.
- The total manufacturing time of the part will be about 2 days. This does not include the delivery time of the material from the supplier to the manufacturer or the delivery time of the part from the manufacturer to the client.
- The total cost price for the African mahogany, machining, CNC engraving and transportation will be KES 31,960 which is equal to € 246.
- Wood is very scarce so as little waste as possible is created during production.

Village Photo Shop:
The following suggestion was made to the buttons by the spokesman for the company:

- Print the pictures on MDF wood, because MDF has a smooth surface and the woodgrain will not show through the pictures.

The spokesman said the following about manufacturing the piece, the cost and how the company deals with sustainability in their practice:

- The wood will be retrieved from a local wood source and then cut to the desired size.
- The total manufacturing time will be between 2 and 3 days. This does not include the delivery time of the material from the supplier to the manufacturer or the delivery time of the part from the manufacturer to the client.
- The total cost will be about KES 30,000 which is equal to € 231.
- As little waste as possible is created by trying to use less paper and other materials. The pricelist for instance is not printed on paper, but always emailed to the client. All wood is sourced locally to support local entrepreneurs.



Geviton:
Felix, spokesman for the company, suggested the following regarding the electronics:

- The buttons can best be regular push buttons instead of electronic buttons that can stay pressed in, as this will be more cost efficient and is more suitable for rough handling.
- The LED strip can best be on the inside of the button instead of around the outside edge, as this will reduce the chance of damaging the LED's. The LED's will indicate status of button press and results. If the LED is yellow, it indicates the button is pressed and if the LED is green or red it shows a correct or incorrect answer (match).

Felix also provided the following about manufacturing the piece, the cost and how the company deals with sustainability in their practice:

- The electronics are sourced from a local manufacturer called Gearbox Europlacer.
- The code is written in-house.
- Geviton can assemble all the different parts, hence the base plate, buttons and screen have to be transported to them.
- The total manufacturing time will be about 20 hours. This does not include the delivery time of the material from the supplier to the manufacturer or the delivery time of the part from the manufacturer to the client.
- Costs are KES 8,810 for the components and KES 58,340 for assembling and writing the code. This totals a cost price of KES 67,150 which is equal to € 518.
- Additive manufacturing such as 3D printing is used to make sure minimum waste is created, recycled parts are used and all custom designs implement low power features that put systems to sleep whenever idle/not in use.

Bluewave:
Simon, spokesman for the company, suggested the following regarding the screen:

- An LCD screen with a 1920 by 1280 pixel pitch would best fit this project.

Simon also provided the following about manufacturing the piece and the cost:

- They source the components for the screen from various countries but assemble it in Kenya under the brand name Blue Wave International.
- The total manufacturing time will be 3 days.
- The total cost will be $ 638 (US Dollar) which is equal to € 540.

Simon did not answer the question about sustainability practices in their company, hence this should be further researched or scout for a different company that clearly reports their sustainable efforts.

Discussion
Bluewave was the one company that did not provide answers to questions about their sustainable efforts during production, even after multiple requests for their feedback. Therefore it is suggested to look for alternative companies during the further development of the product. The other companies provided information about their efforts to produce sustainably, however it is not tested if they actually apply these sustainable processes and to what extent. Due to limited time for this project, these are taken as truthful. Both Blackwood Signs & Decor and Village Photo Shop mention they minimize material waste and source their material locally, which is one step towards sustainability, however they could also use recycled wood or minimize their energy usage which would add extra steps in the right direction. It is up to the Green Kids' Museum to decide if they find the sustainability efforts of Blackwood Signs & Decor and Village Photo Shop sufficient or if they want to find companies with a more developed sustainability process for the creation of their installations. Geviton does a little more when it comes to sustainability, as they reduce material waste, use recycled parts and use less energy, which is assumed to be sufficient enough effort for the Green Kids' Museum to work with.

Conclusion

The goal of this research was to find out if "the selected manufacturers are able to produce their respective part of the product and if they can do this in a sustainable way". The results of the research have shown that the four manufacturers can manufacture the envisioned parts of the product, but that some alterations are required to make them more sustainable as well as cost- and time-effective. Most companies take sustainability in some degree into account during manufacturing. It is up to the Green Kids' Museum if their efforts are sufficient enough, however they will be used for this graduation project proposal. Bluewave still needs to be checked when it comes to sustainability efforts within their production process.

Target group

To verify if the target group, consisting of 9 to 11 year old Kenyan children, enjoys both the product and the associated learning, it was necessary to test the game in a live setup. However, since the target group is located in a different country to where the research takes place, a bespoke test needed to be created which the target group could take remotely. For the remote test, an online version of the product was created. In this way the test could be performed without the need for participants to be physically present at the test. However, an online version of the product does not cover all aspects of the product. Therefore a physical prototype of the product also needed to be tested in a live set-up. This was done with a group of 9 to 11 year old children (from the International School Delft) that were able to be physically present at the test. Product validation therefore consisted of 2 parts.

The results of both tests were compared to get a complete picture. From this a final conclusion was drawn.

Validation of target group – Online test

Method

To see if the concept design fits the target group and if they reach the goal of recognizing the different ecosystems in Kenya, and online prototype of the product was made in Figma. Children were asked to play the game and answer questions about the game and what they have learned afterwards.

Research question

Do 9-11 year old Kenyan children enjoy the game and reach the learning goal with a digital prototype of the Match the Ecosystem game?

Participants

This study was conducted with 5 participants. Inclusion criteria were: (a) between 9 and 11 years old, (b) born and raised in Kenya, (c) have at least 1 Kenyan parent, (d) go to school in Kenya, (e) have access to a laptop/computer, (f) speak English or Dutch. The participants were recruited via the Dutch School in Kenya.

Apparatus

- Online prototype of the concept design
- Laptop with Zoom/Skype/Teams and internet connection
- Question sheet

Setup

The setup for the participants was a laptop with the Zoom meeting and the game on it. The setup for the researcher was a laptop with the Zoom meeting and the questions on it. Figure 28, 29 and 30 show the setup of the game.

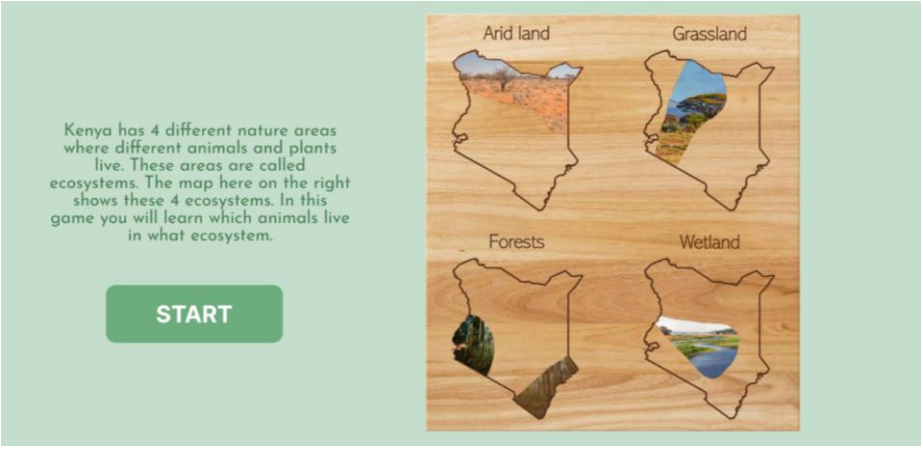


Figure 28. Home screen of the game

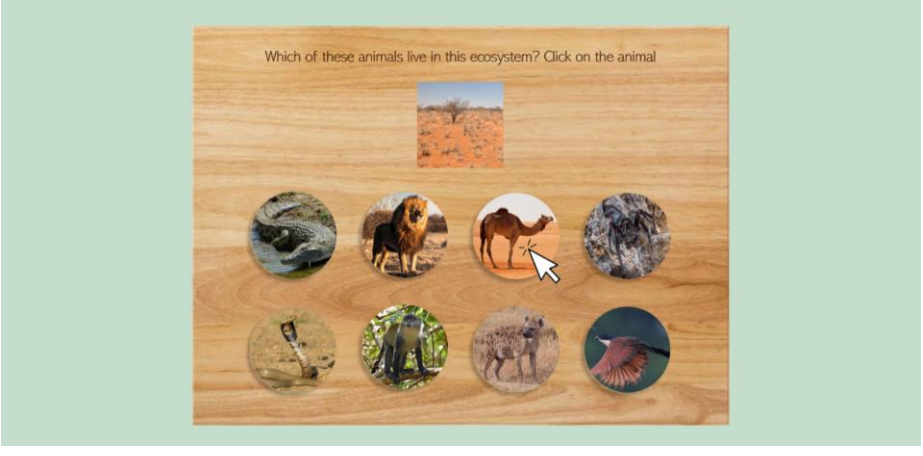


Figure 29. Gif that explains you have to click on the animal

Figure 30. Final screen of the game that shows you have finished the game

The online prototype can be found here.

Procedure

1. The parents would first receive an informed consent form and were asked to sign for approval. After the form is signed, the user test could start.
2. At the start of the test the participant was verbally asked for consent. When the participant gave consent, the recording of the interview started.
3. The participant was informed about the reason and goal of the interview.
4. The participant was asked to open the game, share their screen and play the game. During this the researcher observed the participant and their behaviour. These observations were written down. When they were done with the game they could stop sharing their screen.
5. After the game, the participant was asked the following questions:
    a) Which 4 ecosystems did you see in the game?
    b) What animal belongs to what ecosystem?
    c) Do you feel like you learned something new with this game? Why (not)?
    d) What did you like about the game?
    e) What do you think could be improved about the game?
    f) Did you find the game easy or difficult? What made it easy/difficult?
    g) Would you play the game again? Why (not)?
    h) If you see this game in a museum, physically, would you play it? Why (not)?

The questions served as a guide for the interview and was tweaked along the way.

Data collection

The data was collected, written down and processed in Word on a private laptop to which only the researcher has access. The participants were made completely anonymous. The recorded interview is only viewed by the researcher and will be deleted after 6 months.

Results

Below shows a summary of the results. The complete interviews can be found in Appendix D. The results of the online test showed that all 5 participants learned something from the game. Where some participants would first make some mistakes such as matching the blue-headed coucal with the forest ecosystem, they would match all animals correctly when asked to play the game for a second time. 4 out of 5 participants said they liked learning something with this game and that they would play it in a museum because of it.

The test showed that the online version of the game was not representative enough for the real physical game. Namely, 3 out of 5 participants did not understand how many animals they had to click for each ecosystem. This was because you only saw one ecosystem at a time which is not the case in the real game. You were not able to click any animal and match it with any ecosystem. Therefore nothing can be said about how well they understood the game. The same goes for the average time it took children to complete the game. As the online version works differently than the real version the results of the physical test are more representative when it comes to playing time.

Something can however be said about what the participants think could be improved about the game. Namely all 5 participants mentioned that adding more animals to the game would improve it as it would increase the time to complete the game and it would be more fun. Some mentioned that you could add some more difficult animals to increase the game's complexity.

Another interesting observation was that 3 out of 5 participants did not read the text next to the game when they got a match correct. They immediately wanted to match another animal to their ecosystem. These same participants also did not look at the map at the start of the game where they could see which ecosystem was called what. Therefore when asking the participants what each ecosystem is called most said they did not know. However, the participants that did look at the map at the start of the game knew exactly what the ecosystems where called when asked about this during the interview. This shows that adding a map next to the game can be beneficial in the learning process to make them more familiar with the different ecosystems in Kenya, but only when they actually look at it. Users therefore have to be stimulated to actually look at the map before playing the game.

Two participants worked together whilst playing the game. They discussed every decision they made and would each alternately answer a question. This shows that the game can also be played together. An 8 year old Kenyan child also participated in the test. This participant understood the purpose of the game and did not need any additional explanation. He made the same mistake as other participants by matching the blue-headed coucal to the forest ecosystem. However, because only one participant outside the age range took part in the test, no definite conclusions can be drawn from the results of this participant. It is recommended to test with more participants outside the age range to see if they also understand and enjoy the game.

Figure 31. Zoom session with one of the participants. The participant is made anonymous.

Discussion

The online test showed that the digital prototype is not representative enough for the physical game when it comes to the operation. Therefore no conclusions could be made about how understandable the game is. Data gathered on this aspect was therefore labelled as invalid.

Having to test the digital prototype with participants of which 1 of their parents is Dutch and the other is Kenyan caused no problems. The participants all spoke Dutch, which made communication easier. The participants responded similarly to Dutch children, however it is unclear if this is due to having 1 Dutch parent or if fully Kenyan children would also respond similarly to Dutch children. It is suggested to test the product with fully Kenyan children during further development.

Conclusion

The goal of the research was to find out if "9-11 year old Kenyan children enjoy and reach the learning goal with a digital prototype of the Match the Ecosystem game". The results of the research have shown that children recognize the different ecosystems in Kenya and what kinds of animals live in them after playing the game. Therefore the learning goal of the game is reached after playing it. Children also enjoy the game and specifically enjoy the learning element of the game. What would improve the game and make it more fun, according to the target group, is adding more (difficult) animals to increase the game's complexity.

Validation of target group – Physical test

Method

To see if the concept design fits the target group a physical prototype was created that was tested live with children between 9 and 11 years old that could be physically present at the test. Children were asked to play the game and answer questions about the game and what they have learned afterwards.

Participants

This study was conducted with 6 participants. Inclusion criteria were: (a) between 9 and 11 years old, (b) can be physically present at the user test, (c) can speak Dutch or English. The participants were recruited via the International School Delft.

Research question

Do 9-11 year old children enjoy and reach the learning goal with a physical prototype of the Match the Ecosystem game?

Apparatus

- Physical prototype of the concept design
- Camera for pictures and recordings
- Question sheet

Setup

For the set-up of the physical test a laptop was used which had the sounds for each correct match. The laptop was placed on a table near the researcher. A phone which recorded the test was placed in the corner of the room. The game was placed against the wall on the correct height. 8 foil papers with tape on the back were placed on the table where the participant could easily reach them. See figure 32 and 33.

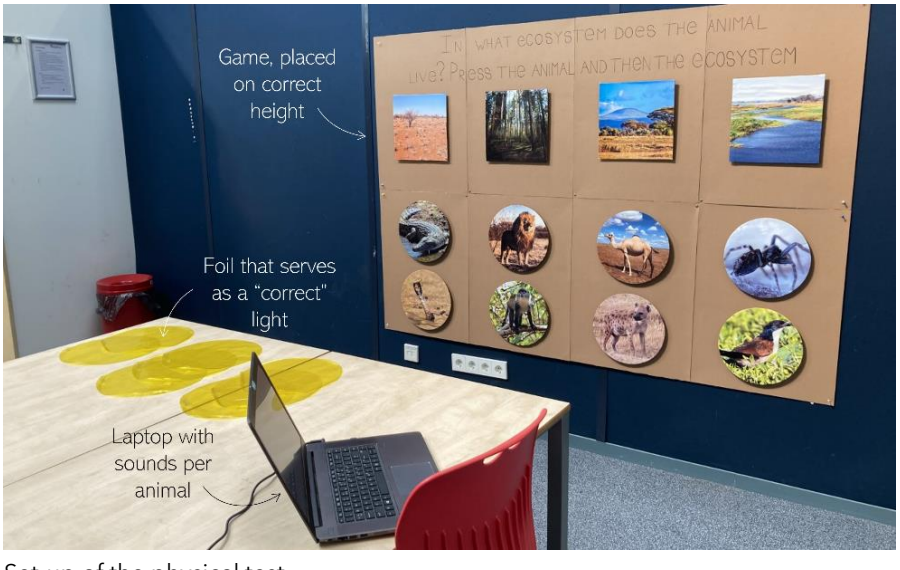


Figure 32. Set-up of the physical test

Figure 33. Set-up of the physical test

Procedure

1. The parents would first receive an informed consent form and were asked to sign for approval. After the form was signed, the user test started.
2. At the start of the test the participant was verbally asked for consent. If the participant gave consent, the recording of the interview could start.
3. The participant was informed about the reason and goal of the interview. They were then asked about what they already know about the different ecosystems in Kenya and the animals that live in it.
4. The participant was then asked to play the game. To play the game they had to press an animal and then the ecosystem they live in. When the participant got a correct match, they were asked to place a foil paper over the correct animal. Simultaneously the researcher would play the corresponding sound from the laptop that goes with the correct match. During this the researcher observed the participant and his/her behaviour.
5. After the game, the participant was asked the following questions:
    a) Which 4 ecosystems did you see in the game?
    b) What animal belongs to what ecosystem?
    c) Do you feel like you learned something new with this game? Why (not)?
    d) What did you like about the game?
    e) What do you think could be improved about the game?
    f) Did you find the game easy or difficult? What made it easy/difficult?
    g) Would you play the game again? Why (not)?
    h) If you see this game in a museum, physically, would you play it? Why (not)?

The questions served as a guide for the interview and were tweaked along the way.

Data collection

The data was collected, written down and processed in Word on a private laptop to which only the researcher has access. The participants were made completely anonymous. The recorded interviews are only viewed by the researcher and the photos and videos are anonymized and deleted after 6 months.

Results

Below shows a summary of the results. The complete interviews can be found in Appendix E. Figure 34 shows some of the participants playing the game. The results of the physical test showed that all 6 participants learned something from the game. They would all first make mistakes such as mismatching the bird, lion or spider. When asked to match all animals a second time they would almost all match them correctly. They all said they learned something new from this game, such as one participant that said he/she did not know some spiders lived in the forest. 3 out of 6 participants said what they liked most about the game is learning something new.

When the children stepped into the test room they immediately looked at the game. Most children directly started playing it without looking at the text above the game. The others would wait for instructions. They were asked to read the text above the game first and were then asked if they understood it. All participants immediately understood the game and knew what they had to do. Therefore the game is intuitive enough for children to understand how to play it. The test has also shown that the text above the game is clear and does not need more explanation. On average the children took 5 minutes to finish the game, with the shortest time being 4 minutes and the longest time being 8 minutes.

5 out of 6 participants pressed the pictures as if they were real buttons. This shows that the buttons are sufficiently intuitive for children to understand they are actual buttons. One participant pointed out that the details in the background of some animals matched the wrong ecosystem and that this could be deceiving. Such as the background of the lion that had a tree in it that looked similar to the tree in the arid land. 2 out of 6 participants matched all animals correctly to their ecosystem. Both participants said they still learned something from the game via the fun facts of the animals.

Most participants pointed out putting the sound in the back of the game and putting lights behind the animals. 4 out of 6 participants said the buttons should be real and 2 out of 6 participants suggested adding more animals to extend the game.

In the test results there was no clear difference between the boys and girls and how they played the game or answered the questions. Therefore no conclusions are drawn comparing the different genders.

Figure 34. Children playing the physical game

Discussion

When asked about what improvements could be made to the game, most participants suggested to improve the interactivity of the game, by making the buttons actual working buttons, etc. Due to the non-interactive prototype used in the test other improvements might be overlooked. Therefore it is suggested to test the actual finished and working product with the target group to see if there are more improvements to be made to the game. It is also suggested to test with a larger sample size to improve the accuracy of the results.

Conclusion

The goal of the research was to find out if "9-11 year old children enjoy and reach the learning goal with a physical prototype of the Match the Ecosystem game". The results have shown that the game is intuitive and children do not need much instructions to start playing the game. The results also show that children recognize the different ecosystems in Kenya and what kinds of animals live in them after playing the game. Therefore the learning goal of the game is reached after playing it. Children also enjoy the game and specifically enjoy the learning element of the game. Finally, the results show that adding more (difficult) animals to the game to increase the game's complexity and making the game actually interactive would improve the game and make it more fun.

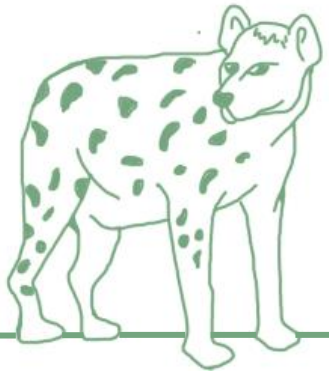
Overall conclusion

The tests showed that Kenyan children and non-Kenyan children respond similarly when playing the game and answering questions. Therefore the test results can be combined to create a final conclusion.

Both tests showed that children learn something when playing the game. All children reached the goal of learning about the different ecosystems in Kenya and what exemplary animals live in it. The children also overall enjoyed the learning element of the game and would play it if they saw the game in a museum. The physical game was intuitive for the non-Kenyan children and because it is concluded that non-Kenyan and Kenyan children respond similarly regarding the game, it is assumed that Kenyan children will also understand the game and play it without the need for instructions.

What overall needs to be improved about the game:

- Add more animals to the game and choose more unknown ones to increase the complexity level
- Give the LED's around the animal a red colour when they get a match incorrect and change this to a different colour once they get it correct
- Make sure the details in the background of the animals match with their ecosystem
- Add the map of the locations of the different ecosystems and their names next to the game



Chapter 8: Final design

The results from the user tests showed that the game needs some improvements to better fit the target group and improve the manufacturability. These improvements are:

1. *Change the material and dimensions of the game to something more available and sustainable.*
2. *Change the placement of the LED's to reduce the chance of damage*
3. *Replace the button with regular push buttons*
4. *Convey button press with LED's and increase LED visibility in the game*
5. *Increase the game's complexity by adding more (unknown) animals*

This chapter describes in detail how the improvements have been implemented and shows the final design. This chapter also covers the most suitable suspension system for the game, the exact operation of the button and the most suitable electronics.

The improved game now looks and works as follows:

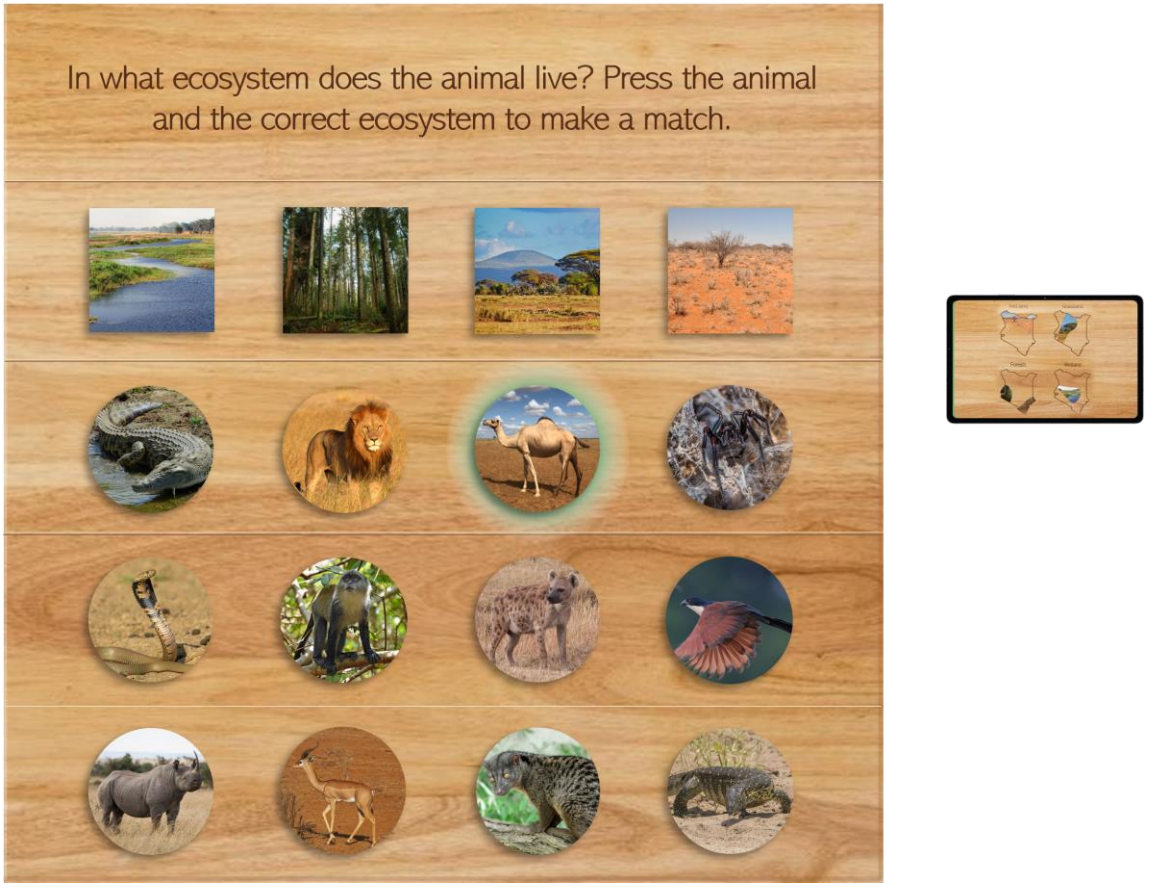


Figure 35. Final game

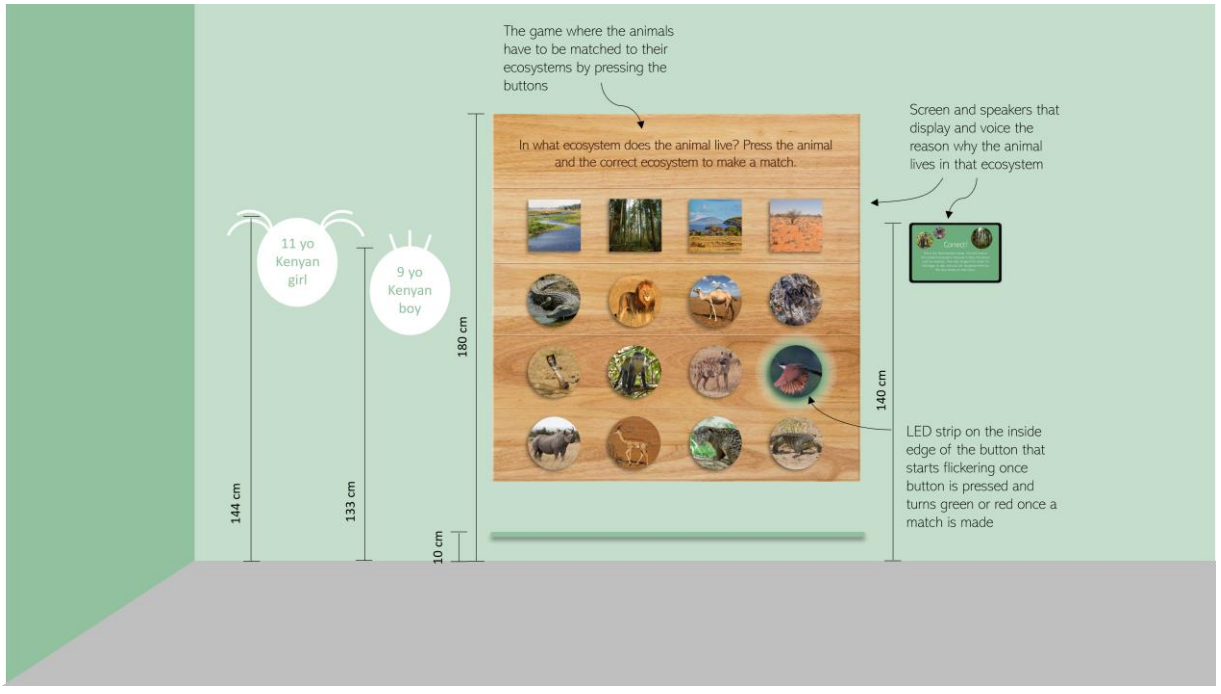


Figure 36. The game displayed in a museum

In this final iteration the user still has to press buttons to make a match, however the buttons are replaced by regular push buttons. The LED light in the button will indicate button press. Once an animal is pressed the LED light in the button will start to flicker in a white colour. Then an ecosystem is pressed. The LED of that ecosystem will start to flicker in a white colour for 2 seconds. If the match is correct the LED of the animal will turn green, the LED of the ecosystem will turn off and the speaker behind the board will voice the reason the animal lives in that ecosystem. This fact will also appear on the screen next to the game. If the match is incorrect the LED of the animal will turn red and the speaker will tell you to try again. At the start of the game the screen will display a map of the different ecosystems in Kenya and their locations (see Figure 37). In this way the user will get familiar with the locations and names of the ecosystems. The name of the game has also changed from Match the Ecosystem to The Great Kenya Eco Challenge.

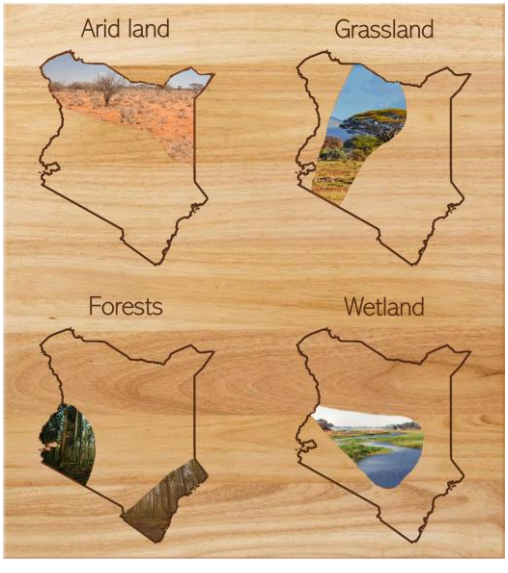


Figure 37. Map of the 4 ecosystems in Kenya and their locations

The Green Kids' Museum has the intention to increase participation and knowledge transfer of visiting schoolchildren by means of a quiz. A set of questions, aligned to the different themes in the various rooms, is to be answered at the end of each room. This will achieve three objectives: 1) it will increase the educational relevance of the installations, 2) the ability to check if children gained knowledge through the museum's installations, 3) it adds an element of fun and competition. Questions for The Great Kenya Eco challenge could be:

1. What are the four ecosystems in Kenya and what characterizes them?
2. How is the camel able to live in the arid land when there are few water sources?
3. What quality does the hyena have so that they can survive in the grassland?
4. Why is the forest ecosystem important for human survival?
5. True or false: the wetland ecosystem can expand by 2% in the rainy season.
6. Which animals presented in The Great Kenya Eco Challenge are at the top of the food chain?

User scenario

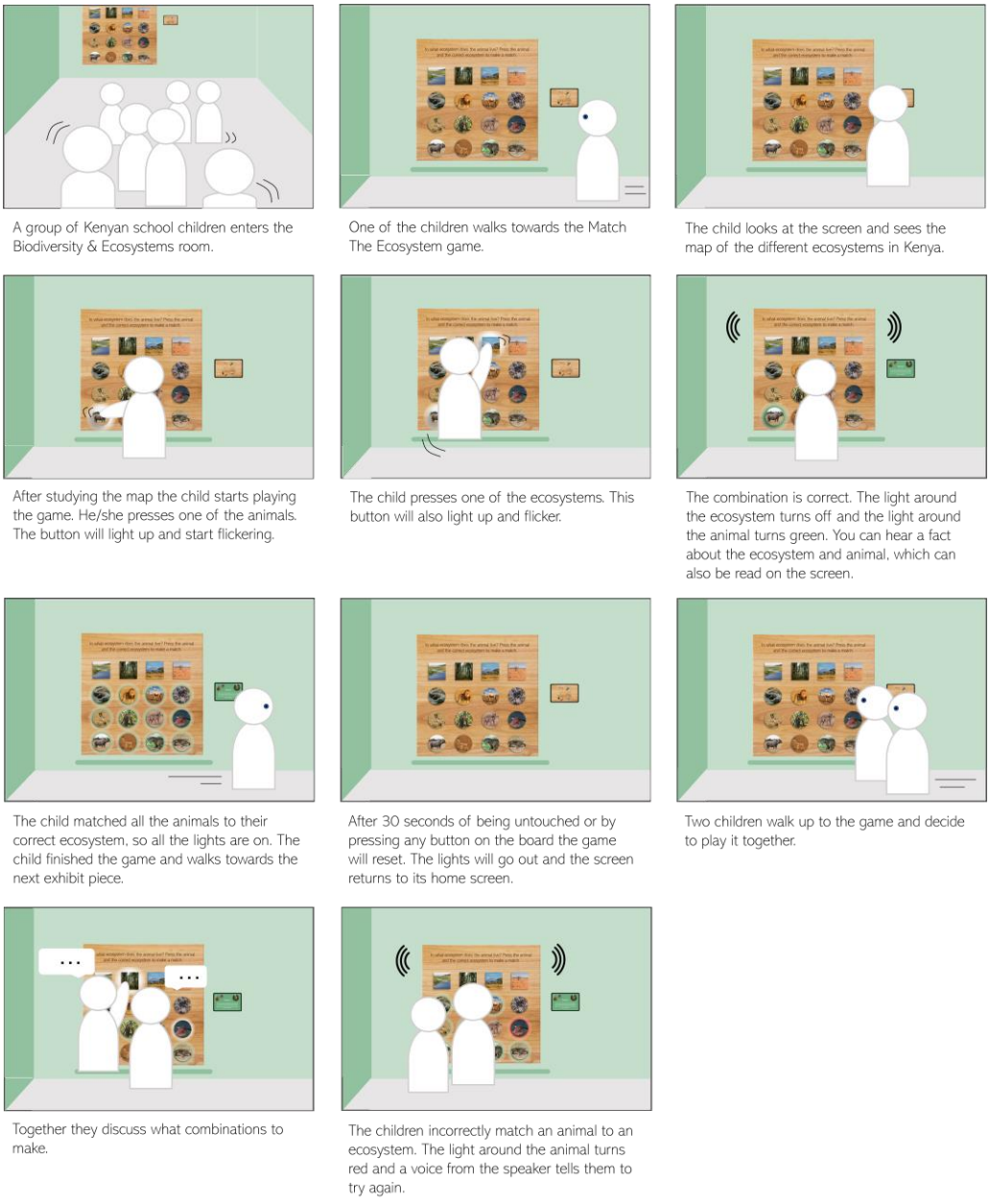


Figure 38. User scenario

Sounds

Once a child matches an animal correctly to their ecosystem, a fun fact about the animal and the ecosystem they live in can be heard from the speakers behind the game. These sounds should help children better understand what a certain ecosystem is and what makes it different from other ecosystems. This will help children recognize the different ecosystems in Kenya, which is the learning goal of the game. This also creates an extra layer in the game, which is assumed to make the game a better fit for 9 to 11 year old Kenyan children. The sounds per correct animal are:

Wetland:

Blue-headed Coucal

Correct! This is the Blue-headed Coucal. This bird lives in the wetland ecosystem, because it enjoys still or moving water such as swamps. Kenya has 6 different types of wetlands, ranging from river wetlands and lake wetlands, to human-made wetlands. All are the home to different animal and plant species. (The Guardian, 2011) (Abiri, n.d.)

Nile Crocodile

Correct! This is the Nile Crocodile. This animal needs an environment that is tropical, has water and has safe places for them to lay eggs, which the wetlands are perfect for. This ecosystem is known for its lakes and rivers and is the home to many water and land animals. (Allison, 2000)

Nile Monitor

Correct! This is the Nile Monitor. This animal lives in the wetland where they are near or in the water. The Nile Monitor spends most of their time looking for food or sunbathing on the shoreline, logs or rocks. 4% of Kenya's land consists of wetland. This can however increase to 6% during the rainy season. Therefore this ecosystem is inhabited with animals that like water, such as the Nile Monitor. (Animalia [b], n.d.)

Forest:

African Palm Civet

Correct! This is the African Palm Civet. This animal lives in the rainforest where there are many places for them to find shelter such as crevices, holes, tangled vines and trees. It is mostly the animals that can climb and are good in hiding that survive in this ecosystem. The forests in Kenya are very dense with many plants and trees covering the ground, however this changes with the conversion of forests to croplands and grasslands or things like illegal logging. (Kotelnicki, n.d.) (Rotich, 2021)

Black House Spider

Correct! This is the Black House Spider. This spider lives in the forest where they build their webs in tree-trunks or a burrow in the ground. The forest ecosystem is the most diverse ecosystem, from dry forest to coastal forests and mangroves. Forests provide many ecosystem services such as fuelwood for energy supply and timber for products, and are therefore very important for human survival. (Rodríguez-Veiga, 2020)

Sykes Monkey

Correct! This is the Sykes Monkey. They live in the forest where the trees shield them from the sun and predators. Deforestation and soil erosion force animals such as the Sykes Monkey to move from their natural habitat to shelter somewhere else. However, when more forest is cut the possibility of finding new habitat gets smaller and smaller. (Munyua, 2020)

Grassland:

Black Rhinoceros

Correct! This is the Black Rhinoceros. This animal likes to live in places with a healthy supply of scrubs and trees and likes to live near a place that has a water source and mineral licks, which the grassland ecosystem is very fit for. The animals that live in the grassland have to face many challenges. They have to cope with quick temperature changes, rain and predators everywhere. These animals, including the Black Rhinoceros, have adapted to survive such extremes. (Save the rhino, n.d.)

Hyena

Correct! This is the Hyena. This animal lives in the grassland because they are fast which allows them to survive in the open tropical grassland. In this way they can easily chase their pray. For grassland animals, speed is the key to survival. (World Biomes Task, n.d.)

Lion

Correct! This is the Lion. This animal needs tall grass and bushes for their hunting, which the grassland is perfect for, as this ecosystem mainly consists of grass, small trees and scrubs. The grasslands are very important for livestock production and wildlife, which are in their place important for tourism. (Real Onomics, 2022) (Mwangi, 2015)

Arid land:

Dromedary Camel

Correct! This is the Dromedary Camel. This animal lives in the arid land. It does not rain much in this ecosystem and the temperatures can go to extremes making the land very dry. Therefore it is the home to animals that do not need much water and can stand heat, such as the Dromedary Camel that can go several months without drinking water and can cool its own brain. (Elkhawad, 1992)

Gerenuk

Correct! This is the Gerenuk, the arid land specialist. The arid land ecosystem is extremely dry, however this is not a problem for the Gerenuk, as they obtain most of their water from the leaves of plants, flowers and fruits. The population of Gerenuks can actually increase when they are away from permanent water, as the chance of an attack from a predator then decreases. (Expert Africa, n.d.)

Red Spitting Cobra

Correct! This is the Red Spitting Cobra. Cobras need hot temperatures to remain body heat and can therefore perfectly survive in the arid land where temperatures can go up to 65 degrees Celsius. The arid land is located in Northern Kenya where few water sources are located, however Red Spitting Cobras still try to find water holes to lay near. (Animalia [a], n.d.) (Mawari, 2011)

When a wrong match between an animal and ecosystem is made one will hear the following sound:
This is incorrect, but please try again.

Technical specifications and operational process flow

To better understand how the game works, it is important to understand the technical aspects of the game. This chapter will explain the flow of the game, the operation of the buttons and LED's, the operation and placement of the different electronics, and the suspension system.

Flowchart

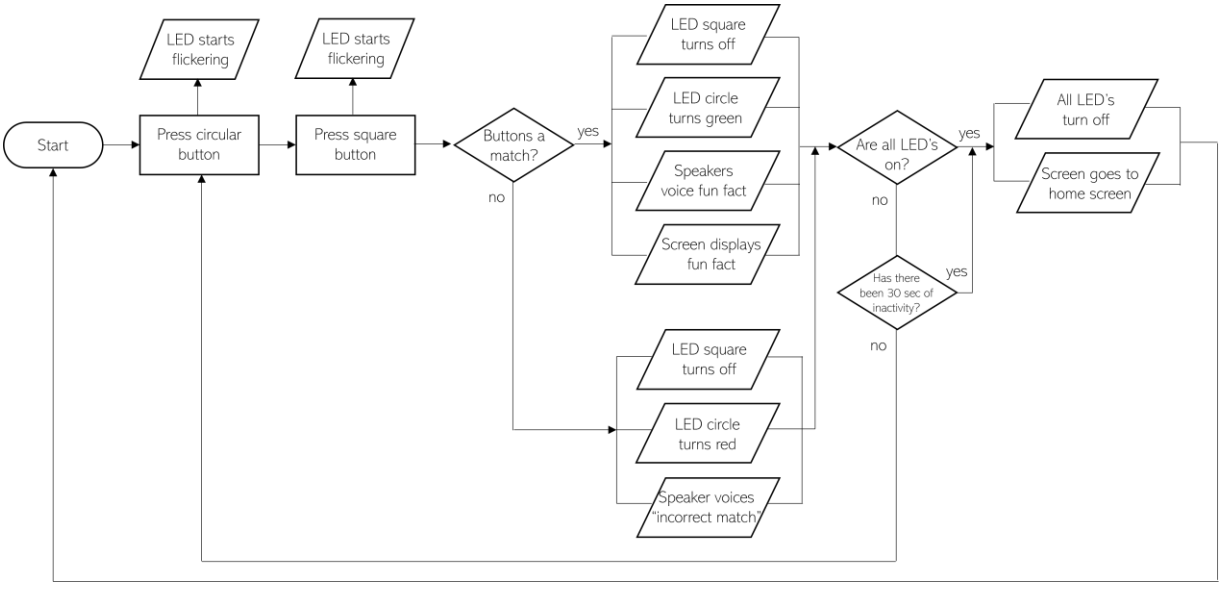


Figure 39. Flow chart of the game

Operation of the button

To understand what the button has to exactly look like it is important to create criteria for the button to be able to choose a design that best fits the purpose of the game.

Design criteria:

1. The button should be able to move freely and smoothly when pressing anywhere on the button cap
2. The button should be able to withstand the force of an 11 year old pushing down on the button with maximum force
3. The button cap should always stay in its original horizontal and rotational position
4. The button should be accessible for repair and replacement
5. The button should be easily repairable with standard components
6. The button should be able to be safely pressed down
7. The picture on the button cap should keep its original quality throughout the use of the product

Operation of a regular push button:

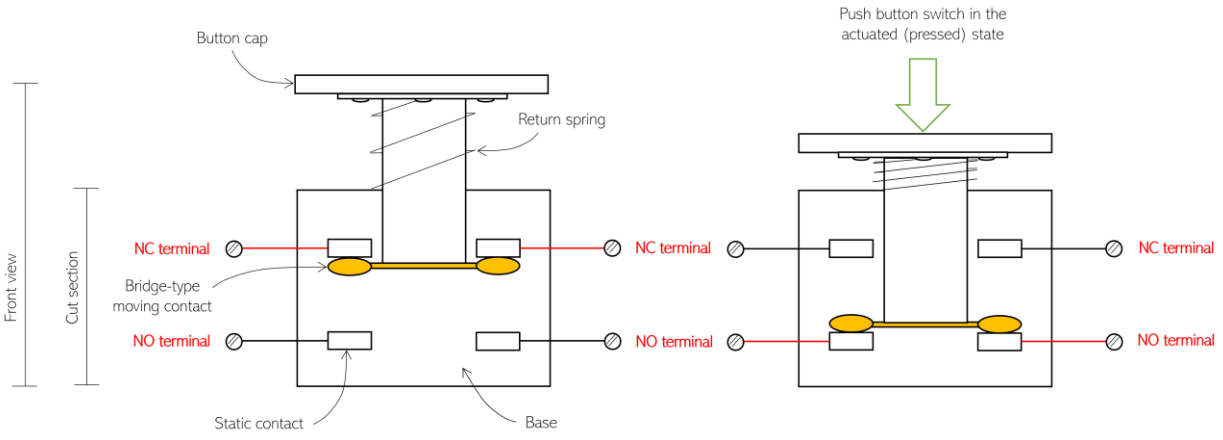


Figure 40. Push button system. Unpressed (left) and pressed (right)

Push button switches are actuated via a button that is pressed and released. The above pictured push button has an internal spring mechanism returning the button to its "unpressed" position. When the button cap is pressed the bridge-type moving contact is pushed down as well. The NC (normally closed) contact opens and the NO (normally open) contact closes. This enables the current to run through the NO contact resulting in different information flowing to the Arduino. When the button cap is released, the spring returns the button cap to its unpressed (starting) position. The moving contact will now go back to the NC terminal, opening up the NO contact and closing the NC contact (Quisure, 2020).

Ideation push button

To find out what kind of button system best suits the game an ideation phase was started. The ideation was done for different parts of the button. All sorts of possibilities were drawn out for each part and the plusses and minuses were summarized. Below shows the ideation.

Custom vs standard:
The button could either be a standard part or a custom made button. A custom button could have measurements to exacly fit the base plate. This could look as follows:

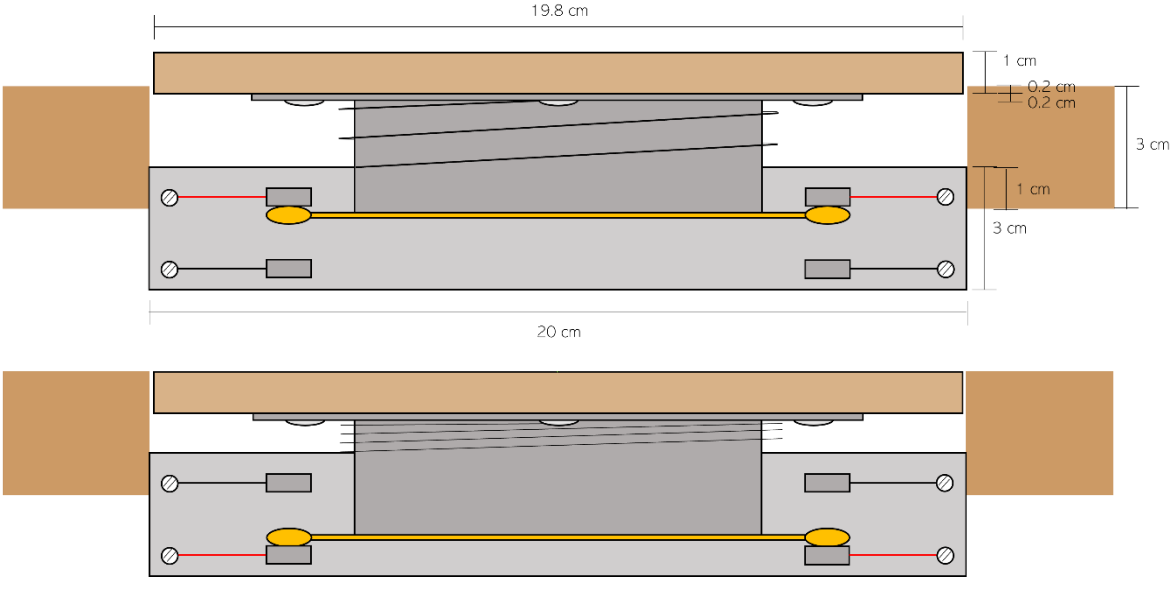


Figure 41. Custom made button

The base of the button could be the same length and width as the button cap to allow for an exact fit in the square or circular hole of the base plate.

Plus:
+ The button can be fully made according to the requirements, so the rod with the spring can be made wider, for instance, to catch more surface of the cap and therefore reducing the chance of vertical rotation resulting in jamming

Minus:
- There are barely any companies in the world that make custom buttons
- A custom button is difficult to repair and replace. It will also take longer to remake the button and have it installed
- A stop needs to be built in the button to reduce the chance of damaging the bridge

For a standard button a regular push button would be used, see Figure 42.

Figure 42. Standard push button (Bol.com [a], n.d.)

In this option a regular push button would be used as the button in the game and the button cap would be mounted on top of it. This could look as follows:

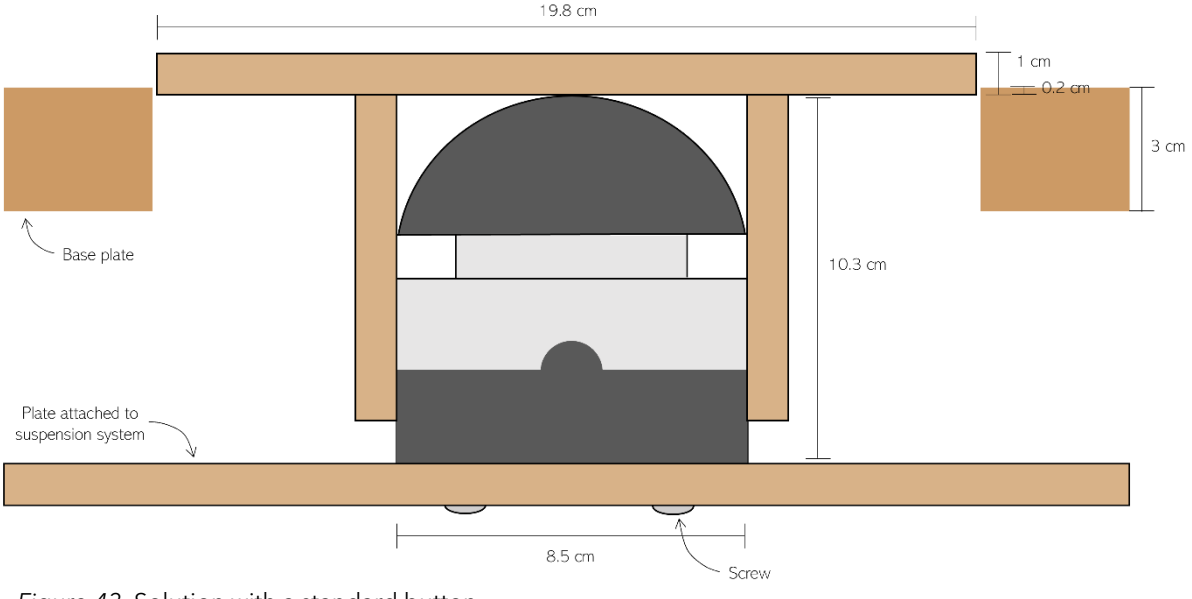


Figure 43. Solution with a standard button

In this design the button has to be attached to a plate which in turn is attached to the reinforcement as the base of the button cannot clamp in the base plate anymore.

The Nemo museum has a reaction game in one of their themed rooms which contains around 20 buttons. The objective of the game is to hit the button that lights up as fast as possible to test the user's reaction speed. Users (children) will evidently hit the buttons hard and with high frequency.

To assess if a regular push button would easily break and would therefore require much maintenance, the Nemo museum was contacted given their extensive experience with push buttons. The Nemo museum stated that the reaction game does not break down easily, neither do the individual buttons and it does not require more maintenance than the other games in their museum. They also confirmed they use regular push buttons in their game. Therefore it can be concluded that regular push buttons will also be suitable for the game for the Green Kids' Museum. The complete correspondence with the Nemo museum can be found in Appendix F.

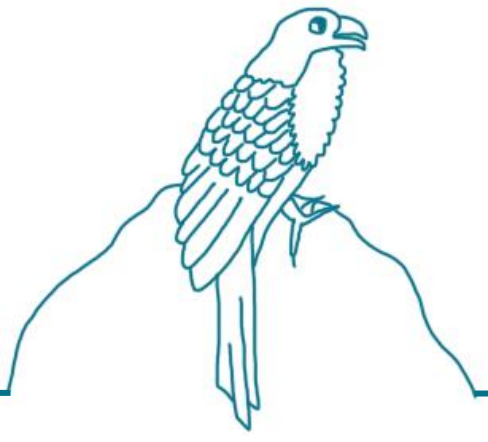
Plus:
+ Can be easily replaced and repaired, as it is a standard product used in all sorts of installations
+ Can be purchased all around the world, including in Kenya
+ Less production steps required as this is a purchased part
+ Already has a built-in stop

Minus:
- Because the base of the button is smaller, there is a larger chance of vertical rotation of the button cap, which causes jamming

From the plusses and minus it can be concluded that a standard part for the button would better suit the game. Repairability is a very important factor for the buttons as these are the parts of the game that can get damaged the easiest because of user interaction. In addition, the buttons are easily and quickly replaceable, which is not the case with a custom button. It is, however, important that the button cap has minimal vertical rotation to prevent jamming. This should be furter looked into in the next ideation.

Button cap attachment:
It is important that the button cap can be easily removed from the button for repair and replacement as well as that the button cap causes no jamming when pressing it down. The button cap can be attached in multiple ways, which is described below.

The dome cap is taken off the standard button and the new wooden button cap is screwed on top, as can be seen in Figure 44.



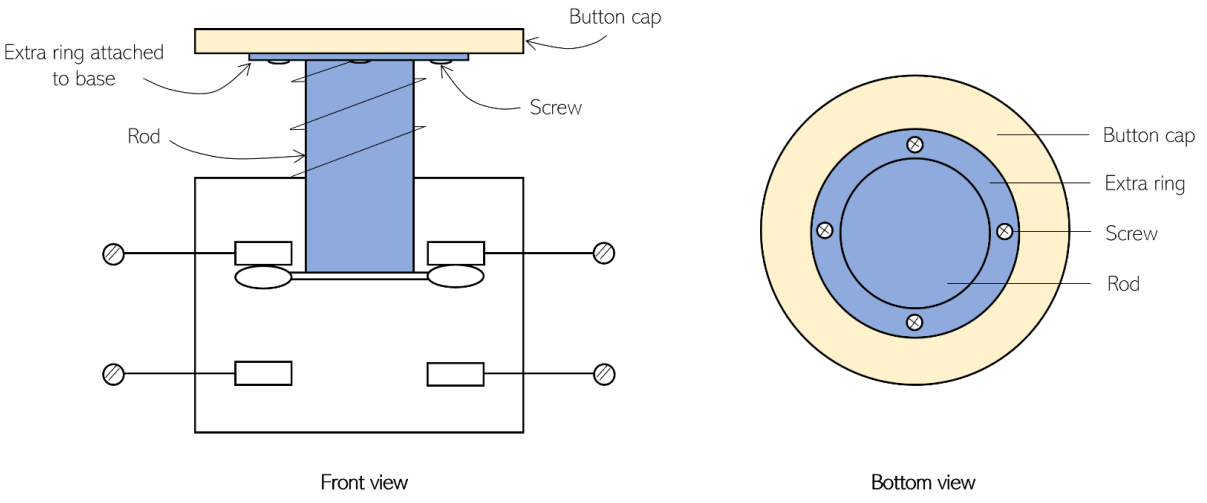


Figure 44. Attachment of button cap by screwing it on top of the rod

In this design the rod requires an extra ring around the top to allow for the cap to be attached on top of that ring. However, this ring does not exist in the standard push button, so it would have to be attached manually, which would significantly increase time and cost. The rod is also hollow so the screws cannot go through the top of the cap.

Plus:
+ Cap can still be taken off the rod for repair and replacement

Minus:
- Takes an extra production step
- Higher cost
- Low technical feasibility given access to the rod and angle of the screws
- The button cap is less stable on top of the rod, as it has less surface area to rest on

Another solution would be to glue the cap on the rod (see Figure 45), but this would mean the cap can never be separated from the rod, which is not practical for repair or recycling.

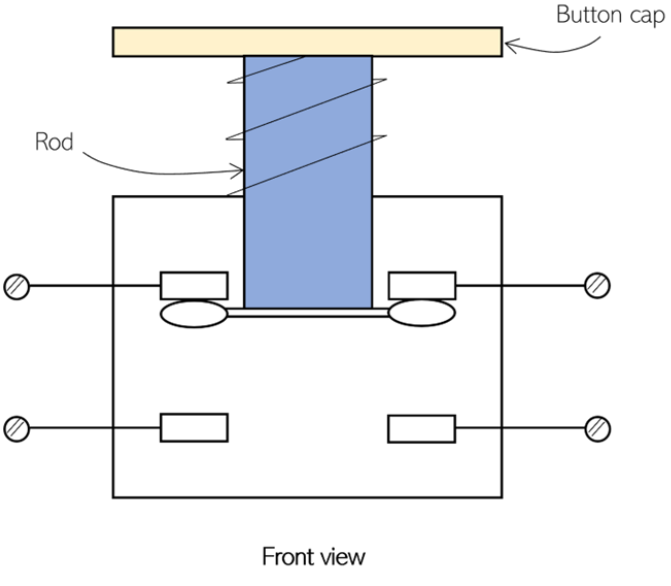


Figure 45. Button cap glued on top of the rod

Plus:
+ Quick installation
+ Easy to execute
+ Low cost

Minus:
- Cap cannot be taken off the rod, which means in case of damage, the whole button and button cap have to be replaced
- Glue is not a sustainable solution, as the parts cannot be separated for recycling
- The button cap is less stable on top of the rod, as it has less surface area to rest on

Another solution would be to leave the dome on top of the standard button and to build the button cap around it:

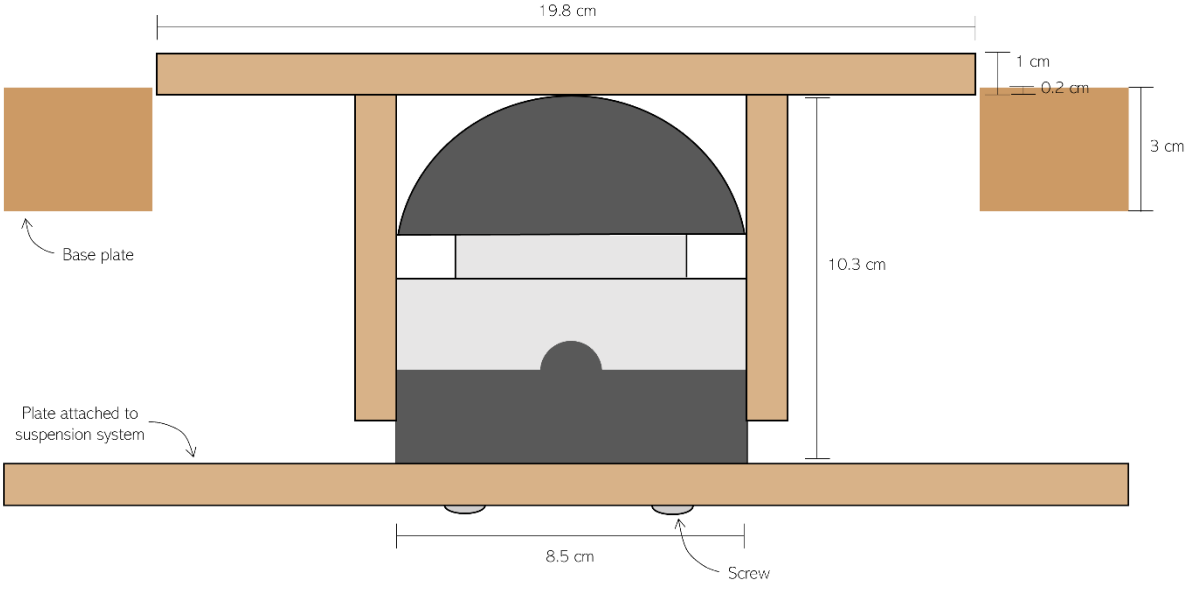


Figure 46. The button cap is built around the dome of the standard button

Figure 47. 3D visual of the button cap

Plus:
+ The button cap has the whole area of the base to rest on, so the cap will have more stability
+ The button cap can be easily removed from the button for repair or replacement
+ The button cap can be easily recycled

Minus:
+ More production time

From the plusses and minus it can concluded that leaving the dome on the original button and building the cap around it is the most suitable option. As was mentioned before, repairability is very important, hence a cap that can be easily removed from the button is a must. At the same time, recyclability is a key criterium, therefore all parts need to be able to detach so they can be correctly recycled in the future.

Placement of button in base plate:
The placement of the button in the base plate can also differ. There are two different options that have both their pros and cons. The options are shown below.

The first option would be that in the original starting position, when the button is not pressed, the button cap is lifted up from the base plate. Once the button is pressed, it will fully level with the base plate. Since the button in its starting position (unpressed) is always slightly recessed in the base plate, yet at the same time raised from the base plate, it reduces the risk of jamming:

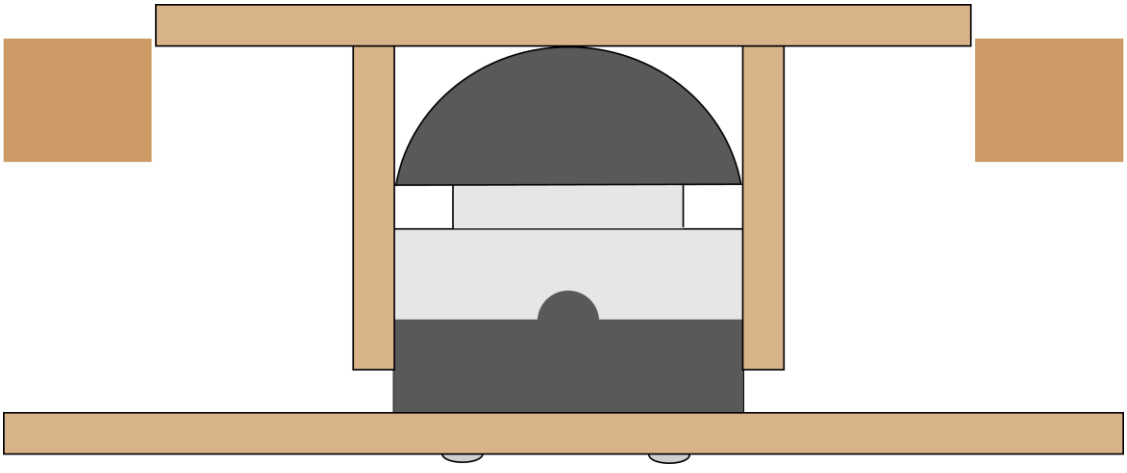


Figure 48. Unpressed state: the button cap is slightly raised from and recessed in the base plate

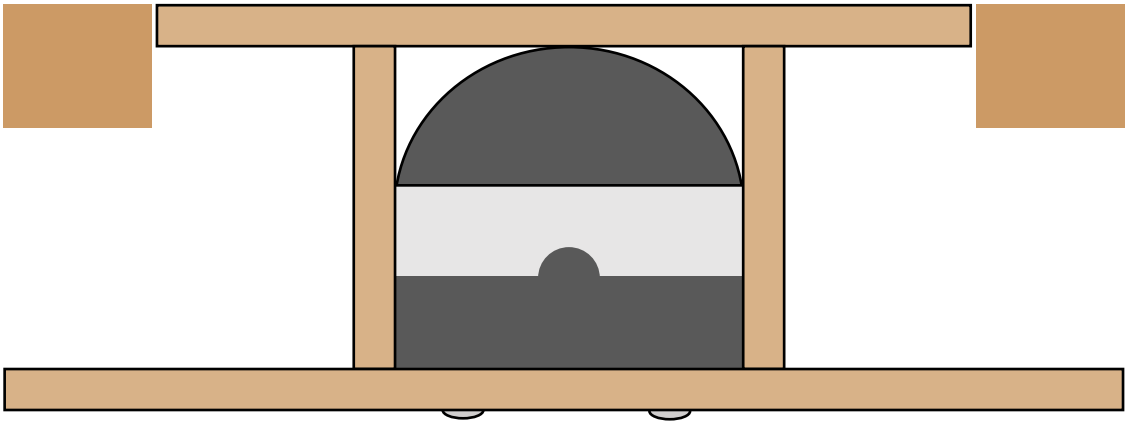


Figure 49. Pressed state: the button cap is levelled with the base plate

Plus:
+ The button is more recognizable as a button, as something one can press, as it sticks out

Minus:
- Because the button sticks out of the base plate, it might be more inviting to slam on it
- The small section of the button cap that lays in the base plate might not be enough to stop the chance of getting stuck

The second option would be that the button cap levels with the base plate in its starting position, unpressed. When pressed, the button cap will further recess into the base plate:

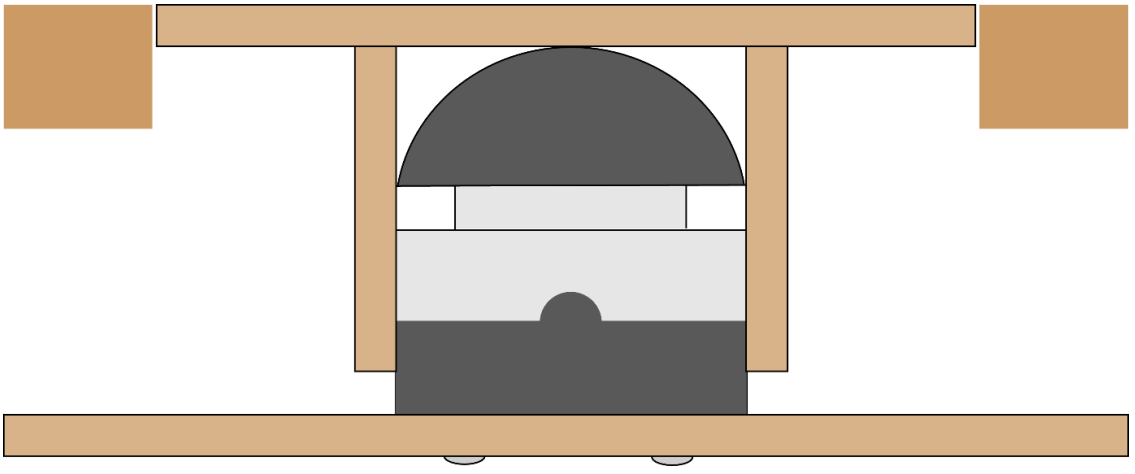


Figure 50. Unpressed state: the button cap is levelled with the base plate

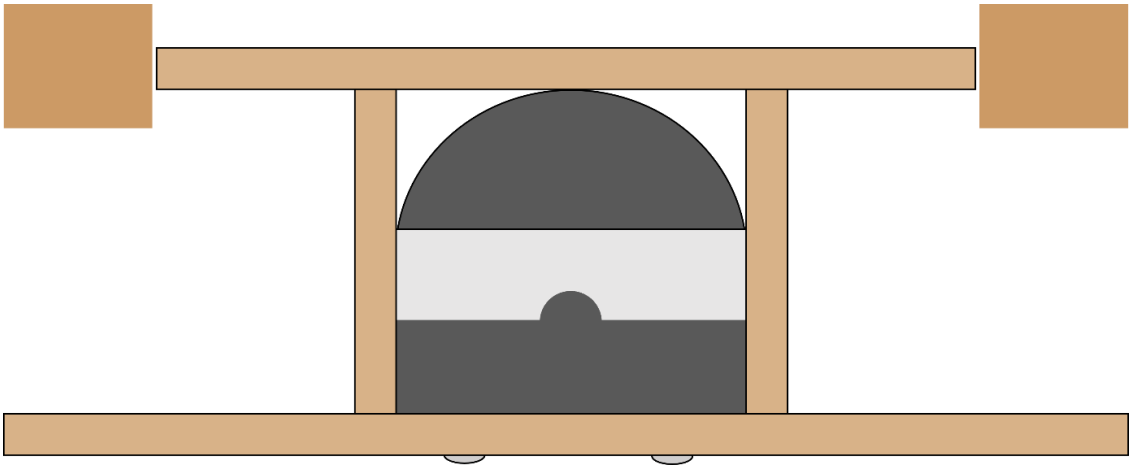


Figure 51. Pressed state: the button cap is pressed further into the surface of the base plate

Plus:
+ The button cap sits completely between the walls of the base plate, which reduces the chance of jamming
+ Children might slam less hard on the button because the button does not stick out, which could reduce the chance of damaging

Minus:
- When pressing down on the button, the edge of the hole in the base plate appears, which might cause injury when the edge is sharp

From the plusses and minus it can be concluded that levelling the button cap to the base plate in the unpressed state is the best option for the game. This option has less chance of causing jamming or damage. During manufacturing special attention needs to be paid to the edges of the space in the base plate, in which the button cap is placed. The edges must be filed, ensuring smooth edges opposed to sharp ones, and thus cannot cause injuries.

Placement of the LED's

Now that the design of the button is complete it is important to review best placement of the LED's. Below the design criteria for the LED's.

Design criteria:

1. The LED's should be protected during use, so the risk of damage is minimized
2. The light of the LED's should be visible in a brightly lit room
3. The LED's should be accessible for repair and replacement
4. The LED's should be able to change colour
5. The LED's should be able to flicker
6. The LED strip should be long enough to be placed along the channel of the button cap
7. The LED strip should be able to have a snug fit in the channel of the button cap
8. The cables of the LED should be long enough to be able to be attached to the Arduino

The design criteria are split in two parts: one part concerns the placement of the LED, criteria 1 to 3, and the other part concerns the LED itself, criteria 4 to 8. The next visuals show the ideation of the placement of the LED strip, therefore the ideas are rated according to the first three design criteria.

Since the light of the LED's need to be visible when the button is in the unpressed state, the LED's need to be placed on the top of the button cap. Creating a channel will provide a cavity in which to place a silicone LED strip. The light of the silicone LED strip shines through the top, can bend in multiple directions and can change colour, see Figure 52.

Figure 52. Silicone LED strip (Ledkia, n.d.)

The position of the channel can differ. The first option would be to put the LED strip in a channel in the button cap, near the edge. This would look as follows:

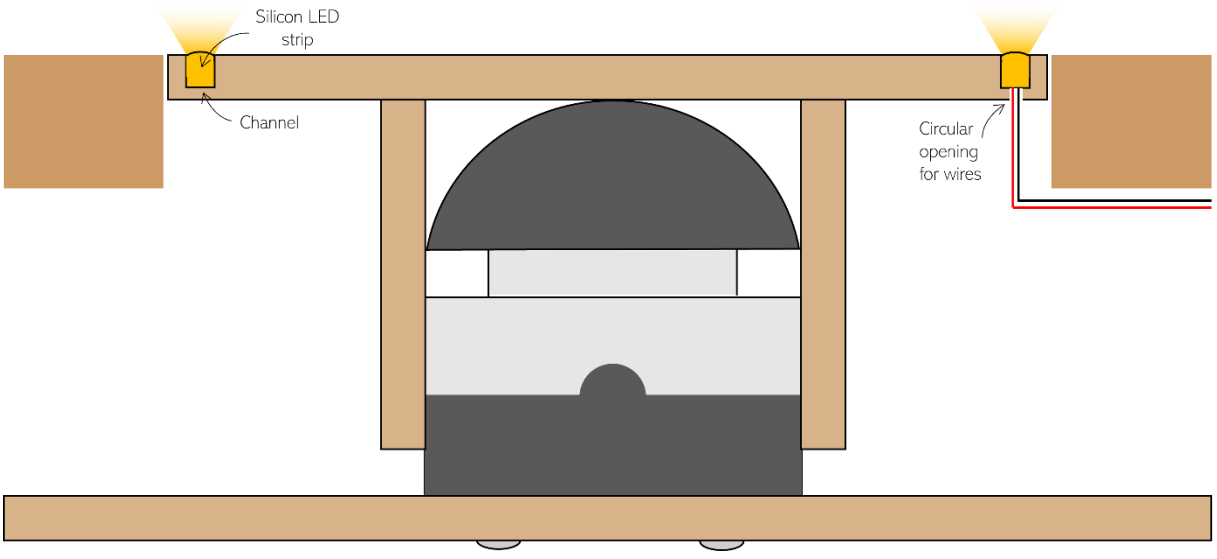


Figure 53. Silicon LED strip in the channel of the button cap at the top

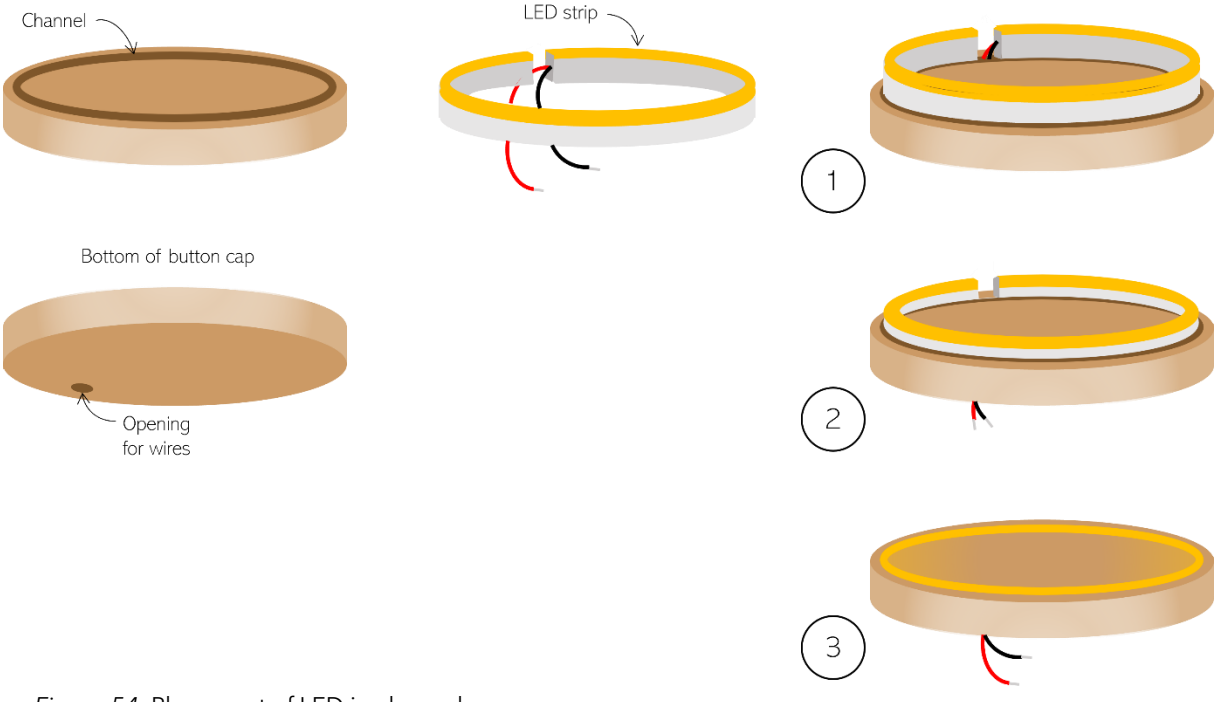


Figure 54. Placement of LED in channel

The silicone strip is clamped in the channel, therefore no glue, etc. is needed to secure the strip. A small opening in the bottom of the channel serves as an exit for the wires. These can subsequently be connected to the Arduino.

Plus:
+ The light of the LED will be visible in a brightly lit room as the LED strip faces the user so color change and flickering will be visible
+ The LED is easyly accessible for repair and replacement
+ Placement of the LED in the button cap might give a clearer, more obvious effect, since one's eye is focussed on the picture; the closer the light is to the picture, the better the eye picks up the reflected light

Minus:
- The wires of the LED strip move when the button is pushed down which increases the chance of damage
- The LED strip distorts the picture of the animal/ecosystem

Another option would be to place the LED strip in a channel in the base plate. This would look as follows:

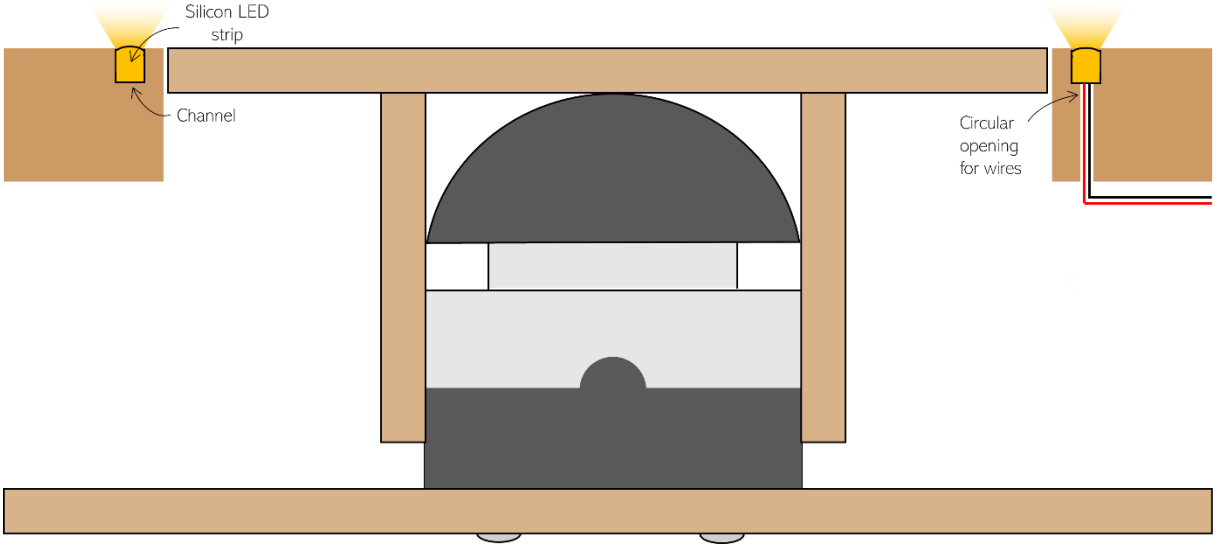


Figure 55. Silicon LED strip in the channel of the base plate at the

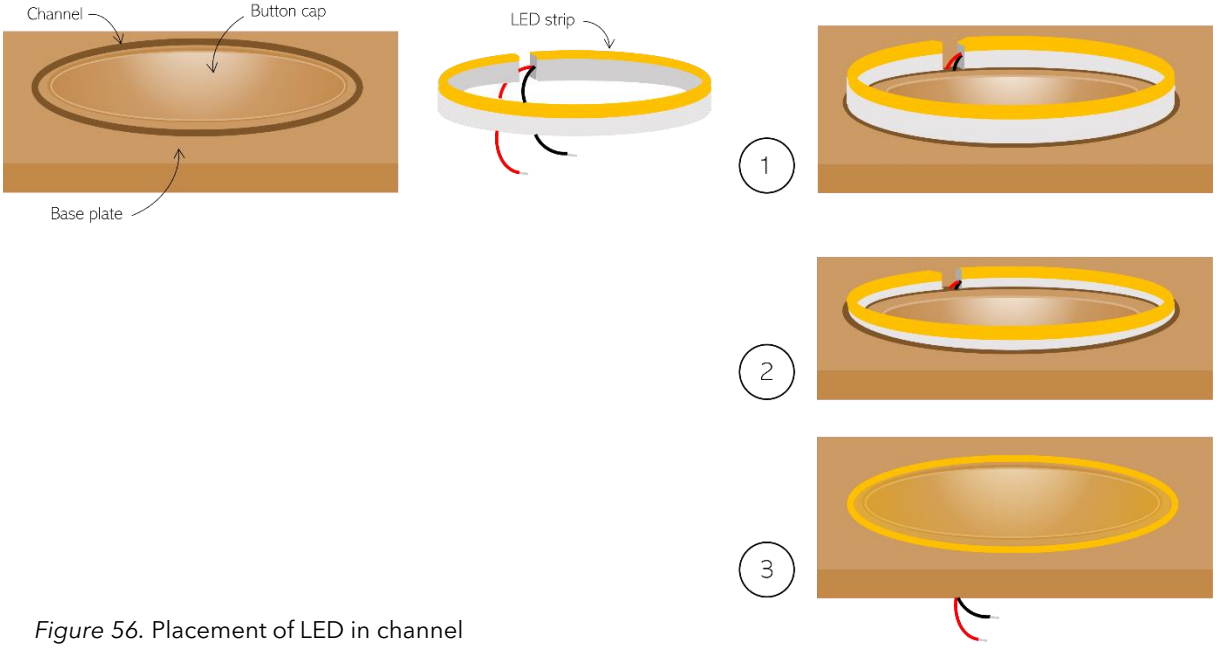


Figure 56. Placement of LED in channel

Plus:
+ The wires of the LED's do not move and are out of the way of the button's movement, reducing the risk of damaging
+ The light of the LED will be visible in a brightly lit room as the LED strip faces the user so color change and flickering will be noticable
+ The LED is easily accessible for repair and replacement
+ The LED does not distort the picture of the animal/ecosystem

Minus:
- This placement of the LED might create less of a coherent picture

From the plusses and minus it can be concluded that the silicon LED strip can best be positioned in the base plate of the game, as this causes the least chance of damaging, which is a very important design criterium. However, it is important that the button and LED still form a coherent picture so it is obvious that the LED belongs to that button. Therefore the LED is placed as close as possible to the button cap.

Attachment to base plate

The button will be attached to the game by screwing it on a plank that is attached to the reinforcement. All buttons in one row will be attached to that plank. This is done as follows:

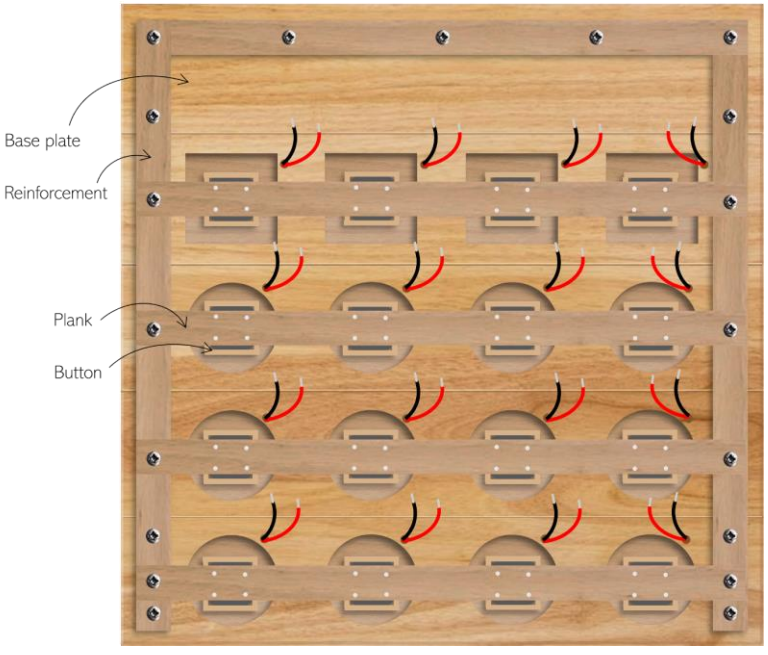


Figure 57. Back of the board. The buttons are attached to the planks which in turn are attached to the reinforcement.

A side view of just a row of buttons on the plank looks as follows:

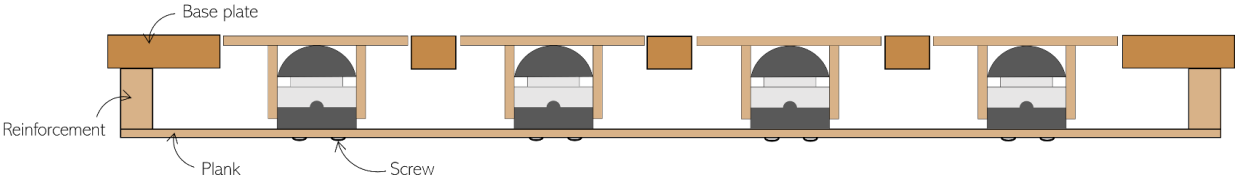


Figure 58. Side view of a row of buttons attached to the plank by screws

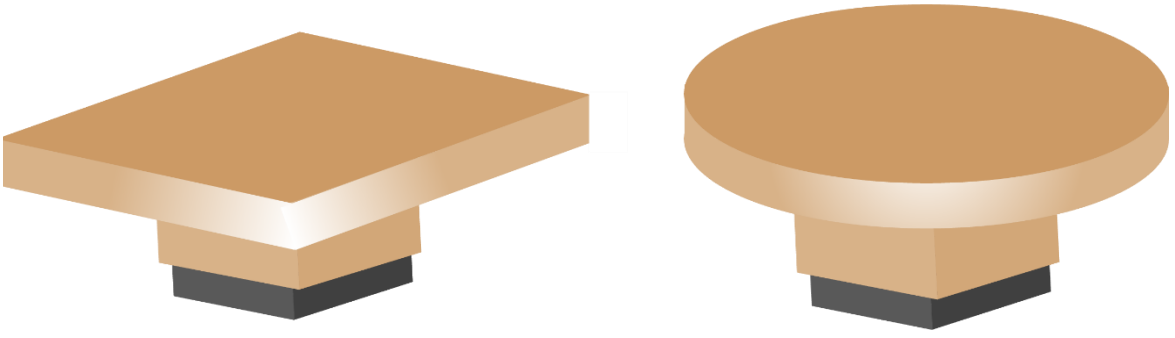


Figure 59. A button with a square button cap and a circular button cap

As can be seen from Figure 59, both square and round button cap will have a square casing around the standard button.

Measurements

The measurements of the length and width of the button are equal and as follows:

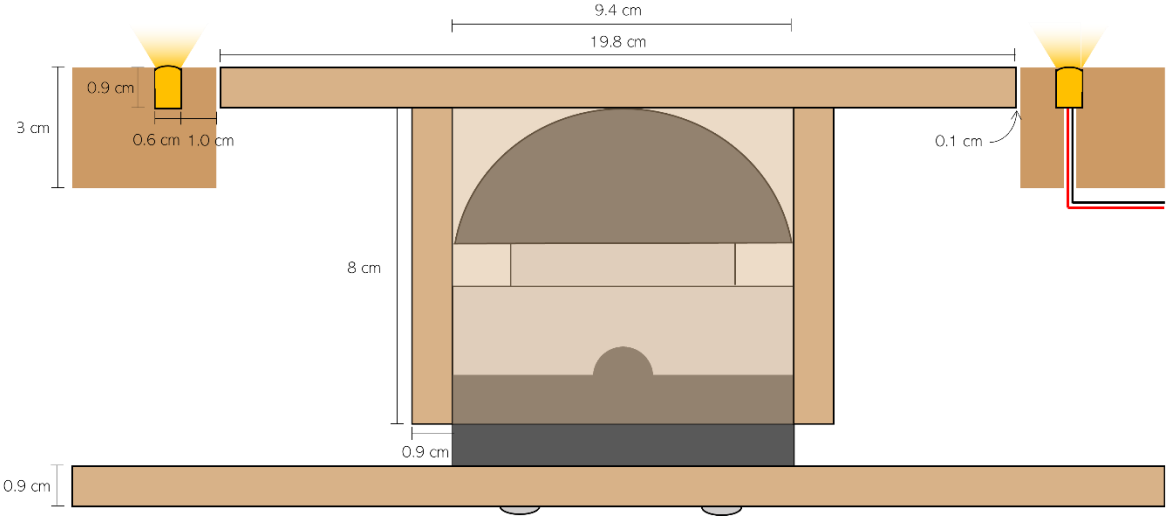


Figure 60. Measurements side view

The button cap will have a 1 millimetre tolerance around the complete edge of the button cap to ensure it will not get stuck in the square or circular opening and can be pressed down smoothly. The measurements from the top of the button are:

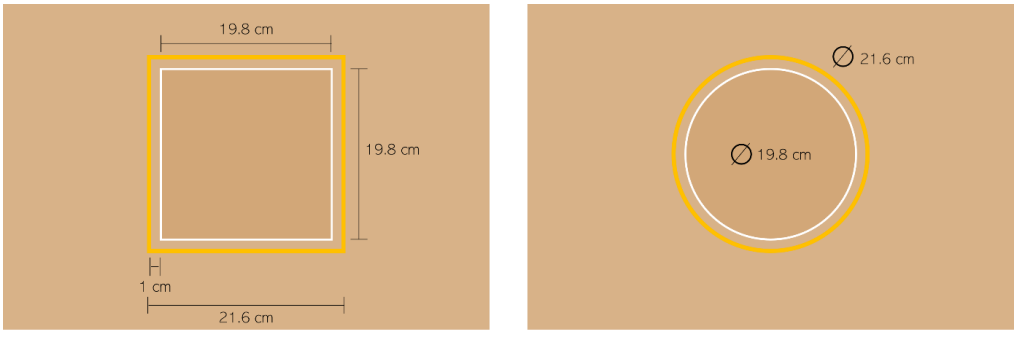


Figure 61. Measurements top view

Material, production and end-of-life

Both the casing and button cap will be made from MDF (see interview with Village Photo Shop in Chapter 7). MDF is not a waterproof material hence it is essential that a waterproof top coat is applied to the finished button. This coating should be eco-friendly in the way that it should allow for recycling together with the wood. To make the MDF wood durable and waterproof linseed oil is rubbed into the MDF. Linseed oil is made from renewable sources and is non-toxic. It can also be recycled together with the wood. On top of that, linseed oil has a short drying time, and thus will not add much additional time to the production of the button (Farabaugh, 2019).

A picture will be printed on top of the button cap via wood printing. This is done by a UV-printer that sprays the ink on the wood which is then directly dried by the UV lamps in the printer. In this way no toxic solvents are released (Woodprint, n.d.). The print is rubbed in with the same linseed oil, which can be recycled.

The MDF button cap can also be recycled. This is done by a slightly different process than regular wood recycling. The MDF wood is turned into pulp through a high pressure steam process. The glue (the binding material of MDF) can be separated from the wood fibres and used for new board material (Unilin, 2021). The linseed oil and ink is separated by adding bubbles to the pulp catching the ink and oil. The bubbles float to the top and the ink and oil can then be skimmed off. Recycling and new recycling processes are developing at high speed. Recycling of (painted) MDF is a fairly new technique developed in Europe. It is assumed that in 10 years time recycling of MDF can be executed in Kenya on an industrial level.

Testing the workability

To assess if the design of the button meets all the previously set requirements, a prototype is built. This prototype also provides insights on how the button could be produced and assembled.

Figure 62 shows the button cap that will be placed over the button. The button cap is made from MDF and the different parts are cut to the correct size via laser cutting. The parts are glued together in this prototype, but in the actual product the button cap will be connected to the casing using L-shaped connectors (see production process). A case that represents the base plate is built around it with the same MDF wood so the button and button cap can be placed inside for more accurate testing. This showed that the button cap could still move a bit from side to side, causing the button cap to jam. An additional ring was laser cut and applied around the button, see Figure 63. This ring perfectly fits the button cap and causes less movement, however the ring was not high enough to completely stop any movement. Therefore a second ring was added, see Figure 64. This almost prevented all movement. Given this is still a prototype and not made in a professional production facility, it is therefore not yet perfect and still had some tolerance. For that very reason, it is essential that special attention is paid during the production process to ensuring zero tolerance in terms of movement. In this prototype the rings are attached to the button using double sided tape. In the actual product the rings (or a better fitting solution) can be attached to the planks to which the buttons are attached, using screws.

Code for the button

To gain a better understanding of how exactly the buttons and LED's work, part of the code that directs the game is detailed. This can be found in Appendix G.

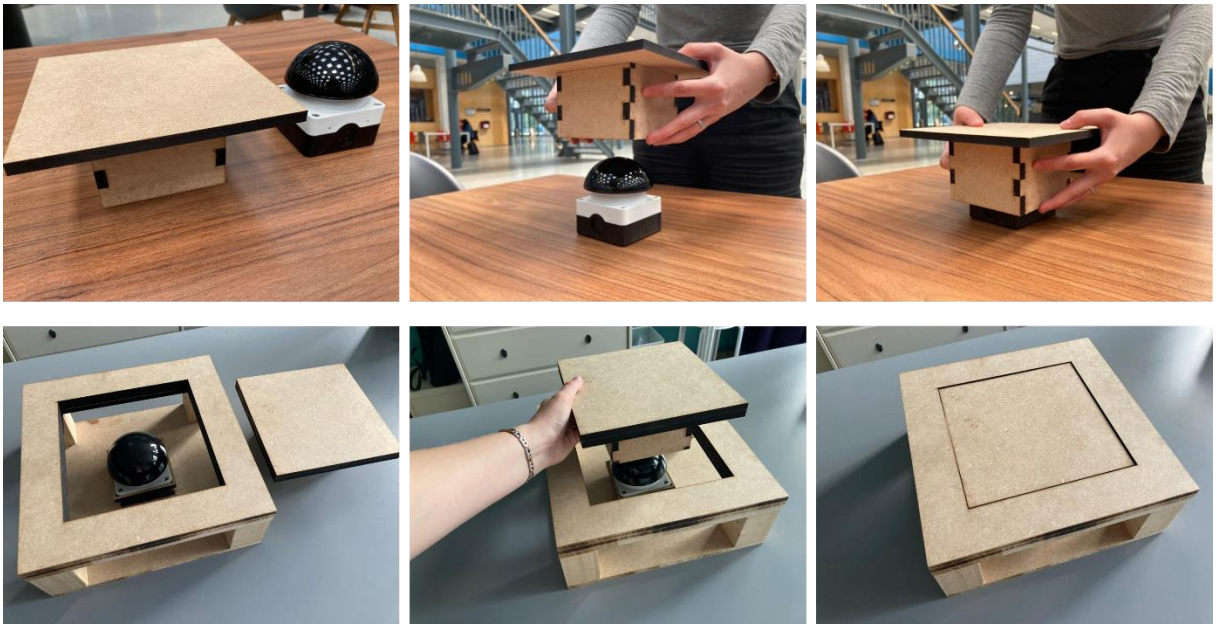


Figure 62. Placement of button cap in the base plate

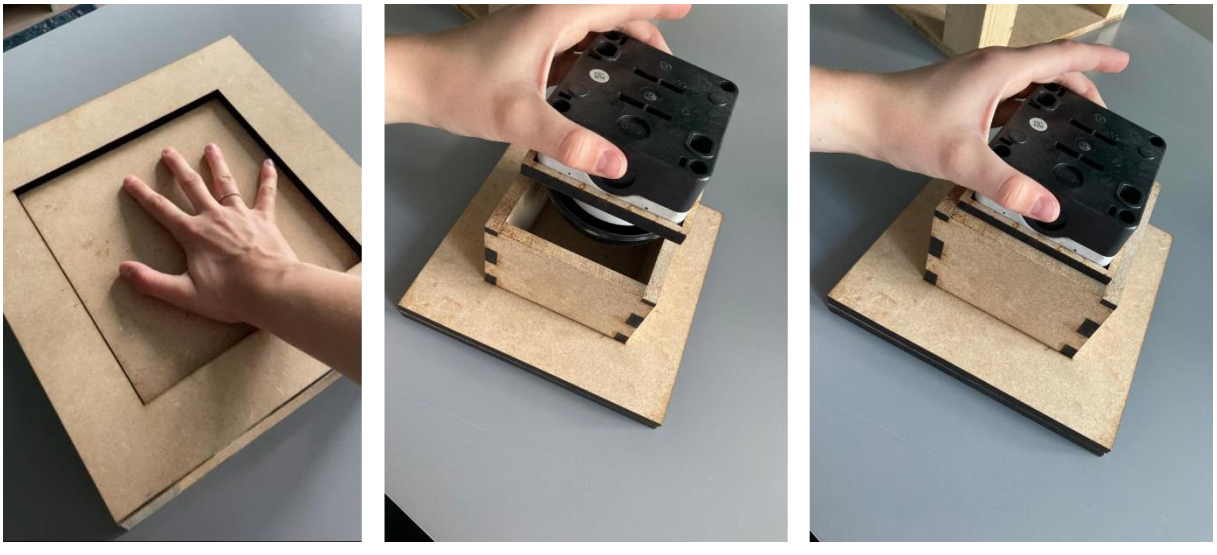


Figure 63. Additional ring around the button that fits exactly in the button cap

Figure 64. Second ring around button

Speaker:
For voicing the fun facts about the animals and ecosystems, two 3W 4 Ω audio speakers are used that are suitable for an Arduino, see Figure 65. Two speakers are used so that the sound is evenly distributed throughout the room and can be heard standing on any side of the game. These speakers are 3 cm in height and 5.26 cm in diameter. The speaker has a full range driver which means it can voice the complete spectrum of sound, including natural high pitch tones. The Applied Labs of the TU Delft suggested that a 3 W 4 Ohm speaker would create sufficient volume for a museum where the user of the game would be able to hear the sounds clearly.

Figure 65. Audio speaker, used in the game (HobbyElectronica, n.d.)

The speakers are attached to the back top corners of the base plate facing the base plate. The sound will voice through the circular pattern of openings in the base plate. This will look as follows:

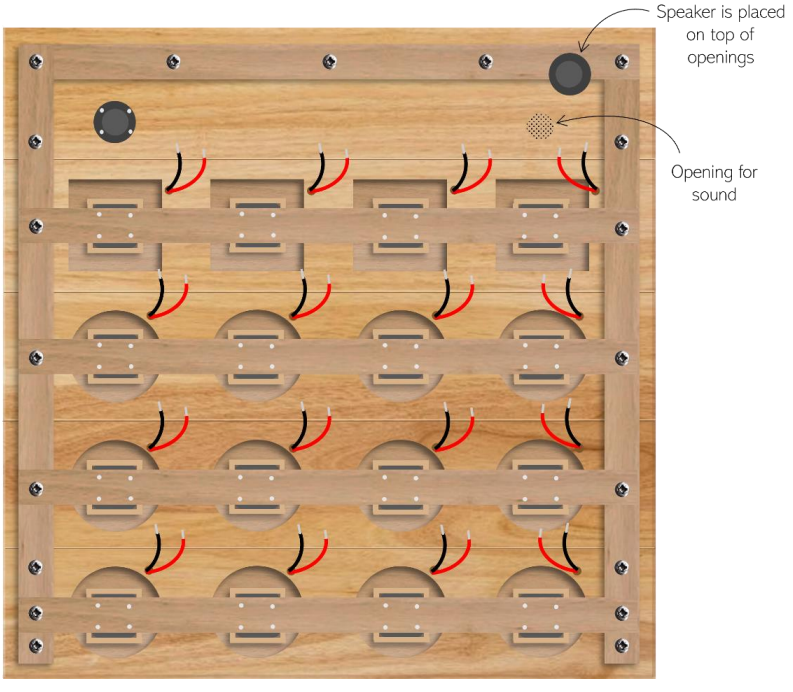


Figure 66. Speaker placement

The speaker is attached to the base plate by screws. The speaker itself already has screw holes by which it can easily be attached to any surface.

For attaching the speakers to the Arduino an Arduino MP3 module is required. If the speakers would be directly attached to the Arduino the quality of sound would be very poor. An MP3 module will ensure the sound quality is good. An MP3 module is a small music player in which an SD card containing the sounds can be inserted. This looks as follows:

Figure 67. DFMini Player MP3 module (Maker Pro, 2020)

The code that is uploaded to the Arduino contains the sounds on the SD card so the Arduino knows exactly when to play which sound. The Arduino can now play the sounds from the SD card and send them to the speaker. This system is placed on a 12 by 8.5 cm breadboard, which then looks as follows:

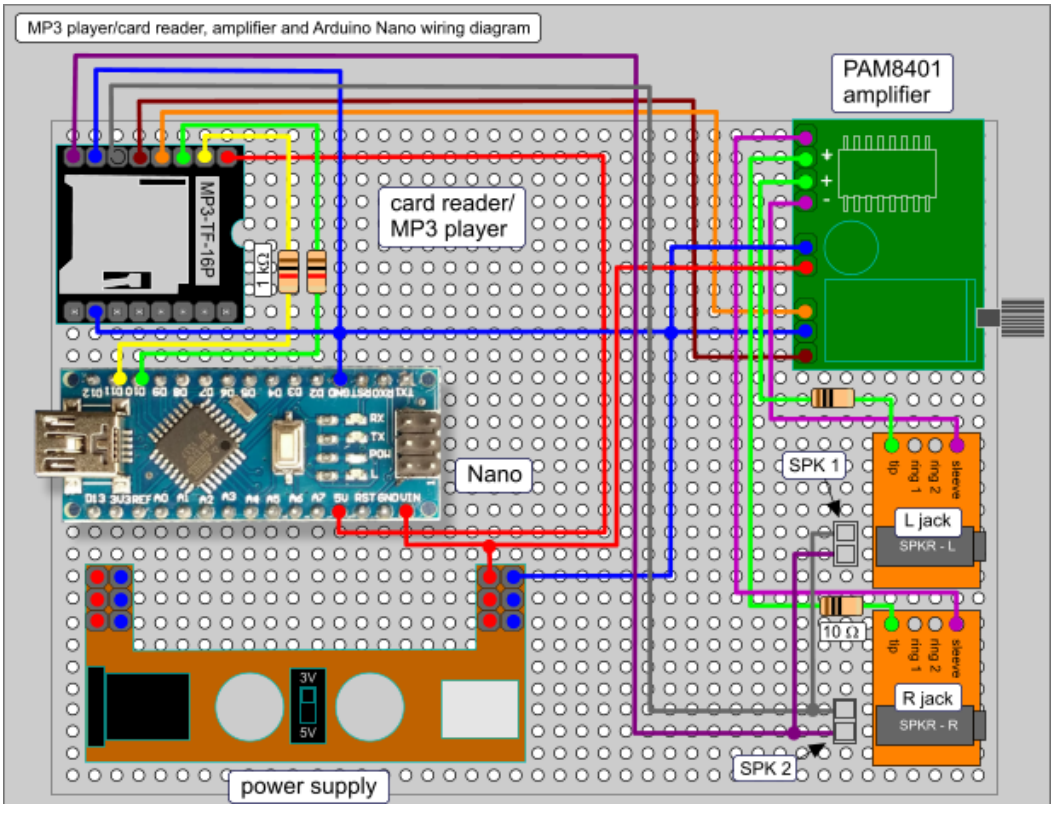


Figure 68. Connection of the necessary electronics needed for the speakers (Wouterlood, n.d.)

Because this system takes up a lot of current (0.6A) an auxiliary power supply is needed. The power supply delivers power to the Arduino which then distributes it to the other electronics (red and blue line). The Arduino is connected to the MP3 module (yellow and light green line) and tells it what sounds to send to the speakers (dark purple and grey lines). Because two speakers are needed a 3W micro amplifier is necessary which makes sure the sound is at its peak level. This amplifier is connected to the speakers via the light purple and dark green cables. These go to the plus of the speaker (tip) and the min of the speaker (sleeve).

As soon as the code for the game is programmed onto the Arduino the USB connecting to the computer can be detached from the Arduino. From that moment the power supply provides the system with power. The power supply comes from a socket on the back of the wall behind the game.

This looks as follows:

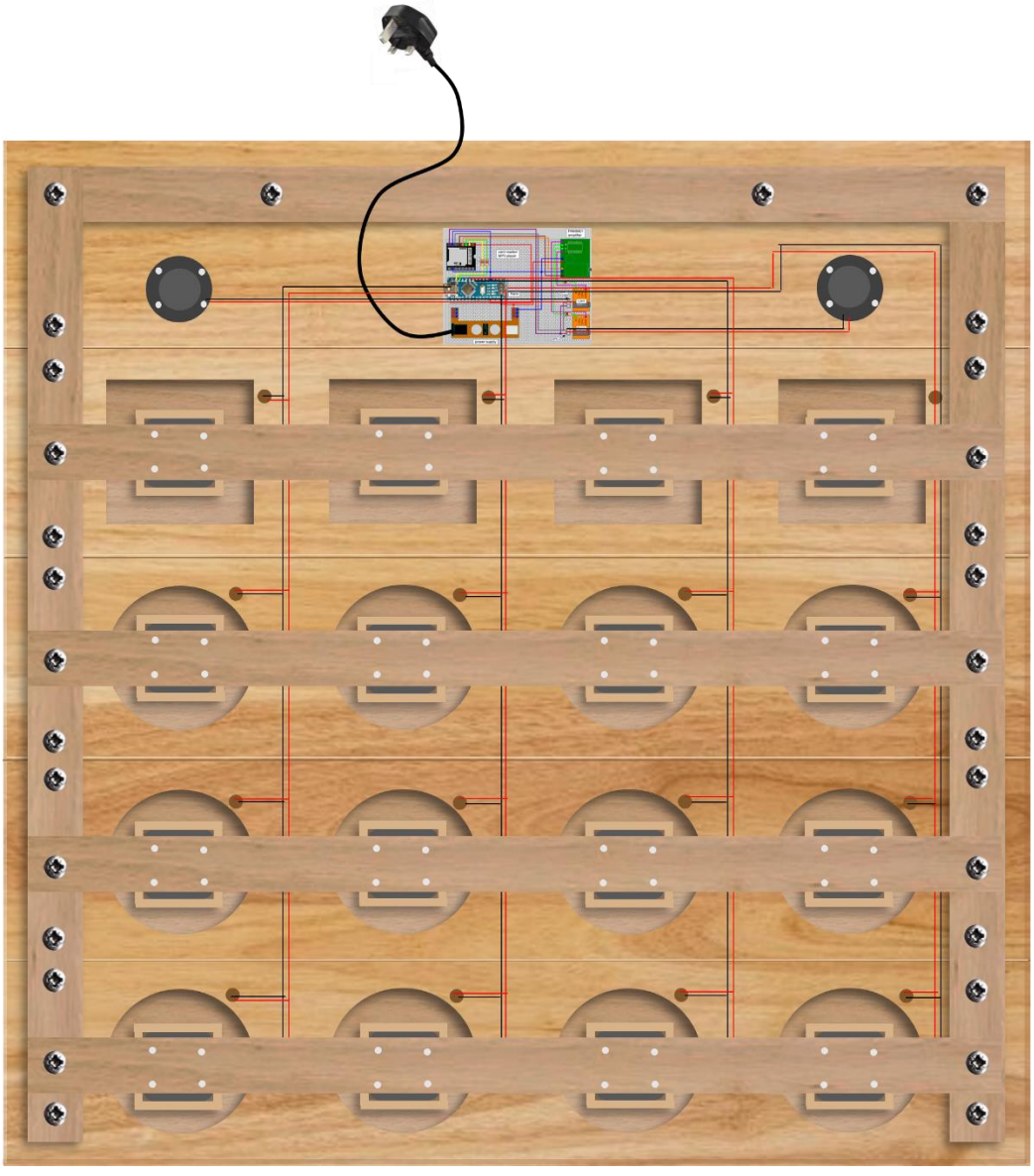


Figure 69. The electronics on the back of the game

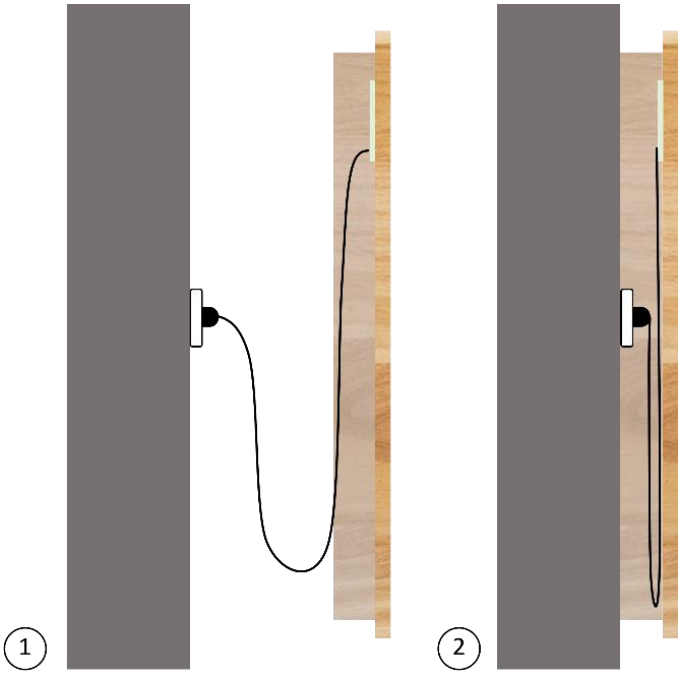


Figure 70. The plug is inserted into the socket on the wall behind the board

Arduino:
It is important that the Arduino has enough ports for the different electronics to attach to, hence the nano Arduino is replaced by a larger Arduino. The Arduino Mega 2560 has 54 digital I/O pins and 16 analogue ports, which is sufficient for the game, see Figure 71.

Figure 71. Arduino Mega 2560 (RS, n.d.)

The code that runs the game is uploaded to the Arduino via the USB port. It therefore does not need to be connected to a computer when running the game.

The LCD screen can directly be connected to the Arduino which sends the correct information to the screen when playing the game.

Suspension system

Now that the game itself is defined in detail, it is important to know how it will be displayed in the museum. Since the product is flat with electronics on the back of the game it can best be placed against a wall. This can be done in multiple ways. This chapter covers the different options as well as the selection of the most suitable option according to the requirements for the suspension system.

Total weight of the game

Before designing the suspension system for the game it is important to know what the total weight of the game is. In this way a suspension system can be designed that is can hold the required weight and can withstand the impacts from rough handling.

The base plate is made of African mahogany which has an average weight of 530 kg/m³. This is less than other hardwoods. Teak wood, for example, has an average weight of 660 kg/m³, which would result in a much heavier installation. African mahogany is also sourced in Kenya and therefore the most suitable material for the game.

The total weight of the game is 40 kg. The complete calculation of the weight can be found in Appendix H. This weight results in a downwards force of 392 N. However, it is also important to take into account the event of a child hanging on the installation. The average weight of an 11 year old girl is 37 kg and of an 11 year old boy is 35.6 kg (Cagle, 2022), however it is important to have sufficient tolerance due to the wide range of the minimum and maximum weight of an 11 year old. Therefore a maximum weight of 100 kg is taken into account. Thus the suspension system needs to be able to hold an extra 100 kg of weight. This results in a total downward force of 392 N + 981 N = 1373 N.

Design criteria

Another preparatory step before designing the suspension system is identifying the design criteria. These are:

1. The suspension system should be able to hold the weight of the game (392 N) plus the maximum weight of an 11 year old, stated at 100 kg (981 N), totalling a maximum downward force of 1373 N.
2. The suspension system should allow the game to be attached to the wall, as the game should remain upright against the wall.
3. The game should be tightly fixed against the wall to ensure the electronics cannot be reached.
4. The suspension system should allow for easy access to the electronics of the game in case of maintenance and repairs and therefore it needs to be easy for the game to be lifted off the wall.
5. The hardware that connects the game to the suspension system should be as light as possible, as to add as minimal extra weight as possible.
6. As little as possible should be visible of the suspension system to not impact the aesthetics of the game.

Ideation

With these criteria the following designs have been realised:

Solution 1

Two rods mounted to the wall and hooks mounted to the back of the board. The game can hang on the wall via the hooks that are placed over the rods. The rods will go inside the reinforcement. The game can therefore be fully placed against the wall and will hide the suspension system. Figure 73 shows how the rod and the attachment to the wall are fully covered by the sides of the reinforcement. The rod has a total width of 7 centimetres whereas the width of reinforcement is 8 centimetres.

Maximum weight per rod, using toggle bolts for attachment: 200 kg (=1962 N)
Source: (Bol.com [b], n.d.) ((Schroeven Online, 2021)
Disadvantage: None

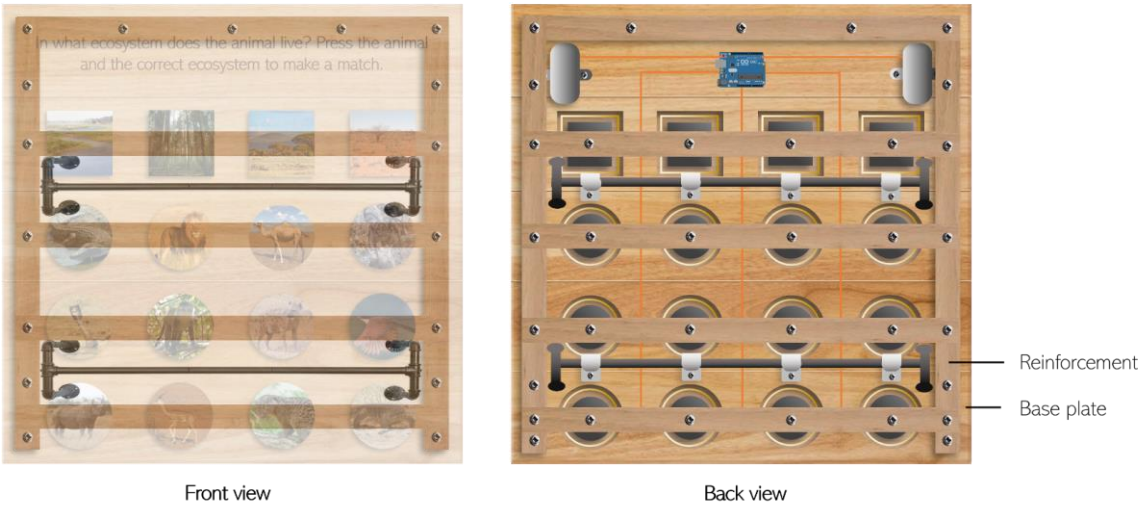


Figure 72. Rods holding up the game

Figure 73. Side view of part of the solution

Solution 2

Hanging from the ceiling. Chains are attached to the reinforcement. The board can be turned around to reach the electronics. The hook used to attach the game to the ceiling can be seen in figure 75.

Maximum weight per ceiling hook: 200 kg (=1962 N)
Source: (Bol.com [c], n.d.)
Disadvantage: Because it is hanging from the ceiling, the board is not fully attached to the wall. This means when someone lifts the board away from the wall, they can reach the back of the board where the electronics are.

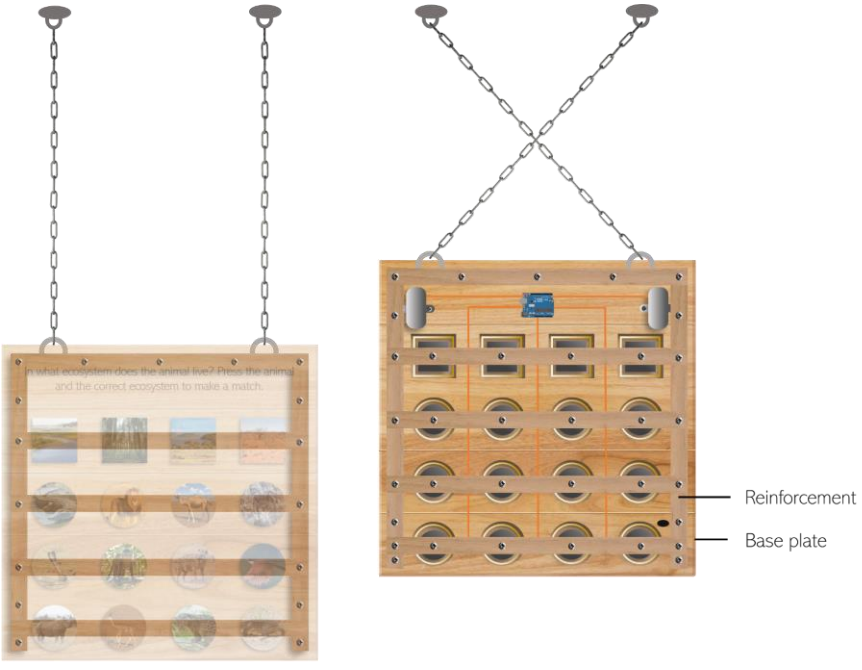


Figure 74. Chains attached to the reinforcement

Figure 75. Hook used to attach the game to the ceiling (Bol.com [c], n.d.)

Solution 3

Z-bar. One z-bar is screwed into the wall and the other is screwed onto the back of the base plate. The z-bars will then hook into each other.

Maximum weight per z-bar: 45 kg (=441.5 N)
Source: (Newly, n.d)
Disadvantage: None

Figure 76. Z-bars connecting to each other (Newly, n.d)

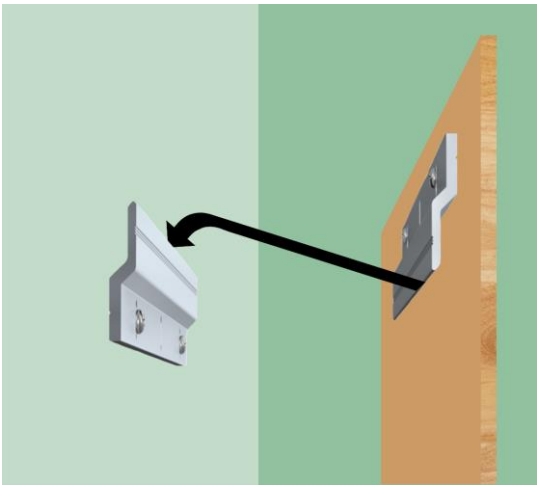


Figure 77. Operation of z-bars

Figure 78. Z-bars connected

Solution 4

L-hook and screw eye. In museums, heavy paintings are being hung by using the L-hook and screw eye connection. An L-hook is screwed into the wall and a screw eye is screwed into the back of the base plate. The screw eye can be slid over the L-hook. The reinforcement can sit on the rest which is also attached to the wall via toggle bolts.

Maximum weight per bolt: 200 kg (=1962 N)
Source: (Walters Art Museum, 2020)
Disadvantage: In the current design there is still a small gap between the wall and reinforcement, however this could be solved by cutting away some of the reinforcement for the rest to fit in.

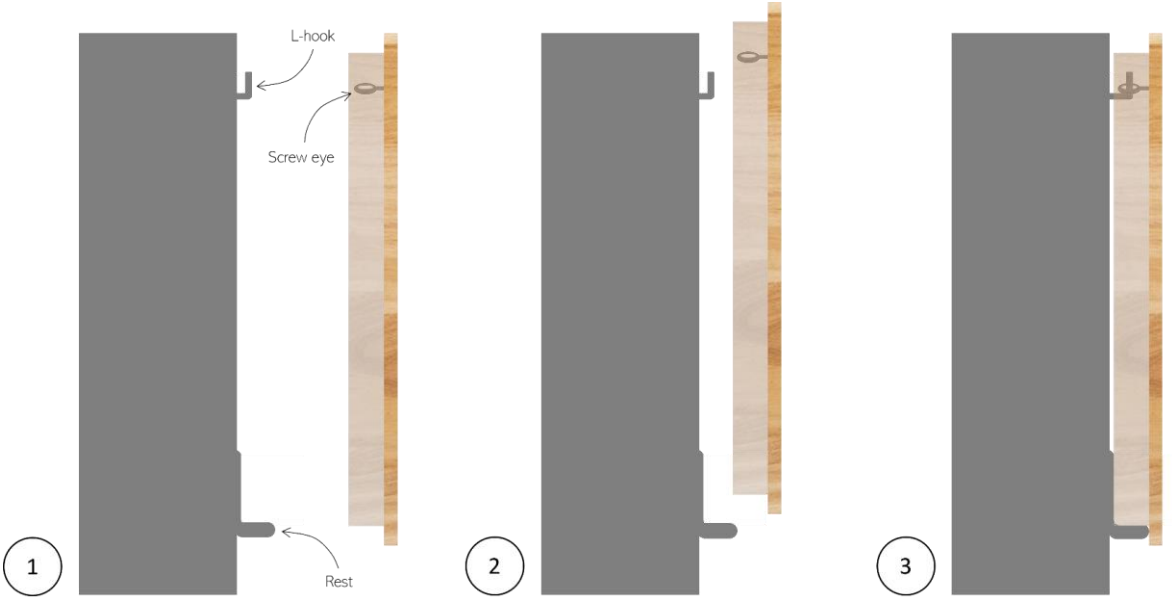


Figure 79. L-hook and screw eye connection

Solution 5

Toggle bolts. Toggle bolts that are not completely screwed into the wall are slid through holes in the reinforcement, fixating the game against the wall.

Maximum weight per bolt: 200 kg (=1962 N)
Source: (Schroeven Online, 2021)
Disadvantage: It is uncertain if the weight is distributed properly with this method and if it can therefore hold all the weight of the game. It is also uncertain if the bolds can stick out of the wall and still hold enough of the weight.

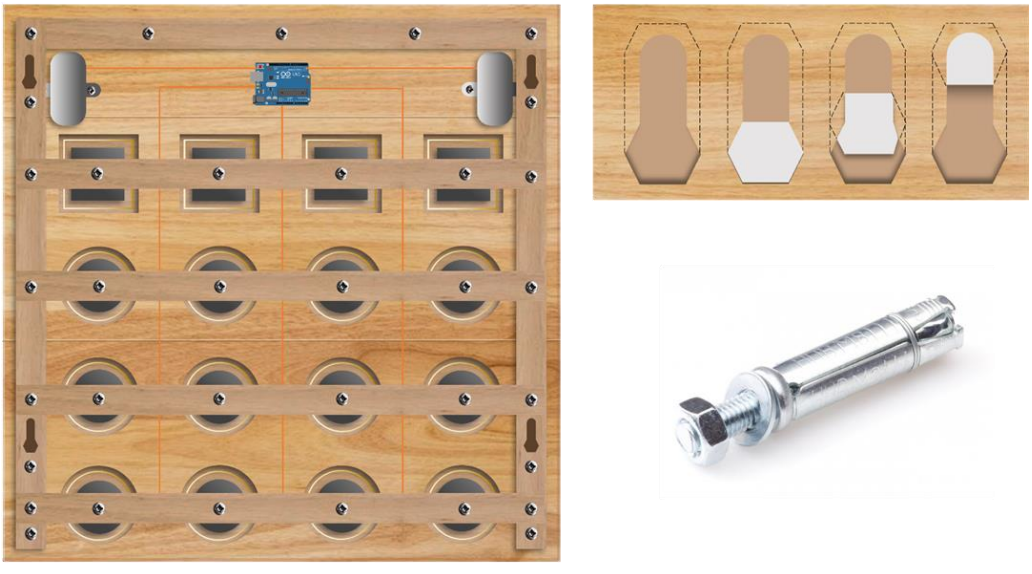


Figure 80. Holes for the toggle bolds in the suspension system (Techniek Webshop, n.d.)

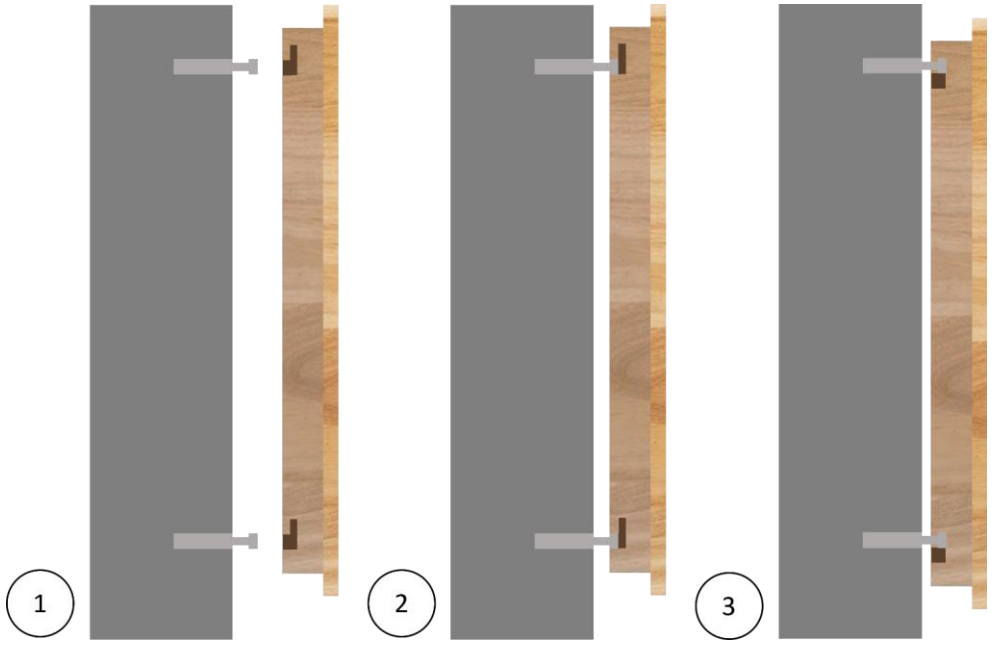


Figure 81. Operation of the toggle bolds into the holes of the suspension system

Solution 6

Small wheels that roll into a frame. The frame is attached to the wall via toggle bolts.

Maximum weight per bolt: 200 kg (=1962 N)
Source: (Schroeven Online, 2021)
Disadvantage: Many wires are attached to the wall, thus when sliding the installation over the wall there is a high risk of wires coming loose or damaging the electronic circuit. Children may also push the game of the frame since this requires less force than lifting the game.

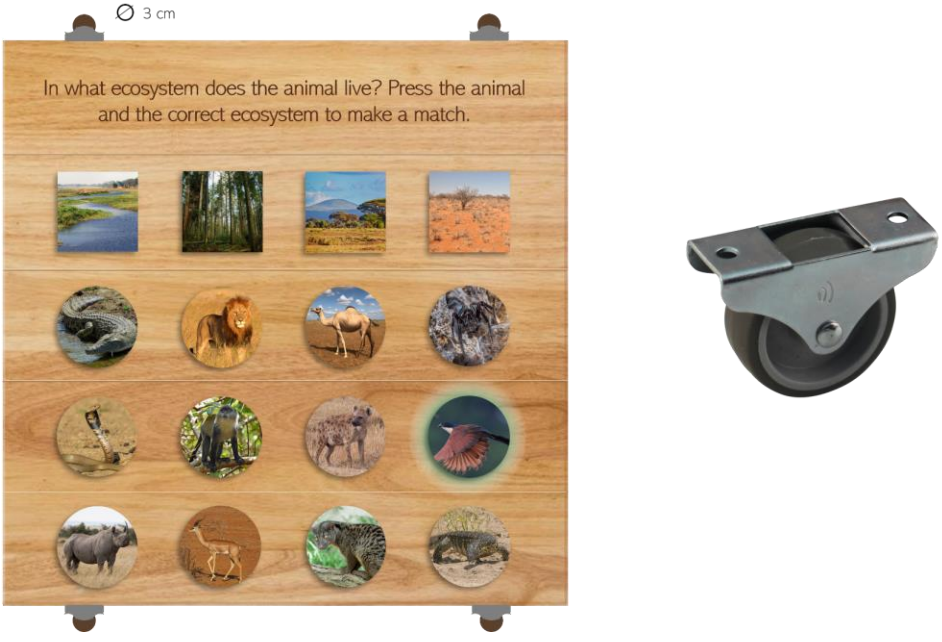


Figure 82. Small wheels attached to the reinforcement (Rollers.nl, n.d.)

Figure 83. Rollers that slide into a frame

Chosen concept

The ideas are rated according to the design criteria for the suspension system using a Harris Profile, see Figure 84 (Van Boeijen, 2016). As can be seen from the rating matrix both idea 1 and 5 comply with all the requirements, however idea 1 has no disadvantages, whilst idea 5 does. As said before, idea 5 is based on a concept that has not been tested yet and proved it will actually work. Are the toggle bolts still able to hold 200 kg when it slightly sticks out of a surface? This is an uncertainty. Therefore idea 1 is the best fit for the game, as it is certain that this system will work and is able to hold the necessary weight.

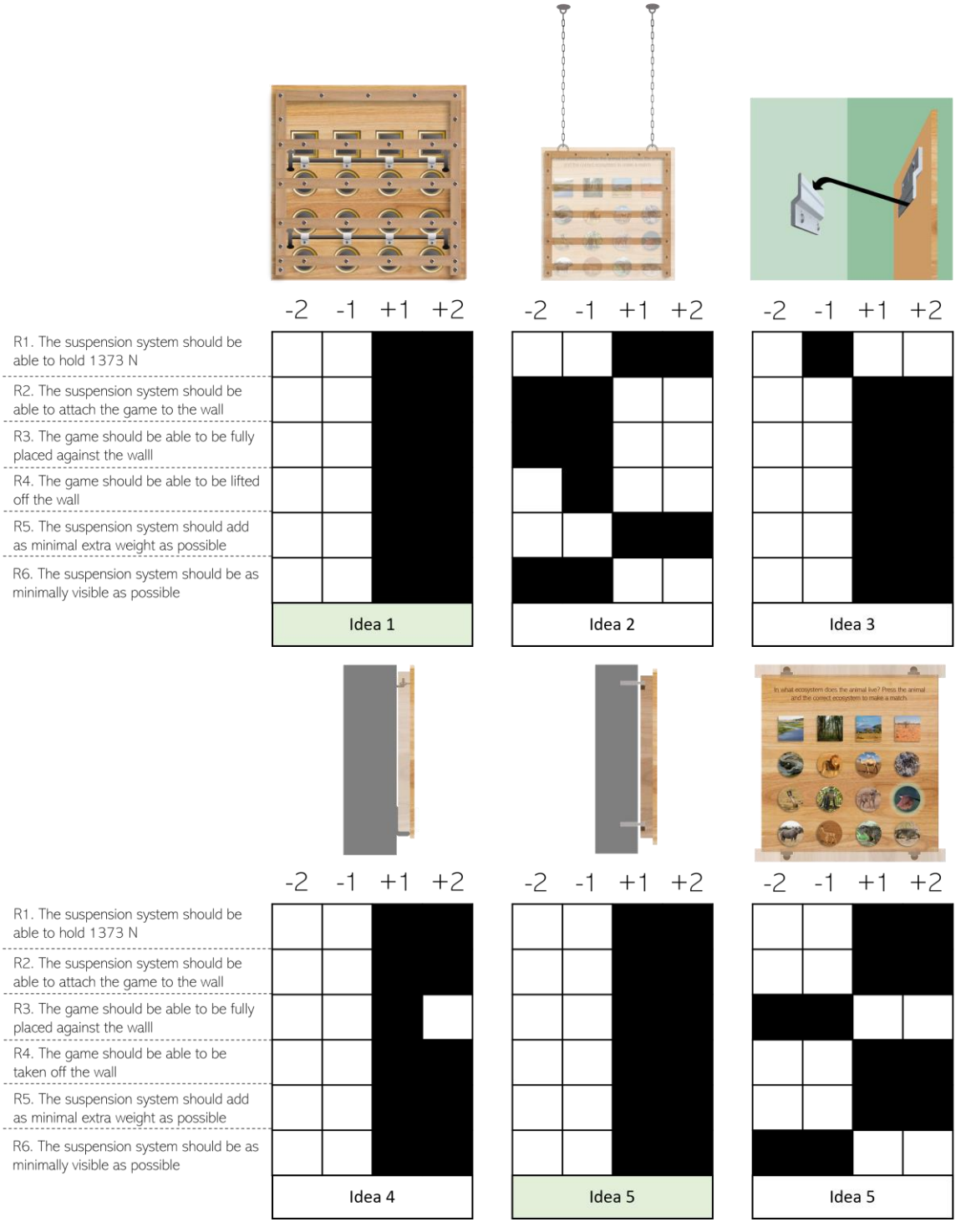


Figure 84. Rating results of the different suspension systems

An additional step in the process of lifting the game off the wall would be the need to remove a “lock” with which the game is securely fastened to the wall. This should require for example a screwdriver to remove the “lock/stop” with which the game is fixed to the wall. For instance, adding a “stop” at the top of the game in idea 1, will avoid the game of being lifted off the bars by visitors to the museum. See Figure 85 for what this could look like.

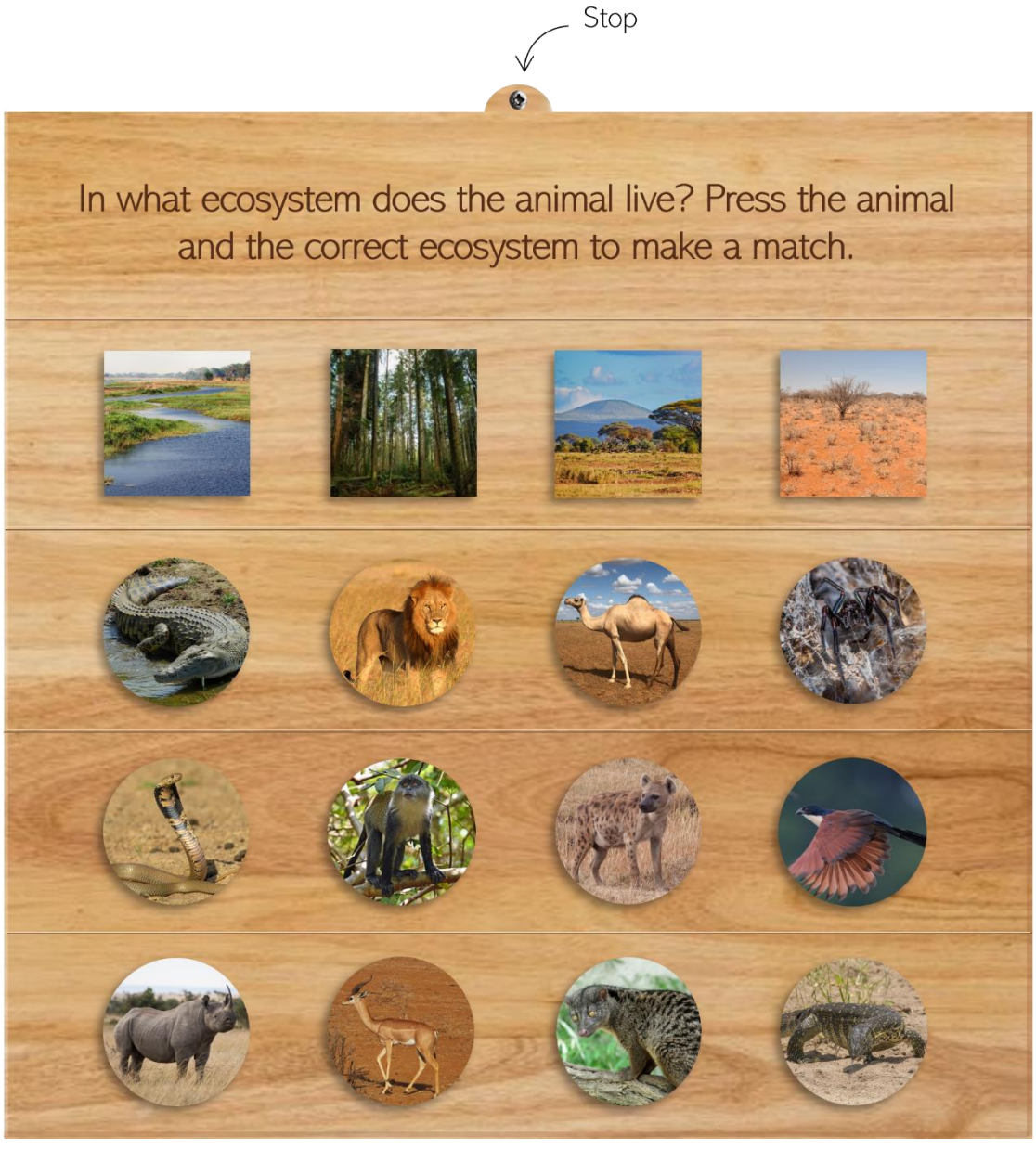


Figure 85. A stop at the top of the board to prevent it from being lifted

Material, size and production technique

Now that all details of the game are determined it is time to look at the material, size and production process. The exact size of the game is as follows:

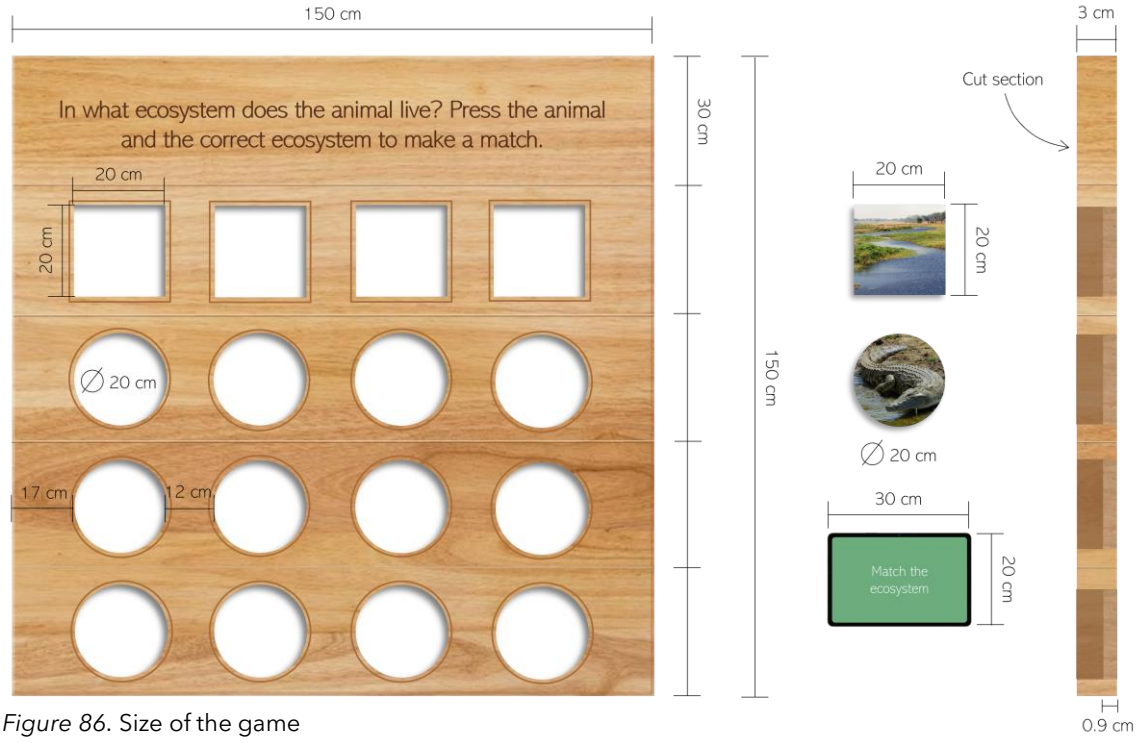


Figure 86. Size of the game

The exact sizes of the electronics can be found in the technical aspects. The material of the game is as follows:

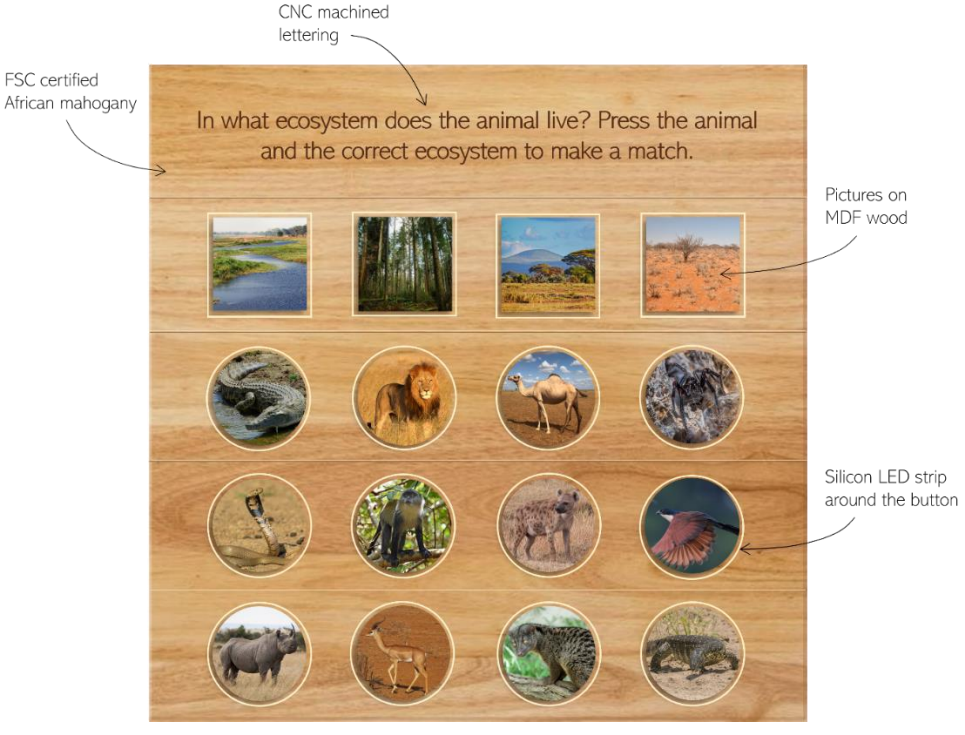


Figure 87. Material of the game

Production process and assembly

As described earlier, the product will be manufactured by different manufacturers. The way each part needs to be produced has been discussed with these manufacturers in detail. The production process is as follows:

Manufacturer: Blackwood Signs & Decor

Part: Base plate

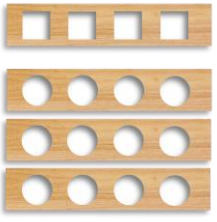
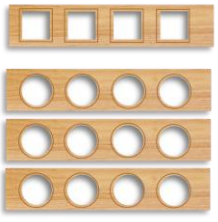
1	2	3	4	5
				
Cut 5 planks of 150 x 30 x 3 cm out of African mahogany. Sand the wood, cure it and give it a linseed oil coating.	Carve out the text on the top plank using a CNC machine (Ooznest, n.d.)	Cut out 4 squares of 20 by 20 cm on one plank. Cut out 4 circles of 20 cm diameter on 3 planks. Use a CNC machine.	Carve channels of 1 cm deep and 0.6 cm wide on 1 cm distance from the edge around the square and circular cutout. Drill a 0.4 cm in diameter hole in the channel that goes all the way through.	Cut out of African mahogany 2 beams of 145 x 6 x 8.3 cm and one beam of 140 x 6 x 8.3 cm. Sand the wood, cure it and give it a linseed oil coating.

Figure 88. Production of the base plate

Manufacturer: Blackwood Signs & Decor

Part: Base plate

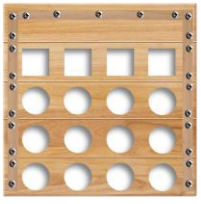
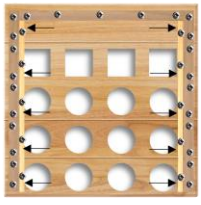
6	7a	7b
		
Secure the 5 planks together by screwing 24 screws of 0.48 x 10 cm through the beams on the back of the base plate.	Two 140 x 2 x 2 cm beams are cut from African mahogany and screwed onto the wood with 4 cm long screws.	These beams are then screwed onto the reinforcement (from the side) with 4 cm long screws. To prevent splittig of the wood, the wood has to be predrilled.

Figure 89. Production of the extra reinforcement

There is a possibility that the reinforcement on the back of the game is not sufficiently secured and an additional reinforcement would need to be added. This will only become apparent during the production process. The extra reinforcement is shown in steps 7a and 7b (see Figure 89). For now it is assumed the extra reinforcement is not necessary, however it can be easily implemented should there be a need for it. It can even be applied after the game is already in use. The production process continues after step 6.

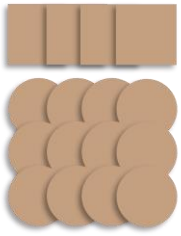
Manufacturer: Village Photo Shop	
Part: Button cap	
7 	8 
Cut 4 squares of 19.8 x 19.8 x 0.9 cm out of MDF wood. Cut 12 circles of 19.8 cm in diameter and a 0.9 cm thickness out of MDF wood. Sand the cutouts.	Print the pictures on the cutouts via UV printing. Coat the cutouts completely with linseed oil.

Figure 90. Production of the button caps

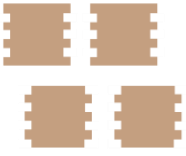
Manufacturer: Blackwood Signs & Decor		
Part: Button casing		
9 	10 	11 
Lasercut 16 times 4 planks of 11.2 x 8 x 0.9 cm out of MDF. The planks should have 1.8 x 0.9 cm cutouts.	The fingers make a tight enough connection for there to be no glue necessary. Push the parts together.	Screw the button casing to the bottom of the button cap using an iron L-shaped connection piece and 0.5 cm screws.

Figure 91. Production of the button casing and attachment to the button cap

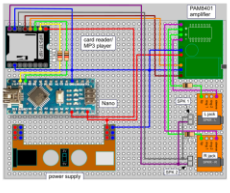
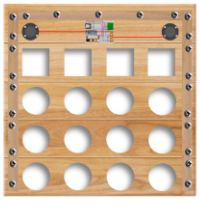
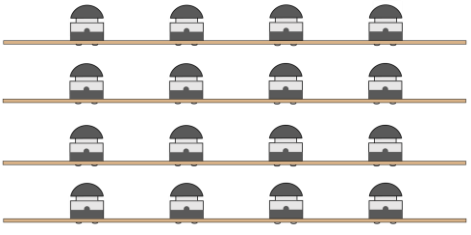
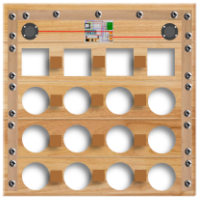
Manufacturer: Geviton			
Part: Electronics			
12 	13 	14 	15 
Connect the Arduino to the MP3 module, amplifier, power supply and jacks using a breadboard.	Attach the breadboard to the back of the base plate using 2 cm screws. Attach the speakers to the top right and left of the back of the base plate using 2 cm screws. Then connect them to the jacks.	Cut 4 planks of 145 x 8.4 x 1 cm out of African mahogany. Attach 4 buttons to a plank using 4 screws of 2 cm in length on each button. Do this also for the other three planks.	Cut 12 beams of 10 x 10 x 8.3 cm out of African mahogany. Place one in between two buttons.

Figure 92. Production and assembly of the electronics

To prevent bending of the plank to which the buttons are connected, supporting beams are added in between each button (see step 15, Figure 92). The beams will absorb the force when someone hits a button.

Manufacturer: Geviton
Supplier: Bluewave

Part: Electronics

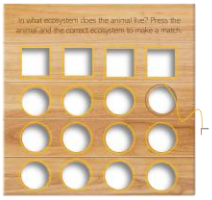
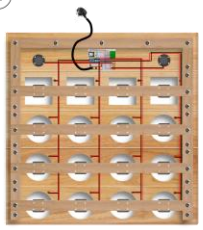
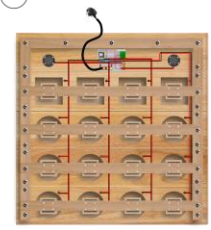
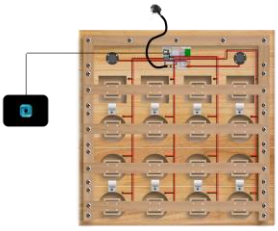
16	17	18	19
			
Place the silicon LED strips in the channels around the cutouts. Make sure the wiring goes through the hole in the channel.	Screw the planks with buttons onto the reinforcement where each button is centered in a circular or square cutout. Also screw the planks on top of the supporting beams using 12 cm long screws. Connect the buttons and LED's to the Arduino. Add the plug to the power supply.	Slide the button cap onto the button an press tightly.	Add 8 hooks to the back of the base plate, each being attached by two screws of 2 cm in length. Connect the screen supplied by Bluewave to the Arduino.

Figure 93. Further assembly of the electronics

Manufacturer: Geviton

Part: Suspension system

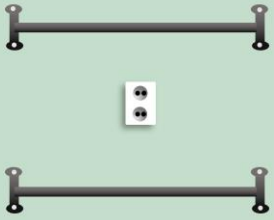
20	21	22
		
Place the bars of the suspension system against the wall on the correct height and secure them using 8 M12 toggle bolts.	Plug the power supply in the socket and hang the game on the bars. Attach the screen to the wall using the suspension system Bluewave supplies together with their screens.	Add a 2 cm thick stop at the top of the game using a 5 cm screw and add a bar that serves as a step below the game. Use M12 toggle bolts to secure the bar.

Figure 94. Mounting of the game on the wall

It has been the researcher's choice to design artistic visuals of the animals and ecosystems in which they live and replace them with the photographs used on the buttons in the report. Figure 95 shows these visuals.

Figure 95. Artistic visuals of the animals and ecosystems in which they live

BOM

Below shows a bill of materials, which are all the parts necessary to build the product. It states which manufacturer delivers the part, the size of the part, the amount and the material it is made of. Some parts, such as the electronics, consist of many materials and therefore do not have a material assigned to them.

Table 1. Bill of materials

	Manufacturer	Part	Amount	Material
1	**Blackwood Signs & Decor**	150x30x3 cm planks	5	African mahogany
2		145x6x8.3 cm plank	1	African mahogany
3		140x6x8.3 cm planks	2	African mahogany
4		145x8.4x1 cm planks	4	African mahogany
5		10 cm screws	24	Stainless steel
6		11.2x8x0.9 cm planks	64	MDF
7		L-shaped connectors	64	Stainless steel
8	**Village Photo Shop**	19.8x19.8x0.9 cm planks	4	MDF
9		⌀19.8x0.9cm planks	12	MDF
10	**Bluewave**	30x20 LCD screen	1	-
11		Screen suspension system	1	Aluminium
12	**Geviton**	12x8.5 cm breadboard	1	-
13		Arduino Mega 2560	1	-
14		MP3-TF-16 MP3 player	1	-
15		PAM8403 5V	1	-
16		3W micro amplifier	1	-
17		3W 4Ω speaker	2	-
18		Auxiliary 5V power supply	1	-
19		4-pin breakout female audio jack	2	-
20		1000 Ω resistor	2	-

21		1 cm M3 nylon spacer	4	-
22		0.3 cm audio cord with on both ends a male jack	2	-
23		Wire	-	-
24		Push button	16	-
25		2 cm screws	64	Stainless steel
26		10x10x8.3 cm blocks	12	African mahogany
27		Silicon LED strip	16	-
28		12 cm screws	12	Stainless steel
29		4 cm screws	8	Stainless steel
30		Type G plug	1	-
31		Heavy duty hooks	8	Aluminium
32		2 cm screws	16	Stainless steel
33		Bar	3	Stainless steel
34		M12 toggle bolts	12	Galvanized steel
35		ø5x2 cm plank	1	African mahogany
36		5 cm screw	1	Stainless steel

Sustainability

This chapter covers the level of sustainability of the product. The game has been designed for the Green Kids' Museum and therefore needs to incorporate all aspects of sustainability: the materials have to come from sustainable sources, the sources of the materials need to be as close as possible to the manufacturer to minimise transportation, the manufacturing process needs to be done in a sustainable way and the product needs to be able to be reused and recycled.

First of all, the sustainable sourcing of the materials. The materials are sourced from manufacturers in Kenya, who mostly source their materials from suppliers within Kenya. The African mahogany, sourced in Kenya, is FSC certified. FSC certification guarantees that the wood comes from plantations that meet the strict requirements for sustainable and social management (Arco, n.d.).

Sustainable material sourcing is followed by the manufacturing process. The majority of the selected manufacturers minimise the use of materials and waste. Some of them, such as Geviton, also make use of recycled parts and reduce their energy usage during production.

The game for the Green Kids' Museum has been designed with a specific use in mind: it needs to withstand rough play/handling, must be safe, durable and last for many years. If recycled materials can be incorporated it is a plus, however full use of recycled materials and parts was not a prerequisite for the design of the installation. The objective has been to manufacture the game at highest possible standards to ensure as little repair and replacement of materials would be required which can sometimes be better achieved with new parts and materials.

Regarding recycling and waste reduction, the product consists of components that can be completely taken apart, which not only supports recycling and waste reduction, but also facilitates easy maintenance and part replacement. Should a small component of the game, for example the button cap, get damaged, it suffices to just replace the cap with a new one. No need to have the complete button replaced which supports waste reduction. The game consists of standard parts and materials widely available globally, hence the museum is not dependent on one specific manufacturer/supplier which might be located on a different continent. In this way transportation is minimised and the logistical impact reduced.

As mentioned throughout this research paper, the product is made of natural materials, where possible, to reduce the negative impact on the environment. For example, the coating on top of the wooden parts consists of linseed oil which is a natural material. The linseed oil coating can be recycled together with the wood and then extracted. The pictures on the button caps can also be recycled together with the wood as the ink can be extracted from the picture during the recycling process.

All in all, the product is quite sustainable. Obviously, there is always room for improvement. For example, the electronics used in the game could have been made from fully refurbished components, giving them a second lease of life and therefore reducing waste. For now, it is assumed that the product meets the sustainability standards of the Green Kids' Museum.

Manufacturing time

To estimate the total manufacturing time of the product, the involved manufacturers have been asked to provide an estimate of the manufacturing time of their part. Geviton, the company that produces the electronic circuit and writes the code, also assembles the product. Geviton therefore also provided an estimate of the assembly time. Estimates provided by the manufacturers:

• Base plate	48	h
• Buttons	72	h
• Electronic circuit and code	20	h
• Screen	72	h
• Assembly (including attaching the suspension system)	22	h

These estimates do not include the transportation time of the material from supplier to manufacturer and the transportation time of the part from manufacturer to client. These estimates are solely for the production of the product.

The total manufacturing time is based on the time that the longest part takes to manufacture, as the other parts can be produced within this time, plus the assembly time. This makes the total manufacturing time to be 72 + 22 = 94 hours.

Estimated cost

To estimate the total cost of manufacturing the product, the involved manufacturers have provided a quotation for their respective part. Included in the quotation are material cost, labour cost and transportation of material to manufacturer and part to client. The cost of the assembly, quoted by Geviton, can also be found in the table below. The original quotations can be found in Appendix I.

The total estimated cost of the product is:

• Base plate	€	246
• Buttons	€	231
• Electronic circuit and code	€	518
• Screen	€	540
• Suspension system	€	188
• Assembly (including attaching the suspension system)	€	42
Total	**€**	**1,765**

The cost per part are converted from Kenyan Shillings or United States Dollars to Euro and then rounded. This is done by using the 2021 Average Rate of Exchange (Exchange Rates, n.d.):
- KES (Kenyan Shilling) to EUR (Euro): 0.0077
- USD (United States Dollar) to EUR (Euro): 0.8458

The suspension system consists of ready purchased parts, meaning the cost of the suspension system can be calculated separately. This is done in Appendix J. The cost for attaching the suspension system to the game is included in the assembly cost.

The visuals for the buttons and screen are specifically made by the researcher for the Green Kids' Museum and are therefore not included in the estimated cost. Should the Green Kids' Museum decide not to use the researcher's visuals, it needs to find appropriate photographs for use in the game. If these photographs are protected by copyright, the licence fees for the photographs need to be added to the total cost.

Requirement evaluation

In this chapter the product is evaluated according to the requirements which were determined and obtained during the research phase. In theory the product fulfils all requirements. Yet in practice, only once the product is actually used can be evaluated if all requirements are met, hence some alterations might still be needed. The progress of each requirement is rated with the help of a progress bar. A full bar shows that the requirement is fully met and no additional testing is necessary. A partially full bar shows that the requirement it not yet fully met or tested, so some adjustments or additional testing is necessary.

1. *The product should not physically harm the user in any way*

The risk of injury is minimized in the design of the product. Cavities between buttons and base plate have been made small enough to avoid any body parts getting stuck in between, the electronics are completely hidden at the back of the game and cannot be reached by the user, a stop ('lock') is added at the top of the installation to avoid the game from falling- or being lifted off the wall by the user, and the game contains no sharp edges or rough wood so the chance of being cut while playing the game is minimized.

2. *The product should not mentally harm the user in any way*

During validation with the target group no signs of mental harm were detected.

3. The product should raise awareness about biodiversity and/or ecosystems via either understanding the interconnectedness of a food chain within an ecosystem in Kenya or recognizing the different ecosystems in Kenya
The learning objective of the game is to recognize the different ecosystems in Kenya. Validation with the target group showed that children reach this learning objective by playing the game.

4. The product should be considered playful by 9 to 11 year old Kenyan children (Gray, 2013)
The game has characteristics of play that make the game playful for 9 to 11 year old Kenyan children. Both the process of playing the game and the outcome of the game are equally important. The game is played in an alert and active, yet relatively stress-free frame of mind. Yet, the game cannot be played in multiple ways meaning the game does not leave much space for creativity. Adding this factor could therefore improve the game.

5. The product should keep the attention of 9 to 11 year old Kenyan children for at least 5 minutes (Ward, 2020)
During validation with the target group children took on average 5 minutes to finish the game. All participants managed to keep their focus on the game and did not get distracted by other things whilst playing.

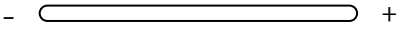
6. The product should be able to be used by both one child or two children at the same time
The game can be played alone or by multiple people at the same time, discussing the choices they make, however it is not specifically designed as a multiplayer game.

7. The product should be able to be used by all genders
The product is not gender specific. The product was tested by both boys and girls and no clear difference between the way they play the game or their responses was detected.

8. The product should be able to be used by both left handed and right handed people
The product can be played by both left handed and right handed people as the buttons can be pressed using either hand.

9. The product should be able to be understood by the user without reading the instructions
Validation with the target group showed that, for children to understand the game, the product does not need any additional instructions apart from the instruction that is on the game, that says: "In what ecosystem does the animal live? Press the animal and the correct ecosystem to make a match".

10. The product should withstand an overall use of 6 days a week, 9 hours a day (Green Kids' Museum, 2022)
It has not been tested if the product can stand the determined daily use, as this can only be validated when the product is in actual use. However, the product is manufactured in a way that its lifespan is elongated. The product is made from durable materials and the wood has a coating that makes it waterproof. The product can also be fully taken apart making it easy to replace or repair a part when necessary. Finally, the chance of breakage is reduced by, amongst others, levelling the button with the base plate so that users are less likely to slam the button, and placing the electronic wiring in such a way that it is fixated to the back of the installation and therefore does not move when the buttons are pressed.



11. The product should withstand rough play
The game is made up of parts and materials that can withstand rough handling. For example, the core of the button is a standard emergency button, tested on numerous levels, including rough handling.

12. The product should withstand moisture and grease from human touch
The wood has been coated with linseed oil which makes the wood waterproof and easy to clean. Therefore greasy fingers can be easily removed from the surface.

13. The product should be able to be fully produced, used and recycled in Kenya
The product will be made by four manufacturers in Kenya using materials mostly sourced from within the country. The product will be used in Kenya and recycled at one of Kenya's many recycling factories. It is assumed that by the time the product reaches the end of its life, the MDF can also be recycled in Kenya.

14. The product should be produced by manufacturers that take sustainability into account when creating a product
During the evaluation of the manufacturers, they have been asked about their sustainability efforts during production. At least three out of four manufacturers claim to apply sustainable production processes. During further development of the product it should be assessed if these claims are true and if they meet the standards of the Green Kids' Museum. The fourth manufacturer did not provide information on their sustainability efforts hence this needs further investigation.

15. The product should be able to be recycled or reused
The product can be fully taken apart making it easy to correctly recycle all the different materials. The product has a linseed oil coating that can also be recycled together with the wood. The same goes for the ink in the pictures on the button caps.

Evaluation of learning objective versus target group

To evaluate if the game fits the 9-11 year old target group Bloom's Taxonomy can be used. This is a framework used to categorize educational goals. It consists of 6 layers with each layer reaching a deeper educational goal. The layers are (Armstrong, 2010):

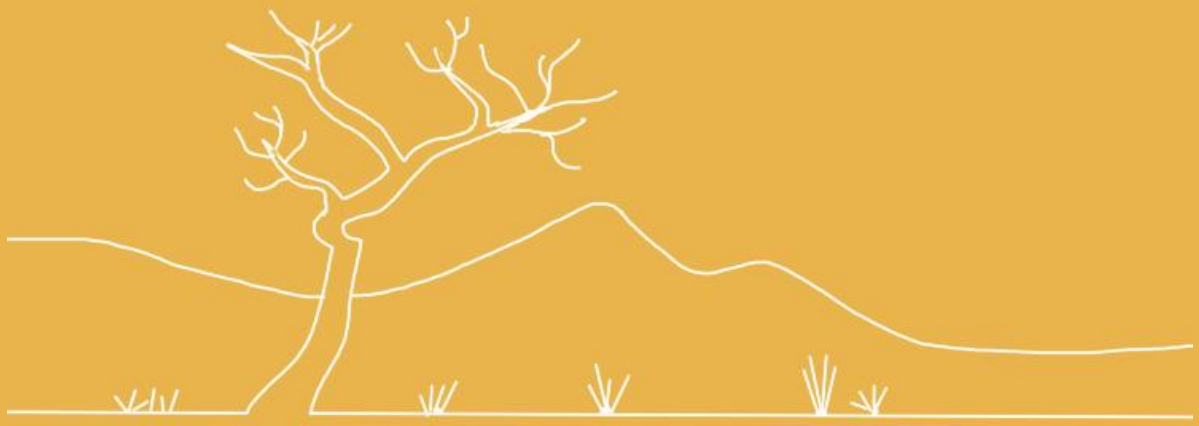
1. Remember: recall facts and basic concepts
2. Understand: explain ideas or concepts
3. Apply: use information in new situations
4. Analyse: draw connections among ideas
5. Evaluate: justify a stand or decision
6. Create: produce new or original work

The Great Kenya Eco Challenge game itself is at level 1-Remember, as the user applies current knowledge to play the game. Whilst playing the game the user learns about Kenya's ecosystems and the animals that live there as fun facts are voiced throughout the game. Afterwards, during the quiz, the user gets to explain what the different ecosystems are and what characterises them, bringing the game to level 2-Understanding of Bloom's Taxonomy.

The learning objectives for the 9-11 year old target group, created by the Green Kids' Museum, are that children are able to:

1. Summarize what an ecosystem is
2. Recognize the different "roles" in an ecosystem
3. Discuss the interconnectedness of an ecosystem
4. Consider their own role in an ecosystem
5. Give examples of human impact (good/bad) on ecosystems

Especially the last three objectives better fit level 3-Apply. Therefore The Great Kenya Eco Challenge is more appropriate for 6-8 year old children rather than the desired target group. Since the museum's target audience includes the 6-8 year old age group, the installation is still a good fit for the Green Kids' Museum.



Chapter 9: Conclusion

We live in a world where biodiversity and ecosystems deteriorate at rapid speed. The new generation needs to be made aware of the importance of different and diverse ecosystems, not just for the animals and plants within that ecosystem, but for human survival itself. The Great Kenya Eco Challenge can be a playful contributor in raising that awareness.

The aim of this project was to design a play-based exhibit piece for the Green Kids' Museum in Kenya with the objective to raise awareness regarding biodiversity and ecosystems in a playful manner, targeted at 9 to 11 year old Kenyan children. The research has shown that The Great Kenya Eco Challenge helps 9 to 11 year old Kenyan children recognize the different ecosystems in Kenya by matching different animals with the ecosystem they live in, although it does not fully meet the educational level the Green Kids' Museum wishes the installations targeted at this age group would have. Therefore the game better fits 6 to 8 year old Kenyan children.

Below the feasibility, viability and desirability of the product is concluded.

Feasibility

Research has shown high feasibility of the product, as it can be fully manufactured in Kenya. Four different manufacturers in Kenya will produce and assemble the product with materials sourced within the country. The product can be made from widely available and standard materials and parts. Manufacturing of the game is not dependent on the selected manufacturers. Any other manufacturer that has the necessary skills could manufacture the part, which reduces dependency on selected manufacturers. Moreover, the game could also be replicated and manufactured for other museums around the world and therefore share knowledge of ecosystems to children in other countries than Kenya.

Viability

To ensure viability of the game, the different parts of the product can be easily maintained, repaired and/or replaced. The game consists of standard parts sold across the globe hence easy to purchase. Moreover, assembly and disassembly is simple. None of the parts are permanently attached to each other hence repair or replacement of each part is simple, low in cost and effort.
Maintenance could best be performed by Geviton since they built the game's electronic circuit and are therefore best placed to carry out repairs. However, given the composition of the game with standard electronics, any electrician or handyman could very likely repair or replace parts.
Other elements that increase the product's lifespan is the added coating on the wooden parts of the game. Both the wooden buttons and base plate are rubbed in with linseed oil to make sure it is waterproof and durable. The same goes for the coating on top of the pictures on the button cap. The coating will make sure the images stay in its original state.

As the game teaches children about the different ecosystems in Kenya, which are in itself stable, the information will still be relevant in the future. The information will actually be even more relevant, as children are getting more disconnected from nature. This game will help children keep in touch with nature, even if they live in cities and come less in contact with wild animals. The game can evolve over time and tackle themes that are relevant at that moment, such as the preservation of bees, a theme that needs attention right now. Another version of the game could be about endangered species giving these animals a platform through the pictures on the buttons. The pictures can easily be updated by replacing the button cap and printing a new picture on top (and adding the coating).

Desirability

During this project no further validation was done on the need for such a game. It has been assumed that the Green Kids' Museum has extensively researched the need and desire for installations that teach children about biodiversity and ecosystems in Kenya prior to the museum's foundation. What was however tested is if children in the target group enjoy the designed game, if it fits their level of desired complexity and if they learn from the game. The first iteration of the game was not complex enough and the children actually desired a game that would better fit their level of desired complexity. Therefore more (less familiar) animals were added to the game, which was suggested by some of the children. The validations with the target group also showed that with this game the learning goal of recognizing the different ecosystems in Kenya was reached, which was a desire of the Green Kids' Museum.

Limitations

During the validation of the product some limitations occurred. It was not possible to validate the product using a physical prototype in Kenya with Kenyan children. Therefore the validation had to be split in two parts: a physical prototype could be tested on location and an online prototype could be tested remotely. The physical test had to be done with participants that could be physically present at the location of the prototype. The participants available at that moment were non-Kenyan children from an international school. The online validation was done by a group of children in Kenya of which one parent is Kenyan and the other is Dutch.

Another limitation of the validation was that the prototype used during the physical test was a paper prototype using the Wizard of Oz technique. This therefore lacked some of the mechanics the real game would have. One could question if the participants could look beyond that. When asked what would improve the game, the test group at the physical location responded with suggestions to make the game more real, using real mechanics. A working prototype might have resulted in different feedback.

The physical test took place at the Industrial Design faculty in one of the project rooms. This is not similar to the surroundings of a real museum, which could also have led to different results.

Recommendations

The game has been validated in Kenya using participants of which one parent is Kenyan and the other is Dutch. This group of children was the closest match to represent Kenyan children of which both parents are from Kenyan descent. The decision to go with this test group was driven by time restrictions and availability. However, when further developing the product it is recommended to build a physical prototype in Kenya and have the product tested there with Kenyan children of which both parents are of Kenyan decent. These children might respond differently to children where only one parent Kenyan. The game can then be altered according to the outcome. It is also useful to have the validation take place in a museum, as the surroundings might influence the outcome of the results.

It is also suggested that the game is validated with children outside the age range of the target group, used during the validation phase. The museum will not only be visited by children between 9 and 11 years old, but also children younger and older than that. Will these children still understand the game and perceive it as fun? This should be validated during the further development of the product.

Finally, it could be interesting to see if non-Kenyans also understand and enjoy the game as tourists will be visiting museum as well.

Personal reflection

In my project brief I expressed the wish to design for children from a country and culture completely new to me. Although I was not able to visit Kenya during the course of this project, I really got to appreciate the country and its people. During the various conversations with the Kenyan children and manufacturers I was touched by their support, patience and kindness.

This project has been an amazing, inspiring and educational journey from start to finish. I would like to sincerely thank Mathieu Gielen and Arnold Vermeeren for their inspiration, support and commitment. Mathieu and Arnold challenged me to the max, resulting in a strong design, fit for the Green Kids' Museum. A special thanks to Evy van Weezendonk, the founder of the museum. Evy provided the opportunity to work on a project that allowed me to use all my skills and creativity as no boundaries were imposed. I hope to stay in contact with Evy after the project as I genuinely love the mission of the Green Kids' Museum and really want this museum to become successful.

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