# GEOTRICITY

## an interactive installation to playfully foster awareness around renewable energy at the Green Kids' Museum Kenya

MASTER THESIS

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# GEOTRICITY

Playfully fostering sustainability at the Green Kids' Museum Kenya


**Master thesis**
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July 2022

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# Preface

My master Design for Interaction has been a discovery of who I am as a designer and how I envision my future. I have done many great projects, with the cherry on top being my graduation project.

This project was a combination of everything I never thought I would find in one project. During this project, I was able to combine my passion for interactive exhibition design with my interest in children's play. And of course I had the fantastic opportunity to discover a new culture and city: Nairobi.

I would like to thank client Evy van Weezendonk for providing this project. Thank you for your reliable support and the inspiring conversations. To my mentors Mathieu and Arnold I would like to express my gratitude, thank you for constantly keeping me sharp and your consistent helpful feedback.

Next I would like to thank all the people who helped me during my research and with testing, especially Mwaniki, Justa and the students of the Nairobi Jaffery Academy. Finally, I would like to express my appreciation to all the people who were present to give me input, support and motivation.

With this report, I hope to give you an insight into my graduation project that I have been working on for the past 5 months. Along the way I learned a lot about play-based learning, renewable energy and children's museums but most of all about myself.

I hope you enjoy reading it.

Kind regards,

Marit van Grinsven

# Summary

This project is in collaboration with the Green Kids' Museum Kenya, which will be the first interactive children museum in East Africa. The museum will become a place for children of age 6 to 14 to learn, inspire and explore, with sustainability at its core.

The purpose of the project is to propose an interactive design to playfully foster awareness around renewable energy at the Green Kids' Museum Kenya, in specific for children aged 9 to 11 living in the Nairobi metropolitan area.

An effective and engaging way to educate children is by providing a play-based learning experience as it capitalises on the motivational abilities and engagement of play. In order to provide such an experience the target group first needs to be triggered to engage with the installation. Once the children are interested in the installation they need to be able to playfully explore, experiment and reflect on the implementation of renewable energy. After which the children will leave the installation with a sense of pride, due to the gained learning experience.

To support the play-based learning journey and to ensure that an exhibition is engaging for children, 12 guidelines have been developed, based on a creative session with children, interviews with stakeholders, museum visits and literature review. Each guideline corresponds with an underlying need of children: support children with different interests, give children the feeling that they are in control, allow children to take a break to reflect on their experience, enable discovery, emphasise the feeling of fellowship, challenge the abilities of the children, provide a clear and simple introduction, allow children to take risks, trigger their senses, reflect everyday life within the installation, utilise humour and create an aesthetically pleasing experience.

The guidelines formed the basis for developing the design Geotricity. Geotricity consists of a table with an interactive landscape projected on it. The challenge for the children is to provide energy to the houses on the table. To accomplish this, the children can place elements that represent renewable energy power plants. Placing an element causes the projection to change accordingly. If a power plant is placed in a correct position, the lights in the corresponding houses are turned on. Through exploration, experimentation and reflection the child will learn about the implementation of the different renewable energy power plants.

Based on an evaluation test with Dutch children at the age of 10, it appears that the concept is experienced as engaging and provides children the opportunity to playfully explore and experiment with the applicability of power plants. Once they properly positioned an element and made a house light up, the children felt a sense of pride.

Further research needs to be conducted to establish if the design has the same impact on the target group of children aged 9 to 11 living in the Nairobi metropolitan area and to determine whether the experience has the desired educational impact.




*Figure 0: Impression of the concept Geotricity*

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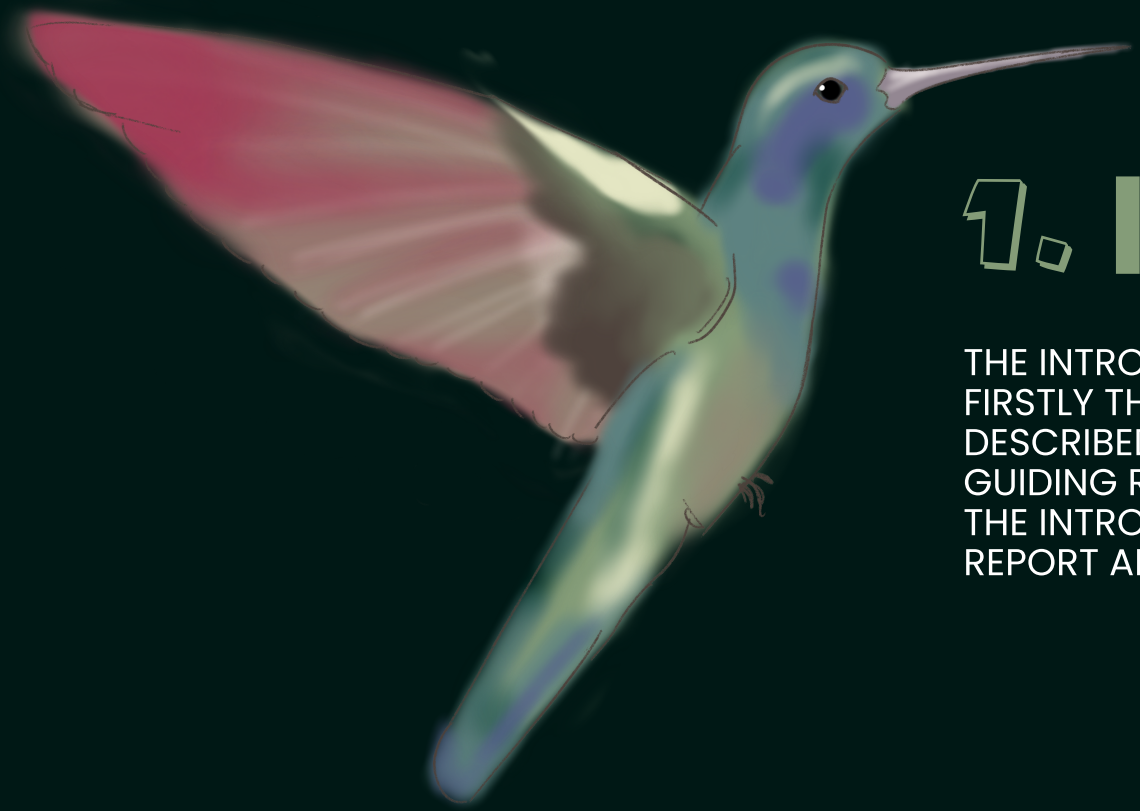
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# 1. Introduction

THE INTRODUCTION GIVES AN OVERVIEW OF THE PROJECT. FIRSTLY THE BACKGROUND OF THE PROJECT WILL BE DESCRIBED. THEN THE AIM OF THE PROJECT AND THE GUIDING RESEARCH QUESTIONS WILL BE PRESENTED. LASTLY THE INTRODUCTION WILL PROVIDE THE STRUCTURE OF THE REPORT AND AN OVERVIEW OF THE USED METHODOLOGY.

# 1.1 Green kids' museum

This project is in collaboration with Green kids' Museum Kenya. The Green Kids' Museum will be a playful museum in Nairobi where children will be able to interact with installations to learn about sustainability. The Green Kids' museum will be the first interactive children museum in Kenya, more so East Africa. The museum believes everyone can be a change maker, especially children as it is convinced that they are the future of the planet. The museum wants to empower children to lead us towards a greener future.

A museum offers visitors a unique chance to explore a topic autonomously. A hands-on, experience-driven museum provides the opportunity for an informal learning experience, allowing children to engage in collaborative and self-directed explorations (Henderson & Atencio, 2007). In addition, a study by Rix & McSorley (1999) shows that an interactive experience can contribute to the discovery of an enthusiasm towards a topic, ensuring long lasting gains of the learning results.

The museum will become a place for learning, inspiring and exploring, with sustainability at its core.

The museum itself is still in the development stage. The main themes of the museum exhibitions have been determined and the corresponding learning objectives have been defined. The different rooms will cover the topics of Biodiversity & Ecosystems, Consumption & Waste, Energy & Resources, Climate Change and the Power of One.

# 1.2 Background Green kids' museum

The Intergovernmental Panel on Climate Change estimates that human activities have caused approximately 1.0 °C of global warming. The root cause of global warming is assigned to the emissions of greenhouse gases due to human activities, which still continue to increase year after year. If the pollution of Earth continues at the current rate, it is likely that global warming is going to reach 1.5 °C between 2030 and 2052. One can assume that this change in temperature will result in a changing climate system and increased climate-related risks (Masson-Delmotte et al., 2018). These risks are related, among others, to health, food security and water supply. For example, due to the increase in temperature, both precipitation and droughts are expected to increase in frequency and/or intensity, thus affecting the food production.
The emissions of greenhouse gases resulting from human activities must be reduced in order to limit climate change.

A critical aspect of meeting the targets for greenhouse gas emissions is the public perception of climate change and its risks (Lever-Tracy, 2010). Climate change is a complex and constantly evolving topic, making it hard to grasp. This results in various perceptions of the topic even though it is widely discussed. In order to make climate change more apparent, Article 6 of the UNFCCC stipulates the commitment of parties to promote education, training, access to information, public awareness and public participation on climate change (UNFCCC, n.d.).

According to the Global Climate Risk Index of 2020, Kenya was in 2018 in the top 10 of countries who were most affected by impacts of weather-related loss

events, due to climate change. These events will become more frequent or more severe over time (Eckstein et al., 2019). Therefore, next to the goals set by the UNFCC, Kenya's Green Economy Plan calls for the promotion of qualitative and inclusive education as a strategy for enhancing sustainable livelihoods (Government of Kenya, 2016). This journey started with the introduction of the Competency-based Curriculum, in which Education for Sustainable Development is one of the six leading components (UNESCO International Bureau of Education, 2017).

It is important to make children aware about sustainability. By educating children they will be capable of contributing to healthy and sustainable ways of living, and they will build resilience and capabilities that equip them as active and informed citizens (Davis, 2010).
Besides, Lawson et al. (2018) argue that children can be a promising pathway to incite climate action among adults and thus create child-to-parent intergenerational learning, where both child and parent collectively become actively involved. This is because children have a unique perspective on climate change and are easier to incite to action (Lawson et al., 2019).

The Green Kids' Museum Kenya will reinforce this journey of learning about sustainability by means of an interactive children's museum. Some of the primary school aged children in the Nairobi metropolitan area might have encountered some of the consequences of the global climate change, such as changing weather patterns, droughts or extreme floods. Yet, as the Green Kids' Museum is the first interactive children museum in Kenya, the children are probably not familiar with the exploratory and interactive way of guiding through an exhibition which invites them to learn about sustainability by means of informative and engaging installations.

## 1.3 Scope

To scope the project, the focus will be on one of the themes of the museum: Energy & Resources. Kenya is becoming a pioneer in terms of green energy (Begisheva, 2018). Most of the themes require a change in attitude from the children. This leads to the challenge of conveying the urgency to change in a beneficial, yet gentle way. However, within the theme Energy & Resources the successful progressive attitude of Kenya in terms of renewable energy can be emphasised, which leaves more room to (solely) focus on the interaction between the exhibit and the children.

The Green Kids' Museum has formulated learning objectives for each theme using the Basic Education Curriculum Framework and the Sustainable Development Goals by UNESCO for Education 2030 (Green Kids Museum, 2021). With regard to the theme Energy & Resources, the following learning objectives have been defined:

- Define energy.
- Identify through images 3 sources of energy.
- Recognise images of a healthy environment.
- Label clean and dirty energy sources appropriately.
- Contrast various energy sources.
- Illustrate clean energy sources.
- Consider the effect on the environment of dirty energy.

# 1.4 Project aim

This project will explore ways in which an interactive exhibit can facilitate play-based learning for children of primary school age in the Nairobi metropolitan area with regard to the theme of Energy & Resources (Appendix A).
Translating the learning experience into a playful interactive experience should inspire the design of other installations for the Green Kids' Museum Kenya.
The following research questions are a means to reach the aim of the project:

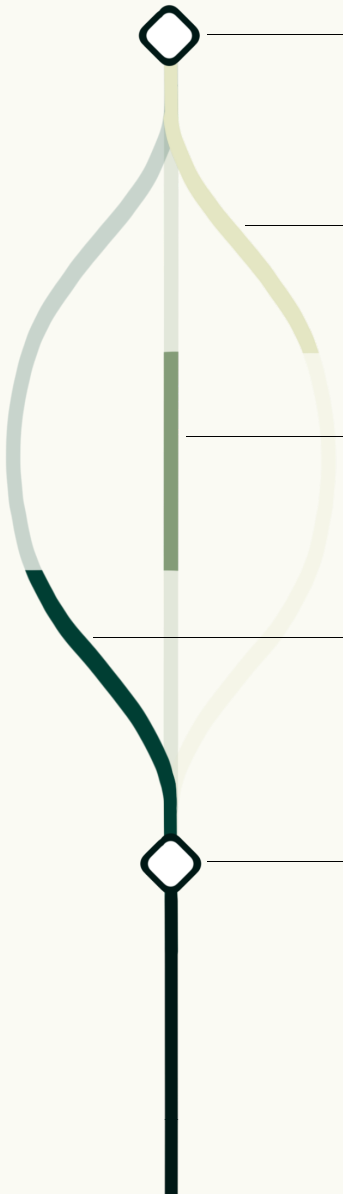
## Research questions

- What interactive, play-based experiences are currently available to children in Kenya?
- What are important (cultural) aspects that need to be taken into account when designing for Kenyan children?
- What is required for a play-based experience to be effective in order to learn about sustainability?
- What triggers children to engage with the play-based learning experience?
- What prior knowledge do the children have regarding (green) energy and what knowledge needs to be taught?

# 1.5 Project approach

Figures 1 & 2 on the next pages provide a visual representation of the structure of the report, showing the steps taken in this project to achieve the project aim. The report consists of two parts: exploration and design. Part one, the exploration phase, consists of researching the relevant topics of the project such as the target group and its stakeholders, play-based learning and renewable energy in Kenya. The research resulted in the intented interaction journey with corresponding guidelines. The exploration phase is used to shape the design phase, part 2 of the report. This part presents the final concept Geotricity by first highlighting the design goal followed by the ideation and iterations executed to reach the design of Geotricity. The design is presented and the validation of the concept is considered.

# Exploration



## Introduction

Context of project, project aim and the methods used in the exploration phase.

## Framing

Defining the target group of Nairobi primary school children age 9-11 and its stakeholders as well as the context of the museum.

## Play-based learning

Exploring the meaning of play-based learning and elaborating on play with regards to the target group.

## Energy

Exploration of the theme energy, to get an understanding of the current knowledge level and determine the learning goals for the exhibition.

## Findings exploration

Combining the key insights gathered in the exploration phase to create the intended customer journey supported by a set of guidelines which is used in the design phase.

*Figure 1: Project Approach part 1 Exploration*

# Design

## Design focus

Presenting the design focus by defining a design goal, interaction vision and design criteria.

## Ideation

Using a creative session and creative techniques to ideate and iterate on promising design directions, resulting in the final concept of Geotricity.

## Final concept: Geotricity

Presentation of the concept of Geotricity. As well the results of an evaluation test of the concept with a representation of the target group.

## Conclusion

Concluding the findings and formulating recommendations.

*Figure 2: Project Approach part 2 Design*

# 1.6 Methodology

Various research methods were used during the exploration phase of the project to gain insights into the research questions described in 1.4: Project aim. The methodology of the various methods will be briefly described in this section. The findings are integrated in the corresponding chapters 2: Framing, 3: Play-based learning and 4: Energy.

## Examine education

To create an understanding of the educational learning process for children in Nairobi age 9-11 and examine the knowledge regarding (green) energy, a schoolwork regarding sustainability was examined.
This was done by reading and completing exercises from a learner's book for grade 3 called Our World - Environmental Activities, which is used in the Competency Based Curriculum (CBC).

## Creative session with children

In order to identify what triggers children to engage with a play-based learning experience, determine their knowledge about energy & resources, and create an understanding of their expectations for the museum two creative sessions with an overall total of 8 children from Nairobi aged between 9-11 (mixed gender) were conducted.

In order to allow open communication between the facilitator and the participants, the participants were given a handmade bracelet, which functioned as a way to create a bond (Figure 3). The participants first filled in a booklet using pencils, pens, and colouring tools provided by the facilitator (Appendix B & C). The booklet was reviewed in advance by a Kenyan designer to examine if it corresponds with the learning methods in Kenya, a Dutch teacher to check the content and language, a Dutch boy of 11 years old to assess the comprehensibility of the assignments and a Kenyan teacher to assess the suitability for the target group.

During the exercise the facilitator observed the participants and discussed the answers in order to get an elaborated understanding of the preferences of the target group. After the participants finished the booklet, they were asked to draw their vision for the museum, with 2 to 3 participants sharing one large sheet of paper (Appendix D). The discussions among the participants were noted by the facilitator. Lastly the kids were asked to tell the facilitator what they drew allowing for some clarification.



*Figure 3: Friendship bracelets given to the participants of the creative session*

## Interview stakeholders

Semi structured interviews with parents (Appendix E) and teachers (Appendix F) were conducted to determine the expectations and vision of parents and teachers regarding the museum, in order for them to take their children on the trip. Before conducting the interview the participants were asked to sign a consent form (Appendix G).

7 participants were interviewed in a semi-structured style. The participants consisted of 2 teachers from Nairobi and 5 parents with children of the age between 9-11. 2 of those parents were residents of Nairobi and 3 were Dutch. The interviews were conducted at the place of preference of the participant and took around 90 minutes. The interviews were audio recorded and notes were taken during the interview.

## Contextmapping

The gathered data of the creative sessions with the children and the semi-structured interviews with the parents and teachers were analysed using the Data, Information, Knowledge and Wisdom (DIKW) analysis (Sanders & Stappers, 2012). With the goal to determine important aspects that need to be taken into account when designing for children in Nairobi.

In the information phase the quotes and observations were interpreted by the researcher in a statement card (Figure 4, Appendix H). Next, the statement cards were clustered (Appendix I). The different patterns between the clusters are described in the knowledge phase, resulting in the insights relevant to the project (Appendix J).

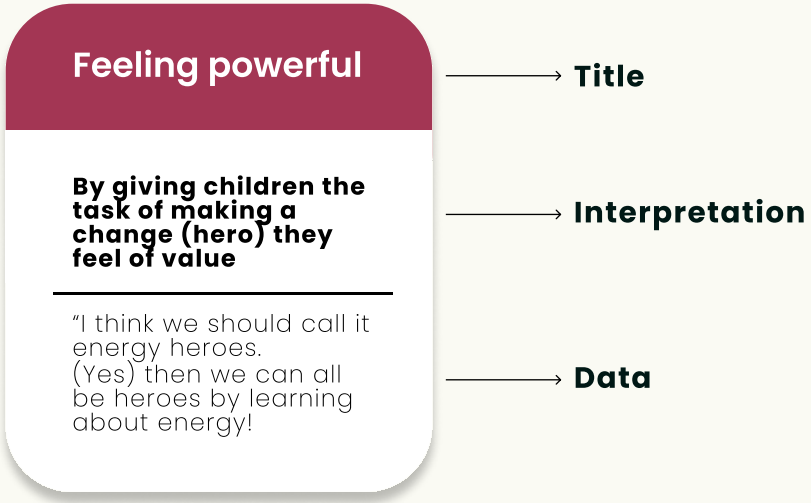



*Figure 4: Example of a statement card*

## Nairobi trips

To create an understanding of the currently available interactive, play-based experiences in Nairobi, 7 trips, often made by children age 9-11 in Nairobi, were visited by the head researcher.

The researcher noted her impressions of the activity and took pictures of the interactive elements. In addition, children present at the trip were observed to form an impression of their perception of the excursion. It needs to be noted that, despite efforts not to interfere, children would occasionally pause from their tasks to direct their attention to the researcher.

## Visit museums

In the Netherlands 4 interactive children's museums were visited to estimate what triggers children to engage with the play-based learning experience.

The same procedure was followed as for the trips in Nairobi by which the researcher noted down her impressions of the museum and observed children who were currently present at the museum, without interfering in the activity.

## Literature review

The goal of the literature review is to support findings of research conducted for this project (see previously described methods) and provide insight into the effectiveness of a play-based learning experience, energy use in Kenya and the culture of Kenya, more specific Nairobi.

Google Scholar was used to find relevant literature which was then examined. The insights were used to formulate or support the findings.

PART 1

# Exploration

*Glossary*

**Play-based learning**
Essentially learning through play. An effective way to educate children as it capitalises on motivation and engagement of play (Jahreie, et al., 2011).

**Guidelines**
A set of 12 guidelines as a result of the exploration phase in this project with the aim to support the play-based learning journey and to ensure that an exhibition is engaging for children.

**Renewable energy**
Energy that is generated from natural sources, of which the replenished rate is higher than the consumption rate. Generating renewable energy creates far lower emissions than burning fossil fuels (United Nations, n.d.).

**Power plant**
A power plant is an industrial facility in which energy is generated.



# 2. Framing

THIS CHAPTER FRAMES THE PROJECT. THE TARGET GROUP IS HIGHLIGHTED, FOLLOWED BY ITS STAKEHOLDERS. NEXT THE CONTEXT OF THE MUSEUM IS ADDRESSED.

# 2.1 Target group

In Kenya there is a Free Primary Education program, which enables every child to attend primary school. The schools that offer this free program are public schools. Besides the public schools, there are also private schools. Parents who can afford to do so often choose to place their child in a private school as they have quality concerns about public schools (Zuilkowski et al., 2018). The museum's focus is mainly on children from middle to high income families, as they contribute most to sustainability and have the resources to visit the museum. This group of children almost always attends private schools. However, it was noted that among private schools, there is still a significant diversity in status.




*Figure 5: Representation of target group during creative session at Jaffery Academy Nairobi*

The museum is aimed at visitors aged 6 to 14 living in the metropolitan area of Nairobi, Kenya. The Green Kids' Museum Kenya has divided the children into 3 age brackets with corresponding learning objectives. As the group of 6 to 14 year olds can differ significantly in level, it is decided to select one of the age brackets, 9 to 11 year olds, as divided by the Green Kids' Museum Kenya. The focus of 6 to 8 year olds is mainly on creating a basic understanding of the various themes in the museum. 9 to 11 year olds are expected to also be able to understand and apply their knowledge of the theme in the museum. For the last age bracket, 12 to 14 year olds, it is expected that they can implement the knowledge and bring it into their daily lives after their visit to the museum (Green Kids' Museum, 2021). To extend the learning experience beyond a basic understanding of the theme while also leaving room to design a playful experience which can be evaluated within the scope of the project, it was decided to focus on the age bracket of 9 to 11 year olds (Figure 5).

In order to get a perception of the culture of the learning child in the Nairobi metropolitan area, an onion model was developed, see Appendix K. The onion model presents the cultural practices of the target group by mapping its symbols, heroes, rituals and cultural values (Van Boeijen, 2015). The model functioned as a starting point to get familiar with the target group and was later revised based on insights gathered in the exploration phase of this project.
The most relevant insights will be discussed in part 1 of the report.

# 2.2 The culture of the learning child in Nairobi

During the exploration phase, impressions were gained about the culture of the learning child in Nairobi. These are subjective impressions of the head researcher.

Based on the workbook used in schools (Figure 6, see 4.4: Current knowledge of the target group), it appears that a lot of visual representations are used in the assignments. Almost all images are of the local context, which is recognisable for the target group. The school material does not represent a global perspective. The booklet used during the creative session with children also contained a lot of visual material, which resonated with the target group. It is therefore likely that visual representation and its recognisability are important aspects in the culture of the learning child.

In addition, the workbook showed that the children are often asked to work independently first, and then to share their insights with others, such as peers, parents or in class. This also emerged in the creative session with childeren, in which the they first worked independently and then, towards the end, increasingly discussed their ideas with each other. In general, the target group is very focused on the community. They care a lot about their families, peers or fellow citizens persuing a collective perspective. One way in which this is represented is the urge to complete tasks together.

Furthermore, the number of homework assignments where the parents have to assist the children is noticeable. This was also indicated by one of the interviewed parents from Nairobi, he mentioned that he had to help his son with homework for about an hour a day. Parents are therefore used to being part of the learning process of the child, which may influence their role in the museum and the application of the sustainable knowledge at home.

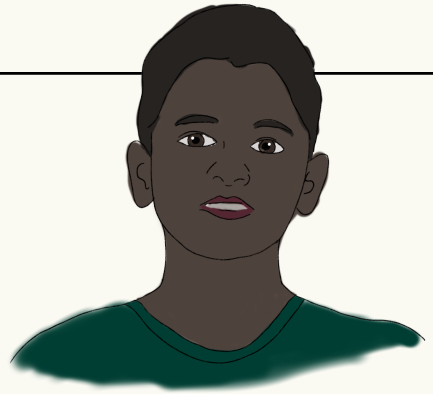
Finally, the school material showed that at the start, the child is asked a question, next they learn about the subject and afterwards the same question from the start is asked again. In other words, the narrative reappears, with the moral becoming clear at the end. If the children are indeed familiar with this approach, it could be useful in an installation to start and end with the same or similair narrative.




*Figure 6: Pages of the workbook Our World used in primary schools in Kenya*

# 2.3 Stakeholders

There are several stakeholders that play a role in the child's experience. Figure 7 provides an overview. All stakeholders are briefly discussed on the next page. The project focused mainly on the target group, but several perspectives of the stakeholders were considered.



## Child

A resident of the Nairobian metropolitan area age 9 to 11, attending a private school.

**Need**
A playful experience that unconsciously educates the student about sustainability.

## Parent

**Role**
Guide the child through the museum

**Requirements**
Wanting child to enjoy and have a pleasant time

**Influence**
Project interests



## Teacher

**Role**
Empower learning objective, continue learning experience

**Requirements** Wanting children to relax while being informed

**Influence**
Strengthen learning



## Other visitors

**Role**
Reinforce learning experience by in-depth discussions

**Requirements**
Relax and have fun

**Influence**
Create engagement with topic and installations



*Figure 7: Target group and its stakeholders*

## Parents

In the interviews, it became apparent that parents (both Kenyan and Dutch) generally decide together with their children which activities they will undertake. The most important thing for parents is that their children have a good time; that way, they enjoy it themselves as well.

The observations during the Nairobi trips and museum visits as well as literature review showed that parents play an important role in their children's engagement with the museum (Henderson & Atencio, 2007). Some parents take the time to explain the topics to their children, their enthusiasm often influences how much the child is interested in the content. Other parents follow the children around without being involved in the exhibition themselves.

## Teacher

For the learning experience it is beneficial to have a co-operation between the museum and teachers. Museums can engage children in self-directed learning. Linking informal learning in the museum to formal learning at school optimises the learning experience (Henderson & Atencio, 2007).

The interviews with teachers indicated that a school trip should above all be a relaxing experience. The trips function as a way to have a shared experience among all the students. The educational value is seen more as an advantage rather than a requirement.

## Other visitors

Literature research showed that peer interaction is beneficial for children, in particular it can help children grasp a concept. In addition, peer learning can stimulate interest in challenging tasks, enhance the learning performance and foster prosocial behaviour (Damon, 1984). During the creative session, the influence of peers was validated. The target group discussed the topics among themselves, which led to exploring the topic more elaborate and gaining new insights (see 4.4: Current knowledge level).

## Environment

The museum's environment is an important factor to take into account. Environments can encourage or stifle play (Henderson & Atencio, 2007). For instance, compared to indoor play, outdoor play helps with more physical activity and allows children to be more assertive (Kemple et al., 2016) Other factors that can influence play is the amount of players, the provided materials, and the arrangement of the space (Henderson & Atencio, 2007).

# 2.4 Museum context

The museum is still in the development phase and has yet to be built. The physical space is therefore still undetermined. To frame the project, a number of assumptions have been made about the context.

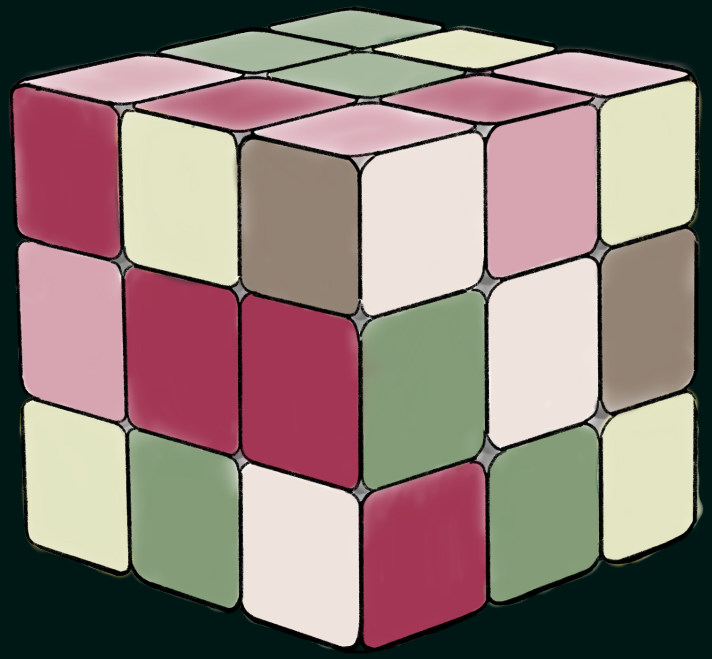
The museum will be built in the Ngong forest, using the existing nature as a part of the museum. The decor of the museum, such as the building materials, will also be part of the exhibition. In total, there will be 1500 square meters of exhibit area for the visitors to discover (Green Kids' Museum, 2021). A separate room will be available per theme, these rooms are connected with trails. All installations will be roofed in order to protect them from weather conditions. Lastly, the perspective of the child is central; the installations will therefore be on a children's scale.

The assumption is made that when entering a room the children are made aware of which theme is addressed. Therefore during the design phase, introducing the theme of Energy & Resources is not taken into account.

# 2.5 Conclusion

This project focuses on the target group of 9-11 year old children from the Nairobi metropolitan area from middle to high income families. The following insights are important to consider when designing for this target group:

- They are familiar with the use of visual materials, mostly representing a local perspective.
- They pursue a collective viewpoint, which results in them also wanting to share their insights with each other.
- In their schoolwork a repeating narrative is often used to reflect on their progress.
- When going on a trip both parents and teachers want the children to have an enjoyable time during which they can relax.
- Parents play an important role in guiding the children through the museum and the engagement with the exhibitions. Especially since parents of the target group already play a prominent role in the learning experience of the target group by helping with their school homework.
- Teachers can strengthen the learning experience by continuing the learning objectives at school.
- Peers can contribute to the engagement with a certain topic or installation.
- The environment, in this case a roofed museum in the Ngong forest, can encourage or stifle play.



# 3. Play-based learning

THIS SECTION EXPLORES THE TOPIC OF PLAY-BASED LEARNING. IT STARTS WITH DEFINING PLAY AND ITS BENEFITS. NEXT, IT ASSESSES THE PLAY PREFERENCES OF THE TARGET GROUP. 3.6 DISCUSSES THE CURRENTLY AVAILABLE PLAY-BASED LEARNING EXPERIENCES  IN NAIROBI AND 3.7 PROVIDES INSIGHTS GATHERED AT DUTCH MUSEUMS.

# 3.1 Play definition

"Every child has the right to play" is stated in Article 31 of the UN Convention on the Rights of the Children. But what is play exactly? Play is a rather complex phenomenon as it comes in many forms and shapes. This also means there is not one final way to describe play. This project uses a combined definition of play as described by Van der Bijl (2000). The definition is a collection of 9 characteristics of play:

- a spontaneous activity;
- focused on the process rather than the outcome;
- an activity with something or someone;
- by behavioural patterns, on one's own discretion and will;
- the creation of a pseudo-reality, marked by specified signals;
- an activity in various ways during human development;
- an activity that occurs under certain circumstances and conditions;
- an activity that meets wishes and needs;
- an activity that fulfils functions of relaxation, processing and practicing.

This project is aimed to design an exhibition which offers a play-based learning experience. Therefore, not all of the 9 characteristics of play described above have the same degree of presence. However, they were kept as a guideline in order to design a fulfilling play experience. The following four characteristics were taken into extra consideration during the design process:

- The child experiences it as a spontaneous activity;
- The experience with the exhibition focuses on the process, not the outcome;
- The exhibition creates a pseudo-reality, marked by specified signals;
- The exhibition fulfils functions of relaxation, processing and practicing.

# 3.2 Benefits of play

Not only is play a way to relax and leisure, play can have benefits on cognitive, social, emotional en physical development of children (Barnett, 1990). For each development level the benefits are shortly highlighted.

Firstly play has a beneficial effect on the cognitive development of children in terms of thinking ability, as children can most easily acquire knowledge through play. As part of the cognitive development of a child, play can stimulate the ability of problem solving and creative thinking. Next, play can benefit the social development; through social play a child can learn how to develop a bond, perform socially appreciated behaviour, work cooperatively and communicate. Peer interaction is a determining factor for social development in play. Thirdly the emotional development of a child can be supported by play, as it helps train emotional self-regulation. This is mostly done by reenacting a stressful situation. Lastly play has influence on the physical development of children by training their motor skills. Sensory materials stimulate the fine motor skills, while materials for moving involve coarse motor skills (Barnett, 1990).

# 3.3 Experiential learning

To describe play-based learning the experiential learning model of Kolb (1984) was used, see Figure 8. Experiential learning is "the process whereby knowledge is created through the transformation of experience" consisting of 4 phases. In the concrete experience phase, an individual is confronted with an experience. This experience is reflected upon in the reflective observation phase. In the abstract conceptualisation, one tries to make sense of what has been encountered, which in turn is tested in the active experimentation phase, resulting in a new concrete experience. The cycle therefore keeps repeating itself, which provides the learning process (Kolb, 1984).

By proposing an exhibition that utilises the process of experiential learning, using the 4 phases, and combining the elements of play, the target group can gain a play-based learning experience.

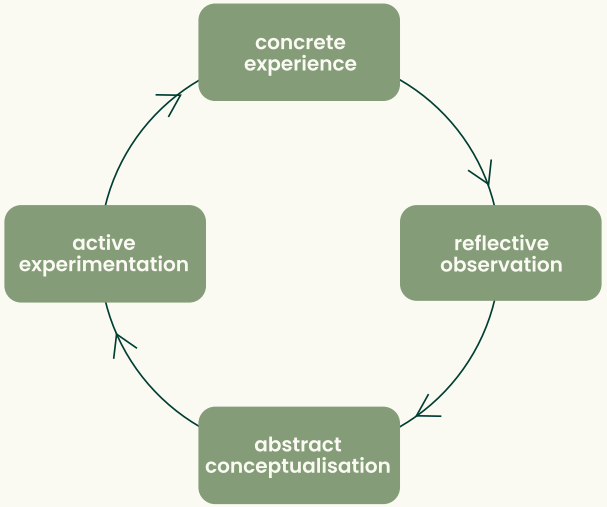



*Figure 8: Kolb's experiential learning model (Kolb, 1984)*

# 3.4 Play preferences

In the booklet of the creative session with the children, one of the assignments, 'pack your bag', required the children to select their favourite toys. Figure 9 indicates which toys were selected and how often.




*Figure 9: Selection of toys in the booklet's assignment "pack your bag" with the numbers indicating the amount of times the toy was selected.*

In 6 of the 7 completed assignments, the Rubik's cube was indicated as (one of) the favourite toy(s). However, it should be mentioned that in the process of asking a participant about the choice for the Rubik's cube, other participants could have been influenced to select this toy as well.
To define the type of play, the categorisation of Vermeer (1972) and Vedder (1977) was used. The Rubik's cube can either facilitate 'success play', by solving the Rubik's cube, or the play type 'playful handling of objects', by which the player discovers how the elements rotate and how the cubes can change places. Besides that the creative session with the target group showed that children experience this process of discovery based on exploration as playful, literature indicates that this process can be an effective way for children to create knowledge, skills and understandings supporting the learning experience (Gurholt & Sanderud, 2016).

The other selected toys also belong mainly to these two types of play. Other types of play that were represented are construction play (mainly by one participant) and fantasy & role-play.
During the creation of the booklet it was taken into account that all types of play were represented.

Besides their favourite toys, the booklet contained the assignment "where should we go" in which the children were asked to describe where they would like to go if they were to organise a school trip (Figure 10). Altough many different answers were given it was notable that the children would like to visit trips which connect to their personal interests. Every child has their own personal field of interest, such as history, care for animals or art, which differentiates them from others.

Besides, locations are mentioned where the children have already been and have fond memories of, wanting to repeat successes. For instance, one of the children mentioned a water park in Nairobi (The Waterfront) where the children went on their last school trip. When asked, the student started telling several stories about his experience.

Based on the creative session with the children it can be concluded that the preferred types of play are mainly the playful handling of objects and success/team play. When asked about selecting a trip they have a preference for familiarity and trips that connect with their personal interest, such as history, art or animals.




*Figure 10: Impression of the play preferences based on the booklet from the creative session with children*

# 3.5 Bridging the gap between learn & play

The study "Curriculum Implementation: Strategies for Improved Learning Outcomes in Primary Schools in Kenya" by Kisirkoi & Mse (2016), assessed that many learners at primary school in Kenya are not enthusiastic in class. The possible explanation given for this is that the education is teacher-focused, as a result of which the children do not actively participate.  By only being able to give a right or wrong answer to the teacher's questions, there is no room for exploration and discussion among the students.

In order to bridge the gap between learning and playing it is important that the museum allows the students to explore for themselves and interact with peers in order to make the learning process more engaging. Also see 4.4 Current knowledge of the target group.

To explore how a dull experience can be made more interesting, and with that the learning process in the museum, the booklet touched upon this topic (Figure 11). The children were asked to complete the following assignment:

***"Finally, we are on the bus! We have to drive a long way and just waiting is boring. How would you make the trip an exciting one?"***

One of the aspects that came up several times is the use of humour. Literature review indicates that humour creates a "sense of openness to discussion and/or interaction", due to the feeling of pleasure that humour brings. In addition, humour stimulates communication and it can enhance the motivation to learn. (Lovorn, 2008). Besides, humour can reduce stress, improve the mood of the child and enhance creativity (Hassed, 2001).




*Figure 11: Impression of the booklet from the creative session with children asking how a dull experience can be made more exciting*

In summary, in order to make a learning experience more playful and trigger engagement, both stimulating interaction between peers and humour can be effective tools.

# 3.6 Current play-based learning experiences in Nairobi

In order to get an impression of the kind of play-based learning experiences that are currently available in Nairobi, research has been conducted into the various school trips/ excursions that can be done within the city. This is a subjective examination by the head researcher based on a single visit, her insights are highlighted.

In Nairobi, several trips for kids are offered, such as in the Nairobi National Museum or on the Safari Walk, for an overview see Figure 12 on the next page. The trips presented in the Figure have an educational aspect.

Some of the trips include a playful element, but this does not affect the learning experience. It is merely a playful aspect, such as turning a disc for more information (Figure 13).

Furthermore, the information provided on these trips is presented in a factual and mundane manner. Observations show that the information is often not absorbed by children. In the example of the discs in Figure 13, children walk up to the discs to turn them over, but they do not take the time to read the information. This showed that children are interested in a playful experience at the trips with a educational focus, but are not yet facilitated with one.

For an extensive analysis of the playful experiences offered on these trips, see Appendix L.




*Figure 13: Flippable discs at the entrance/exit of the Safari Walk*




*Figure 12: Map of Nairobi representing trips provided in the city with an educational aspect.*



*Figure 14: Under the sea: an indoor playground at Village Market (Under the Sea, 2019)*

Besides the trips that have an educational aspect, there are some playgrounds, a water park and amusement centres in Nairobi, often part of a mall, for example the amusement centre "Under the Sea" (Figure 14). However, these experiences mainly focus on children younger than the target group and these experiences do not incorporate a learning purpose for the children.

In conclusion: there seems to be a gap between playing and learning at the trips offered in Nairobi, with few experiences currently combining the two. The Green Kids' Museum will therefore have a unique market position as it will offer children a play-based learning experience.

# 3.7 Play-based learning in Dutch museums

In order to form an impression of how a play-based learning experience is facilitated in museums, several Dutch children's museums were visited: Micropia, Museon, Naturalis & NEMO. During these visits, attention was paid to the interactive elements and children were observed to gain insight into the strenghts of the museum and installations. This is a subjective assessment of the head researcher, based on a specific moment in time.
Some insights, higlighted with a ★ are further explained in section 3.8 Play-based learning needs of target group, by presenting the underlying need of the child based on the contextmapping and literature review.

The insights, gathered by observations and the experience of the head researcher, are listed below, per theme. For an extensive analysis of the museums see Appendix M.

## Guiding through the museum

- Providing a tool, for example a stamp card**,** to guide through the museum is an effective way to keep children engaged with the exhibition, as the observations showed all children are actively involved in these types of activities. *(Museon & Micropia)*
- ★ By providing a clear trail or overview of the exhibitions children worry less about missing out on an installation or experience. *(Naturalis vs. Museon)*
- ★ By actively designing areas to take a break, the museum gives visitors the opportunity to catch their breath. *(Naturalis vs. NEMO)*

## Providing information

- Elaborated texts with information are often not read, the exhibition should speak for itself. However, a small and concise explanation can help convey the message of the exhibition. *(Museon)*
- The key information needs to be provided directly, if it has to be accessed by performing several tasks it is often overlooked. *(Micropia)*

## Engaging elements

- ★ Moving elements, such as water or balls running down a trail create a sense of interest among children. *(NEMO & Museon)*
- ★ By using the decor and triggering the senses of the visitors, for example with sounds, the story of the installations is enhanced. *(Naturalis)*
- ★ Tasks that allow children to test their abilities, for example by timing the activity, are often performed several times in order to improve or compete with peers. *(NEMO, Naturalis & Museon)*
- Children liked hands-on analog experiences which they could manipulate, resulting in immediatly seeing the, real life, influence. *(NEMO & Museon)*

## Interaction between visitors

- The parents or guardians of the children have a lot of influence on the experience of the child. They either help the child to understand the exhibition, taking the time to explain and engage. Or they only guide the children through the museum without interfering. *(Museon & Micropia)*
- By providing tasks to children which they can solve together, peers can help each other to tackle the challenge and stimulate the creativity, see Figure 15. *(Museon)*




*Figure 15: Planet One exhibition in Museon in which children could build a power circuit, helping each other to solve the challenge*

The museum can thus support visitors in focusing on the play-based learning experience by making navigation through the museum straightforward, keeping text concise and accessible, and giving children space to explore for themselves.
The children seem to be engaged by moving elements, triggering multiple senses and testing their abilities.

# 3.8 Play-based learning needs of target group

To explain why the elements mentioned in 3.7: Play-based learning in Dutch museums work well, the underlying needs of the child are discussed based on literature research and the contextmapping.
The highlighted insights from 3.7 are represented, the other insights are explained in other sections in the report.

## In control

Intrinsic motivation, meaning motivation based purely on curiosity or desire for mastery by the child, provides the greatest personal achievements and intellectual growth. Intrinsic motivation is promoted by a sense of competence, autonomy and relatedness (Cook & Artino, 2016).

A sense of autonomy refers to the control the child has over their actions. In order to support this feeling, it is important to give the child the possibility to make their own choices and give them a sense of responsibility (Cook & Artino, 2016). To encourage autonomy the museum should therefore enable children to decide for themselves how to spend their museum visit.
The contextmapping shows that children often become overwhelmed by the amount of installations, which can undermine their sense of autonomy (Cook & Artino, 2016). To support children, the museum can present them with an overview to ensure the children can focus on their play-based learning experience.

## Break

To optimise the use of their working memory the child should not be overloaded, therefore taking a break in a museum is essential to optimise the learning experience during the whole visit. In addition, a break can provide the opportunity to reflect on the child's experience. Reflecting and thus repeating the new knowledge is essential for the transfer of knowledge from the working memory to the long-term memory (Verstraete & Nijman, 2018).

## Triggering senses

The study about Curious Play by Gurholt & Sanderud (2016) argues that the movement of natural elements such as running water, swaying trees or the collapsing of sand gives children direct and varied sensual experiences, resulting in a profound curiosity.

A varied sensual experience not only leads to curiosity, but by stimulating several senses simultaneously, children become absorbed in the experience, resulting in a sense of immersion (Bär & Boshouwer, 2018).

## Challenge abilities

By allowing children to challenge their abilities in a playful way, they can achieve their personal goals (such as improving the time in which an activity is performed or solving a puzzle), resulting in the feeling of perceived mastery and achievement, in other words, competence. The feeling of competence can boost the intrinsic motivation of the child, see 'In control'. It is hereby important that the child has the feeling that they can perform the activity (Cook & Artino, 2016). This is in line with the children's preferred type of play: success play.

Besides, the creative session with children indicated that if the child can improve their abilities they are more keen to repeat the activity. By repeating the activity, the child can increase their learning experience, see 'Break'.

## Risks

Another component that was not found in the Dutch museums, but did arise from the contextmapping and literature review, is risk-taking. Taking risks is foundational for learning and development as it supports children to learn to trust themselves, understand their capabilities, recognise limits and identify when to ask for assistance (Karabon & Steiner, 2020). In addition, children also have a preference for play equipment that is more risky (Bourke & Sargisson, 2014). The reason for children to engage in risky play is explained by the thrill they feel when they are in a dangerous or risky situation, and after performing the activity, the thrill is replaced by excitement and pride in mastering the situation (Apter, 2007). This process was also described by one of the participants in the creative session with children.

Hence, giving children the opportunity to take risks is a means of supporting the play-based learning experience.

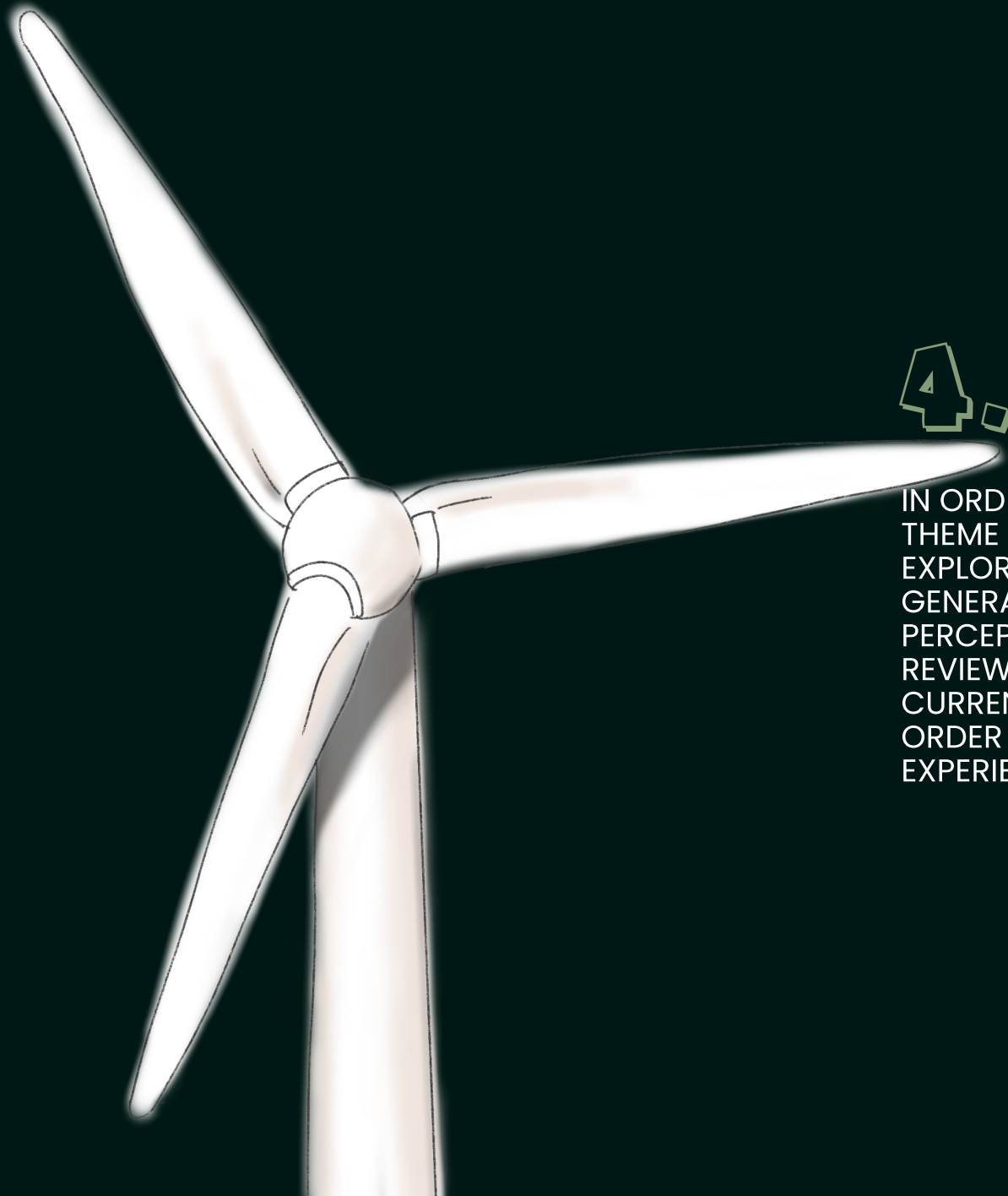
## Beauty

During the creative session with children in which the children drew their vision of the museum, it appeared that they desired a beautiful museum because they expected visitors to be interested in seeing the museum. This is supported by the literature indicating that aesthetics play an important role in promoting curiosity because wonder is easily aroused by beauty (Lindholm, 2018).

# 3.9 Conclusion

Currently, there are almost no play-based learning experiences when going on a trip to Nairobi, Kenya, despite that the target group is interested in exploring these elements. In order to facilitate a play-based learning experience the following aspects are important to consider:

- The journey should provide for experiential learning as described by Kolb (1984);
- Enable discovery, letting visitors explore and manipulate objects;
- Consider utilising humour to trigger the visitors to engage;
- Emphasis on the feeling of fellowship to stimulate the involvement;
- Help children through the museum in a pleasant way;
- The provided information in the museum should be concise and easy to access.
- Increase the intrinsic motivation to explore of children by giving them the feeling of being in control;
- Allow children to take a break between all the impressions;
- Provide stimuli for all the senses;
- Give the child a feeling of competence by challenging their abilities;
- Allow children to take risks;
- Enhance curiousity with beauty.



# 4. Energy

IN ORDER TO FORM AN UNDERSTANDING OF THE THEME ENERGY & RESOURCES THIS CHAPTER EXPLORES THE ENERGY CONSUMPTION AND GENERATION IN KENYA. NEXT, THE PUBLIC PERCEPTION ON THE ENERGY GENERATION IS REVIEWED. LASTLY THE CHAPTER EXAMINES THE CURRENT KNOWLEDGE OF THE TARGET GROUP IN ORDER TO PROVIDE THE MOST VALUABLE LEARNING EXPERIENCE IN THE MUSEUM.

# 4.1 Energy in Kenya

As stated in Chapter 1: Introduction this project will focus on the theme room Energy and Resources. To gain an understanding of the energy use in Kenya, this section presents an analysis of the amount of energy Kenya consumes and what resources are mainly used to produce this energy.

In 2019, the average energy consumption per person in Kenya was measured at 1849 kWh. It is important to note that about 70% of the total population of Kenya has access to electricity. Figure 16 shows the energy consumption of several countries, which indicates that the consumption in Kenya is significantly lower than the other countries.

In addition, Kenya is a pioneer in the field of renewable energy. In 2018 the International Renewable Energy Agency measured the renewable energy supply at 72.3% of the total final energy consumption.
For the remaining part non-renewable energy in Kenya mostly oil is utilised. A small percentage of 2% comes from coal (International Renewable Energy Agency, 2020).

For renewable energy the main resources are geothermal, hydro/marine and wind power plants. In addition, solar energy and bio energy also provide a small percentage of renewable energy (Figure 17). Figure 18 on the next page shows various renewable energy resources, each with a brief description of the resource.

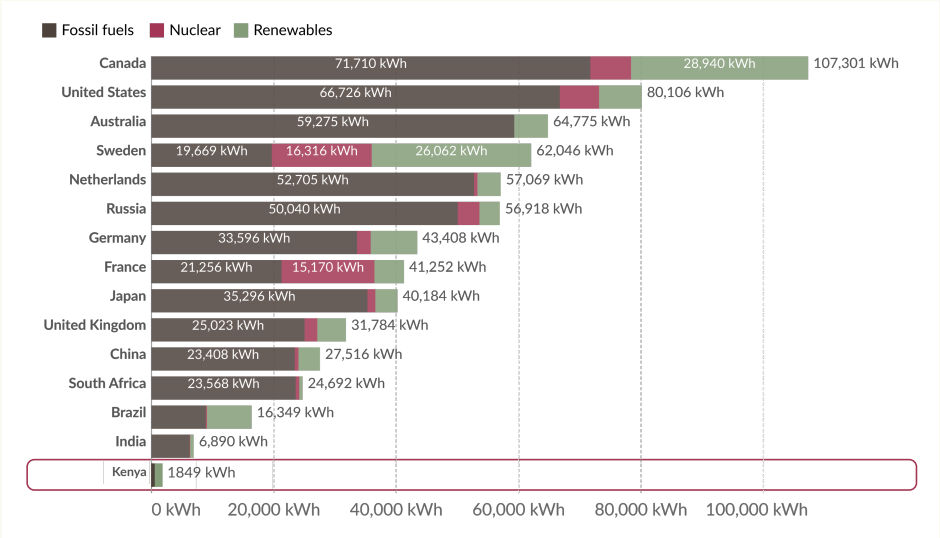



*Figure 16: Energy consumption from fossil fuels, nuclear and renewable per capita in 2019 (BP Statistical Review of World Energy, 2019)*

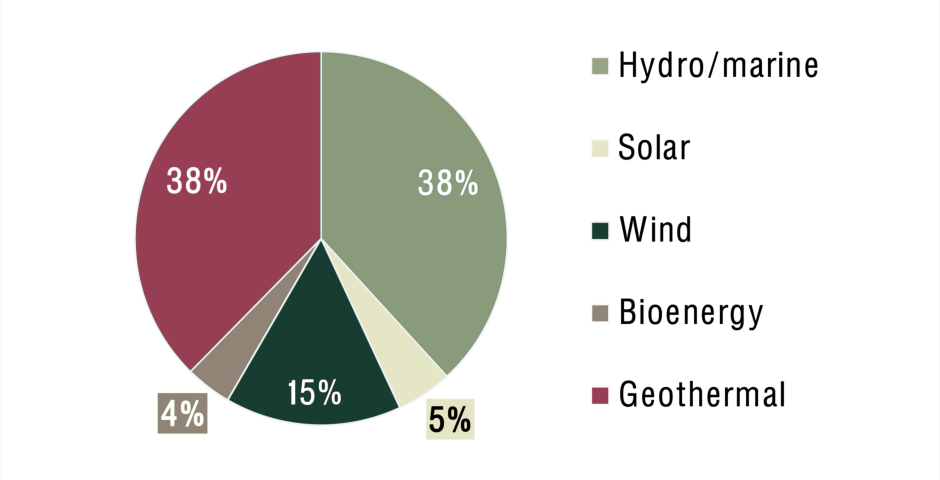
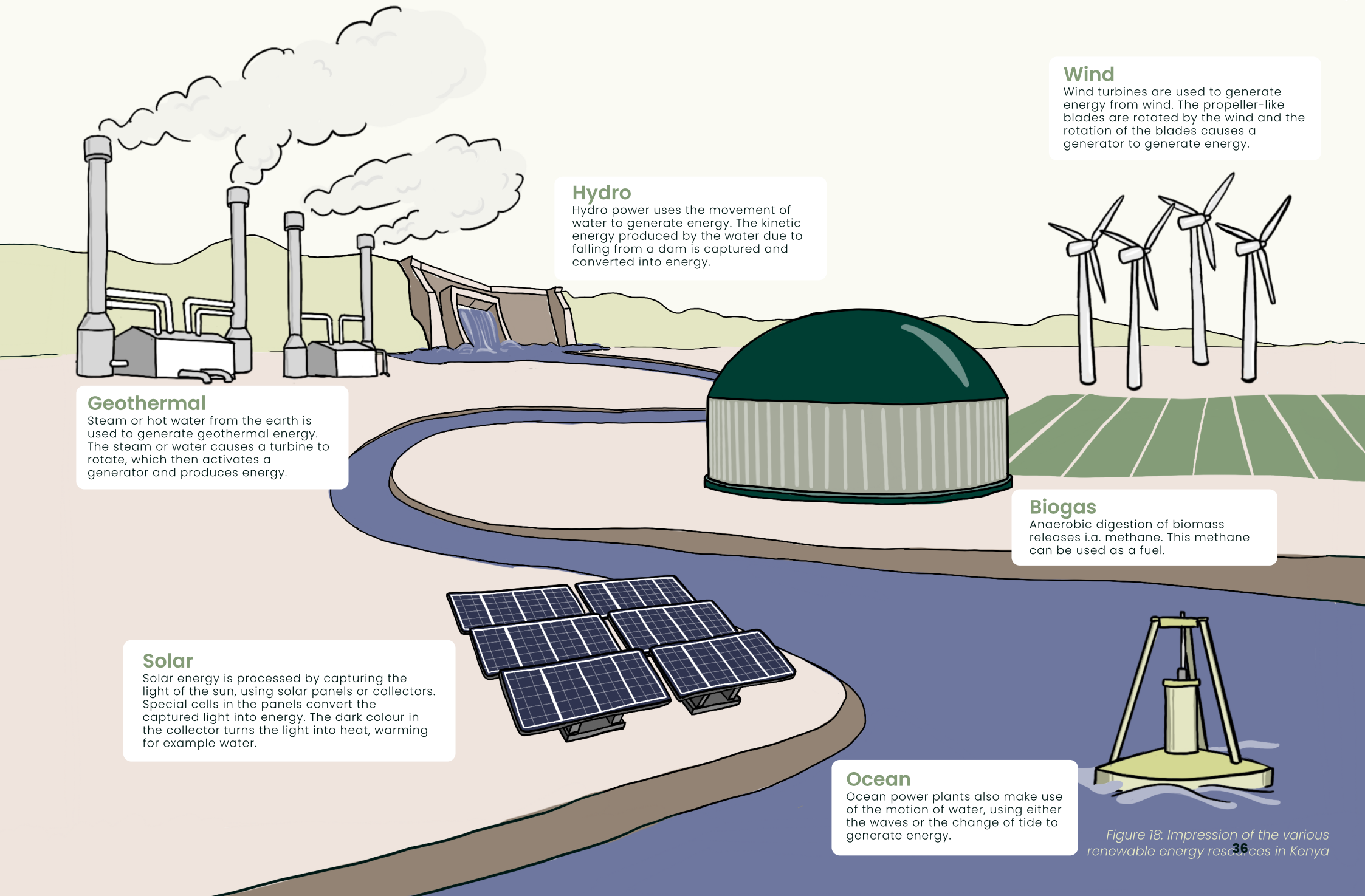



*Figure 17: Renewable energy capacity of Kenya in 2020 (International Renewable Energy Agency, 2020)*



## Wind
Wind turbines are used to generate energy from wind. The propeller-like blades are rotated by the wind and the rotation of the blades causes a generator to generate energy.

## Hydro
Hydro power uses the movement of water to generate energy. The kinetic energy produced by the water due to falling from a dam is captured and converted into energy.

## Geothermal
Steam or hot water from the earth is used to generate geothermal energy. The steam or water causes a turbine to rotate, which then activates a generator and produces energy.

## Biogas
Anaerobic digestion of biomass releases i.a. methane. This methane can be used as a fuel.

## Solar
Solar energy is processed by capturing the light of the sun, using solar panels or collectors. Special cells in the panels convert the captured light into energy. The dark colour in the collector turns the light into heat, warming for example water.

## Ocean
Ocean power plants also make use of the motion of water, using either the waves or the change of tide to generate energy.

*Figure 18: Impression of the various renewable energy resources in Kenya*

# 4.2 Perception energy

It was experienced by the head researcher that residents of Nairobi have an understanding about climate change, mostly relating to the changing weather patterns. However, an elaborated view on what climate change contains was lacking. This insight is also supported by a study by Makau et al. (2018) in which 404 households of Nairobi participated in a survey about climate change and its perception. The survey showed that the majority of participants have previously heard about climate change, but the association with more complex and indirect environmental issues was lacking. The study also indicated that the level of awareness, knowledge, concern and worry is mainly dependent on the educational status of the participant.

Focused specifically on energy, Kenya is a real pioneer in the field of renewable energy and the people of Kenya take pride in this. During the project, several residents from Nairobi were interviewed who, as soon as the subject of (green) energy is brought up, are pleased to mention that their country is very progressive regarding this area, showing a sense of pride. During these conversations, geothermal power plants were explicitly mentioned as an important resource. The study by Smith & Leiserowitz (2014) also showed that positive emotions, in particular hope and interest, play an important role in public support of sustainability.
The feeling of pride and hope with regards to renewable energy is therefore desirable to convey in the theme room of Energy & Resources in the museum.

Besides the fact that many locals are proud of the renewable energy, they frequently encounter this topic. In Nairobi, for example, by the windmills on the border of the city (Figure 19). Many houses have solar panels on the roof and all water in Nairobi is heated with the help of solar heat (Figure 20). Finally, there are many innovative products in Kenya that work with renewable energy, such as a light that can be charged by means of solar home system to be used when the electricity fails (Figure 21). Or a refrigerator that functions on solar panels in which sellers can store their produce for a small fee in order to keep it fresh to sell the next day (Figure 22).

Furthermore, the study on the perception of locals in Nairobi to accelerate the transition to renewable energy by Kathambi et al. (2020) states: "Majority expressed willingness to transit to green renewable energy for perceived benefits socially, economically and environmentally cementing the acceleration for renewable energy transition". Cost effectiveness, the job opportunities due to green energy and a clean and safe environment are mentioned as factors.



*Figure 19: Ngong Hills Wind Power Station, visible from Nairobi city (Wilberforce Okwiri, 2021)*



*Figure 20: Water heated by solar panels on the rooftop of a building in Nairobi*



*Figure 21: M-kopa solar powered light (M-kopa, n.d.)*



*Figure 22: Solar freeze, a freezer to prevent food loss in Kenya (Solar freeze, 2021)*

In summary the locals of Nairobi are mostly aware of climate change but they are lacking an elaborated view. The locals of Nairobi do feel a sense of pride and hope with regards to renewable energy as Kenya is considered a pioneer.

# 4.3 Energy education

Part of the competitiveness based curriculum at primary schools in Kenya is Education for Sustainable Development. Within this program, topics such as environmental education, disaster risk reduction, safety and security education, gender issues in education and animal welfare are addressed (UNESCO International Bureau of Education, 2017). To get an impression of what is discussed within this theme, the workbook used by schools to discuss the theme of environmental education was examined (Figure 23). Based on the examination of the workbook and the creative session with children described in 4.4, it is determined which learning objectives defined by the Green Kids' Museum are most relevant to the target group. The assessment follows at the end of 4.4: Current knowledge of target group.

In the workbook, the theme of energy is discussed and a number of assignments are highlighted.

The first assignment relating to the theme of energy is to name what is shown in the picture (Figure 23, top right). The introduction is therefore a simple question which can easily be answered by (almost) all students. This is in line with what was mentioned by a teacher in Nairobi, who indicated that the assignments should be clear and the students should be guided step-by-step. The children should first be presented with an easy exercise which can progressively evolve into more complex activities.

The theme of energy in the presented workbook is mainly about heat and the possible dangers of using heat-related products. A short section is devoted to the conservation of (heat) energy. It should be noted that their workbook did no mention green or renewable energy within the theme of energy.




*Figure 23: Impression of the workbook used in primary schools in Kenya to educate children on sustainability*

# 4.4 Current knowledge of target group

In order to examine the knowledge level of the target group regarding energy, the booklet, used in the creative session with the children touched upon this topic (Figure 24). The insights were used to determine the most valuable focus point of the Energy & Resources exhibition.

During the test, it appeared that the target group already has adequate knowledge about (green) energy. All students knew a few energy resources, such as solar, wind and hydro. Some students needed a bit more encouragement to explain the concept of energy, but as soon as an example was given ("think of windmills") or the question was made personal ("how is the water in your home heated?") all students could elaborate.

Remarkable during the test were the lively discussions that took place between the students, as they started to talk to each other about the topic of energy. One of the conversations is highlighted below:

*A: "I think my bus drives on solar energy" [assignment in booklet]*
*B: "But then it can't drive at night".*
*A: "Hmm..."*

*A few moments later.*

*A: "Oh I know, my bus will drive both on solar and on lunar energy, then it can drive during the day and at night."*

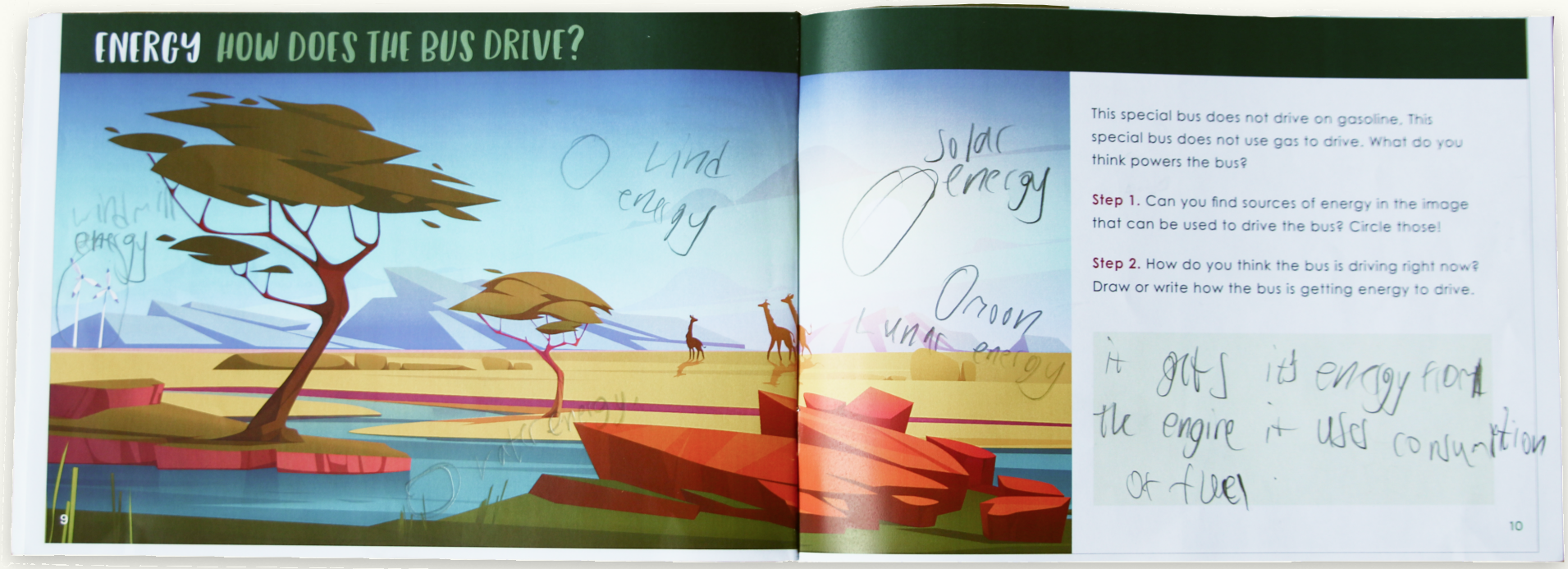



*Figure 24: Filled in energy page of the booklet showing the current knowledge on energy*

As shown in the example, the discussion between the students resulted in many surprising and in-depth conversations, in which they started to think creatively. It is therefore desirable that the museum gives space to the visitors to discuss the topic among peers in order to come to new insights and to explore the possibilities.

After completing the booklet, the students were asked to imagine their vision of what the museum should look like and what they would like to learn from the experience. With the help of large sheets of paper and drawing materials, they were able to visualise their ideas (Appendix D). While thinking about the design, the students were invited to share their thoughts in order to get a more detailed understanding of their preferences. From the drawings and conversations, it appeared that students would like to learn how energy is generated. As mentioned earlier, the students have basic knowledge about different types of energy, but how energy is generated is not clear to them.

In order to learn about energy, they would prefer to see what the equipment looks like in real life, for instance by inspecting a solar panel up close. The contextmapping shows that using real life materials gives the child the impression that they are considered competent, which in turn instils a sense of pride in the children. In addition, the learning process is made more effective when it is linked to the prior knowledge of the child because this facilitates processing and storing the information in the brain. By reflecting everyday life, an installation can connect to prior knowledge and expand the understanding about renewable energy (Ebbens & Ettekoven, 2013).

Looking back at the learning objectives that the museum established with regard to the theme Energy & Resources, the students already have an idea of the definition of energy and can also name different sources of energy. To make the learning experience the most valuable, the emphasis will be on labelling, contrasting and illustrating clean energy sources. Besides, the students indicated they would like to learn more about how energy is generated, resulting in a new learning objective.

## Learning objective

- ✓ Define energy.
- ✓ Identify through images 3 sources of energy.
- ✓ Recognise images of a healthy environment.
- ✗ Label clean and dirty energy sources appropriately.
- ✗ Contrast various energy sources.
- ✗ Illustrate clean energy sources.
- ✗ Consider the effect of dirty energy on the environment.

***New***

- comprehend the operation of clean energy generation

✓ Objective already satisfied by target group

✗ Target group not yet familiar with objective

# 4.5 Conclusion

Kenya is a pioneer in the field of renewable energy. However, although the residents of Nairobi generally know what climate change is, they do not fully understand its impact, meaning they need to be activated to become more sustainable. In order to make the learning experience in the museum most valuable the following aspects should be considered:

- A feeling of pride also reflected in the exhibition of the theme of Energy & Resources.
- The most valuable focus point for the exhibition is on labelling, contrasting and illustrating clean energy. Or the desired objective of comprehending the operation of clean energy generation, as indicated by the target group.
- To boost the target group's self-esteem, first give them a simple, clear task that they can easily perform. this will encourage them to engage in new, more difficult tasks.
- Facilitating lively discussions among peers allows for creative thinking and strengthening their insights.



# 5. Findings exploration

THIS CHAPTER PRESENTS THE MAIN INSIGHTS OF THE EXPLORATION PHASE, STARTING WITH THE RESEARCH QUESTIONS. THE INSIGHTS ARE COMBINED IN AN INTENDED JOURNEY SUPPORTED BY A SET OF 12 GUIDELINES.

# 5.1 Research questions

During the exploration phase the research questions have been answered. Using the different methods as described in 1.6: Methodology. An overview of the question, the key insights and the used methods is provided.

| | QUESTION | METHOD | KEY INSIGHTS |
|---|---|---|---|
| CURRENT SITUATION | **What interactive, play-based experiences are currently available to children in Kenya?** | • Nairobi trips | • There is a limited amount of interactive installations<br>• The interactive parts are very basic and not inviting, lacking either the play element or learning aspect<br>• Text is the commonly used information source |
| | | • Creative session with children<br>• Interview stakeholders | • The target group has a preference for trips where they can see animals or that connects with their personal preference<br>• The target group wants to go on trips that they enjoyed before, repeating the experience |
| TARGET GROUP | **What are important (cultural) aspects that need to be taken into account when designing for Kenyan children?** | • Creative session with children<br>• Examine education | • The target group can be a bit hesitant, not immediately starting. So starting with a short and easy activity helps to build towards an open approach<br>• The target group is used to be provided with a recognisable context<br>• Many aspects of life are approached from a collective perspective |
| | | • Context mapping | • The museum mostly should be exciting for the children in order for the parents and school to take them there.<br>• There needs to be room for reflective moments in order to take a rest in between all the excitement<br>• The target group wants to feel in control, making decisions for themselves based on their interest |

| | QUESTION | METHOD | KEY INSIGHTS |
|---|---|---|---|
| PLAY-BASED LEARNING | **What is required for a play-based experience to be effective in order to learn about sustainability?** | • Literature review | • Play benefits cognitive, social, emotional en physical development of children<br>• Play stimulates the process of experiential learning |
| | | • Creative session with children<br>• Interview stakeholders | • A playful experience can result in in depth conversations and creative ideas<br>• After having a successful play-based learning experience the target group is eager to repeat their successes |
| TRIGGERING | **What triggers children to engage with the play-based learning experience?** | • Creative session with children<br>• Interview stakeholders<br>• Context mapping<br>• Visit museums | • Taking risks makes memorable moments<br>• Stimulating their senses<br>• Discovering and exploring objects<br>• Providing a humorous approach<br>• Aesthetically appreciating an object<br>• Giving the target group a feeling of acknowledgement by reflecting everyday life<br>• Challenging their abilities in a certain activity |
| PRIOR KNOWLEDGE | **What prior knowledge do the children have regarding (green) energy and what knowledge needs to be taught?** | • Creative session with children<br>• Examine education<br>• Literature review | • The target group has a basic understanding of energy and its resources<br>• The target group wants more insight in generation of clean energy<br>• Emphasis in museum should be on labelling, contrasting and illustrating clean energy sources.<br>• Kenyans are proud that their country is a pioneer in terms of renewable energy |

# 5.2 Exhibition journey

First and foremost, the experience must be experienced as pleasant and enjoyable by the children. According to the interviewed Dutch parents, when going on a trip with their children, they get satisfaction from the fact that their children have a good time. This is also the reason for planning an activity together with their children. If, in addition, the child learns something, it is a bonus, but not the main objective. The parents from Kenya also indicate that play and enjoyment apart from school and obligations are very important to them and their children.

For teachers, a school trip is mainly meant as a way to create a bond between the children. The teachers indicate that it is especially important that the excursion should be an enjoyable experience during which they do not have to worry about school. The learning process is considered to be a benefit.

As described in Chapter 3: Play-based learning, play not only contributes to the development of the child but also to the learning experience. In order to design an installation that facilitates a play-based learning experience the journey is described with the help of the experiential learning model of Kolb (1984), see Figure 25 on the next page. The exhibition first needs to spark the child's interest. Next, the child will engage in an experience with the exhibition, and through feedback from the exhibition, the child can reflect on the experience. Following the reflection, the child can learn to understand how the exhibition works and its purpose. Afterwards, the child can use the exhibition to test their findings. This cycle can be repeated several times.
Finally, it is important that at the end of the experience with the exhibition the child has a feeling of pride. Proud of Kenya for being a pioneer in the field of renewable energy and proud of themselves for becoming 'energy heroes' by learning about sustainable use of energy.

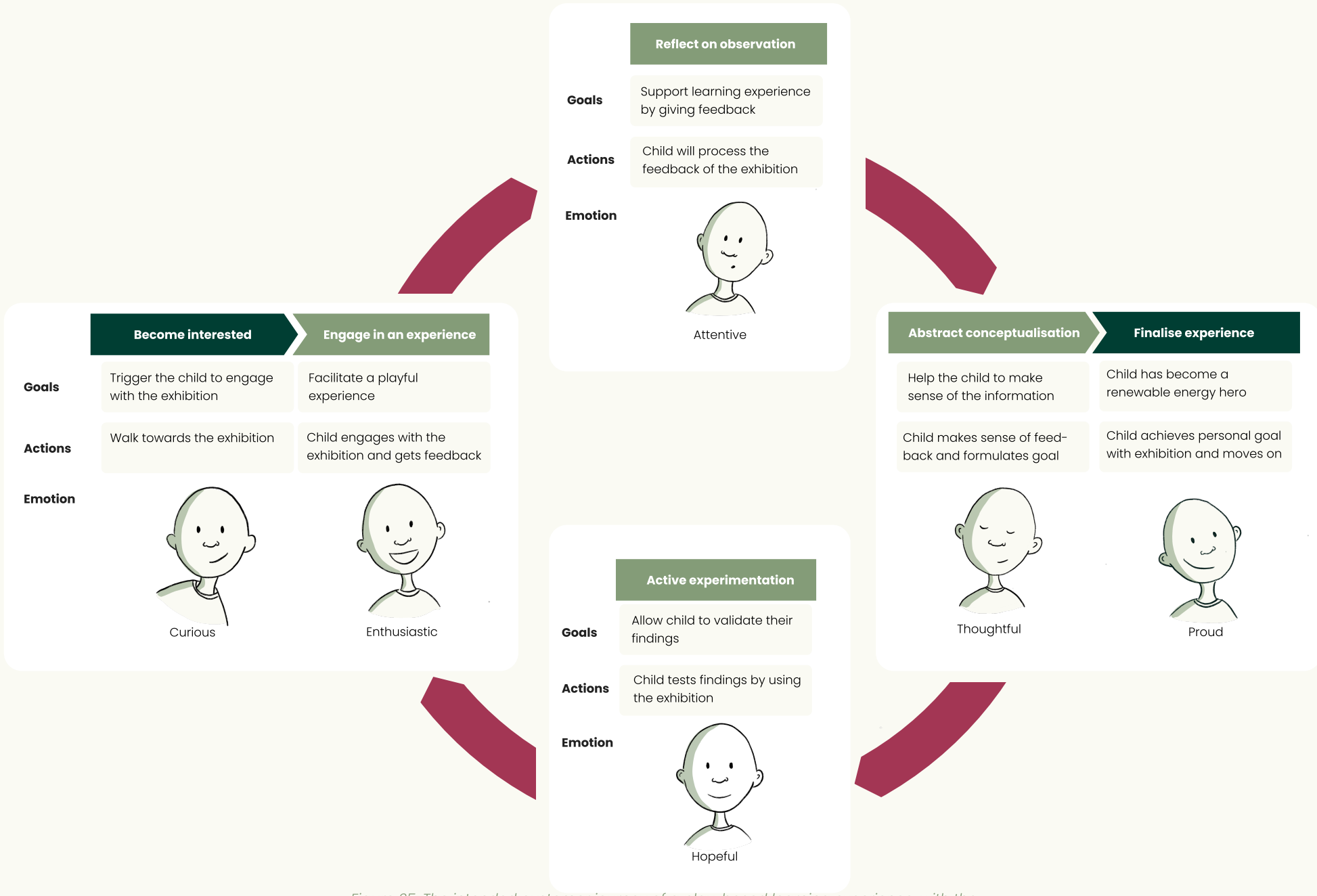



*Figure 25: The intended customer journey of a play-based learning experience, with the light green steps of the journey as a cycle repeating multiple times*

# 5.3 Guidelines

To support the play-based learning journey and to ensure that an exhibition is engaging for children, 12 guidelines were developed.
The research conducted in the exploration phase of this project resulted in several insights, see 5.1: Research questions. Each guideline is an actionable representation of an insight.

The guidelines are a set of cards aimed at assisting the design process of a play-based learning experience in a children's museum. The purpose of the guidelines is to use them as a reference in the design process of an exhibition. The guidelines can be used as a starting point, as a means to gain inspiration or as an addition to make ideas more valuable.

It should be noted that the guidelines are the result of the research conducted in this project, which focused on the target group of 9 to 11 year old children living in the Nairobi metropolitan area. So although it is assumed the guidelines can be used in a more general setting for an exhibition design for children, further research needs to be conducted in order to examine the applicability for another target group and/or museum.

All the cards are arranged in the same way; Figure 26 indicates the structure of the cards. Appendix N contains inspiration of how the guidelines can be implemented by means of pictures from already existing designs.

It is important to note that guidelines 1 to 3 address the museum level, while 4 to 12 are oriented towards the exhibition level.

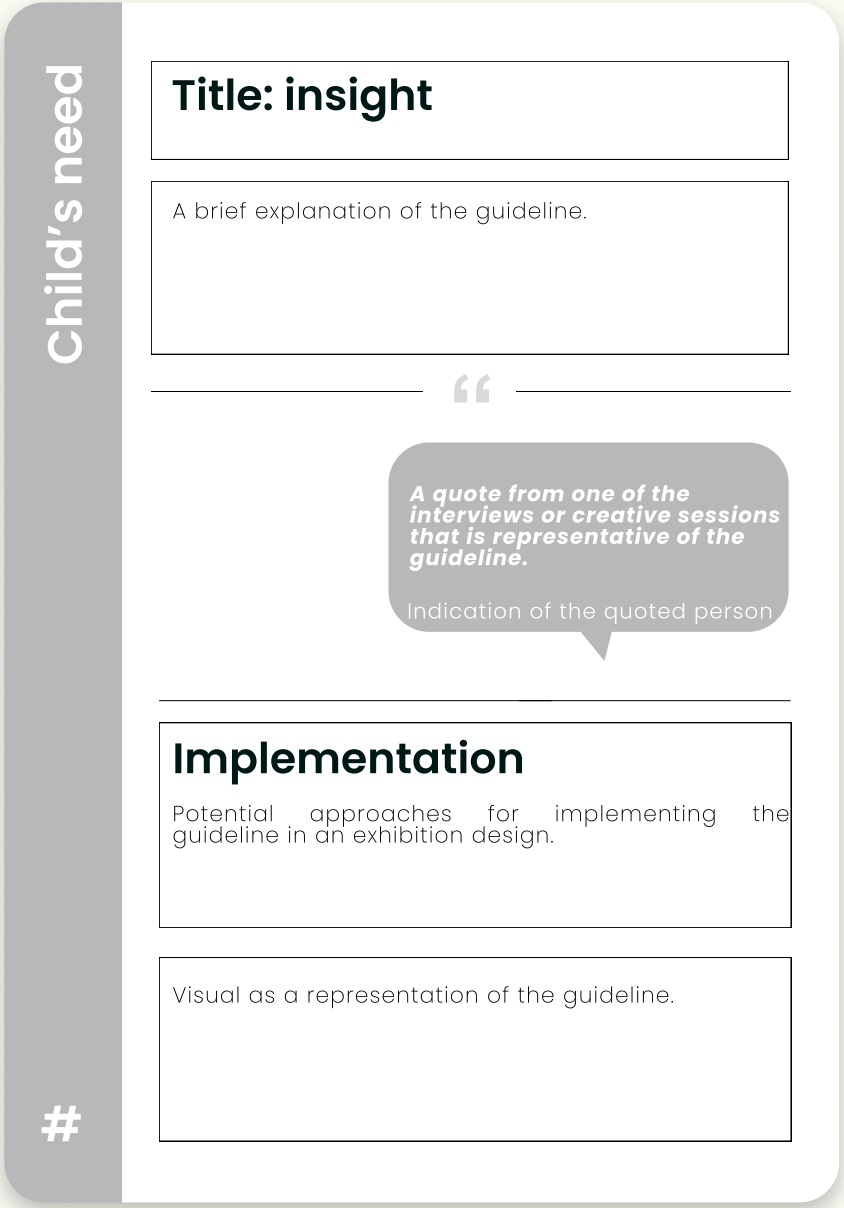



*Figure 26: Representation of a guideline card*

Differentiation

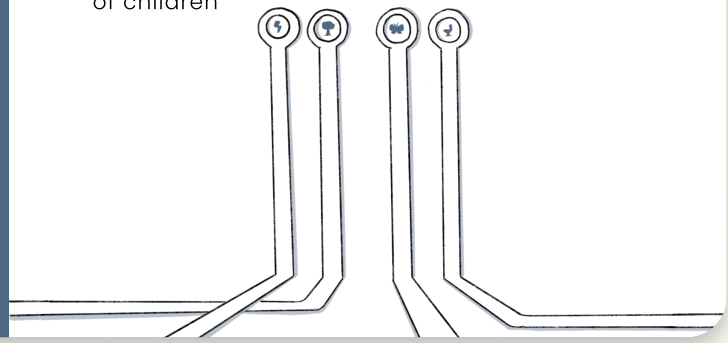
## Support different kind of visitors

Every child is different, they all have their own knowledge level, interests and preferred way of learning. A museum attracts many different visitors and although it is not possible to match all installations to all types of visitors, all children should have the opportunity to express themselves with at least one of the installations. Hence, it is important to have a variety of installations with a diversity in perspective, approach and required experience.

> *"Every child learns differently, and that needs to be taken into account. One likes to listen, so audible, another is more visual so they prefer to see things and yet others have a more kinetic approach so they want to experience things."*
>
> Teacher

## Implementation

- Indicate different trails through the museum based on different interests of children



1

Autonomy

## Feeling of being in control

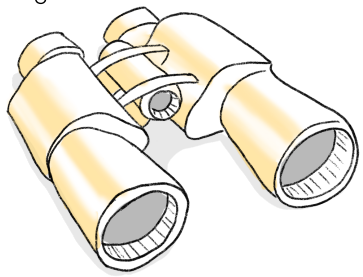
The children must feel that they are in control of their experience. This will enhance the learning process as the visitor is intrinsically motivated to engage in a play activity. Meaning the child must be at the centre of the installation, rather than the supervisor. Furthermore, the feeling of being in control is closely related to self-confidence of the child's own choices. To ensure that the children can start their journey of discovery with confidence, without constantly worrying about missing out, the museum can provide an overview of the various installations. This enables the children to make a well informed decision about the exhibits that appeals most to them.

> *"I would like to have a viewing point so you can see the whole museum [...] then you can have an overview and see what you missed."*
>
> Boy age 10

> *"Some [subjects] just come naturally so it is easy and then it is also a nice subject, but if it is hard than you find it less fun."*
>
> Girl age 11

## Implementation

- Provide an overview point, for example with a high viewpoint
- Provide a map



2

Processing

## Leave room for reflection

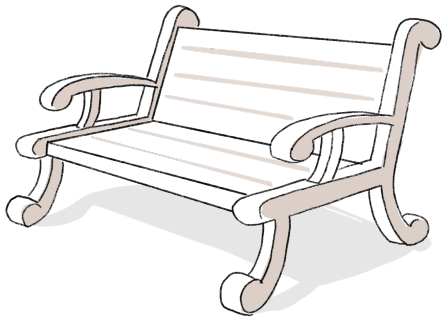
Give the children the opportunity to take a break between all the impressions. A museum can be overwhelming. It is important to allow children to take a break and let them catch their breath. A moment of rest also helps to reflect on what they have learned, increasing the learning experience.

*"We always provide a reflection moment to make children aware of learning moments. [...] The teachers join in the play and afterwards they name what the children have learned. To make the connection from unconscious to conscious learning."*
Teacher

*"Between all the impressions, it is sometimes difficult to let children take a break, for example to eat a sandwich. [...] It is useful if the museum allows these kinds of moments of rest."*
Dutch parent

## Implementation

- Create peaceful resting points at areas where there are few new impressions



3

Exploration

## Enable discovery

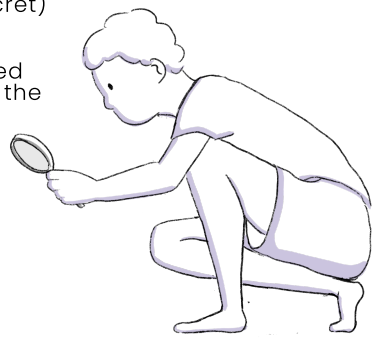
Children enjoy discovering new places and objects. With regards to a museum installation children are mainly interested in exploring elements and manipulating those to achieve the desired result of the child. This discovery process can be an immersive experience for the child in which they are challenged with cause and effect. By reaching the desired result of the child they might feel proud by their competence in discovery.

*"I like to go to new places I have never been before. [...] It is like an adventure and I always get so excited."*
Girl age 9

*"I would like a cycling track. [...] What about the energy here? Maybe the faster the cycle the more energy you have. Yes that is true so, maybe we can light up the track more the faster you cycle? Yes that is cool!"*
Boy age 10

## Implementation

- Let something only become visible after completing a (secret) play activity
- Do not make a fixed solution but allow the visitor to decide



4

Community

## Emphasis on the feeling of fellowship

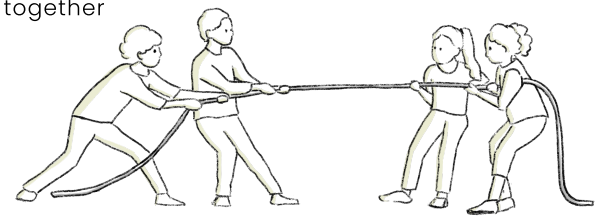
By supporting children in interacting with peers, they are more likely to reach new insights. Discussing and arguing over a topic or challenge stimulates creativity and the ability to solve problems. In addition, children can encourage peers to become more involved with an installation or topic. The interaction among children will result in a feeling of fellowship, which can ultimately lead to a sense of commitment to the museum and its goal.

*"I would like to have a podium. [...] It can be a place where everyone comes together."*
Boy age 10

*"As a ranger, I come into contact with up to 200 people every day. [...] I know almost everybody and that's what's so nice about the forest, it really feels like something we all share. "*
Ranger

## Implementation

- Let visitors build upon efforts made by previous visitors
- Encourage competition
- Establish a common goal to be achieved by working together



5

Competence

## Challenge abilities

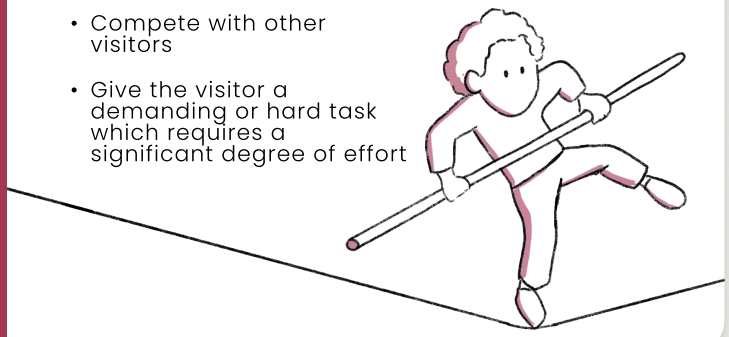
Children like to improve and expand their skills. By giving them the opportunity to test their abilities with a specific task, they are prompted to take up the challenge and practice it several times in order to improve. By repeating a specific task and experimenting in order to progress, the learning curve is enhanced. Besides, by improving and reaching personal goals the child will get a sense of pride.

*"So you like solving puzzles? Yes! and also playing games. What do you like most about it? You can get better at it."*
Girl age 10

*"I can't solve it [A rubics cube] but the friend of my brother can and he will teach it to me."*
Girl age 10

## Implementation

- Score tasks on which they can improve
- Compete with other visitors
- Give the visitor a demanding or hard task which requires a significant degree of effort



6

Recognition

## Clear & simple introduction

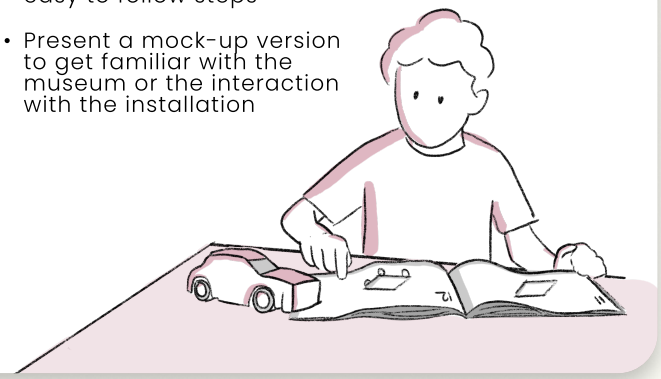
It is important to give children the confidence that they can handle the play activities of an installation and the museum. By starting with a simple, easy task, the child is gently prepared for what is to come, after which they can progressively engage in more advanced play activities. This simple task can also allow for a more open mindset as it reduces some of the visitor's nerves about the installation or museum by indicating that they can experiment, interact and play.

*"It is important to be very clear. [...] Don't ask too much all at once."*
Teacher

*"You really need to explain to them what it is they are going to do and what is expected of them."*
Teacher

## Implementation

- Provide a tutorial with easy to follow steps
- Present a mock-up version to get familiar with the museum or the interaction with the installation



7

Thrill

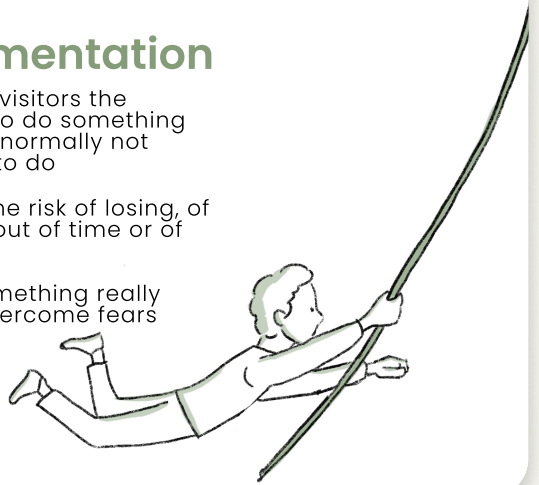
## Allow children to take risks

Taking risks is foundational for learning and development as it supports children to learn to trust themselves, understand their capabilities, recognise limits and identify when to ask for assistance. Taking a risk can leave a lasting impression on a child. First, they experience suspense and sensation, followed by the pride they feel in their achievement after taking the risk. These intense emotions lead to a memory they will remember.

*"We called it the 'Deadly jump' [...] First I was really scared but then I asked them to make my lifejacket extra tight... and then I went and it was really fun!"*
Boy age 11

## Implementation

- Give the visitors the chance to do something they are normally not allowed to do
- Create the risk of losing, of running out of time or of height
- Make something really scary, overcome fears



8

Stimulation

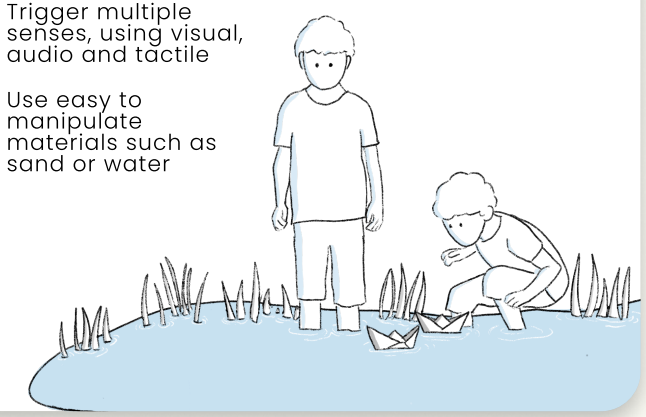
## Trigger the senses

Children need to be able to experience the installation in order to fully immerse themselves with the topic and become part of the created world. This immersion in an installation is enhanced by stimulating the senses of a child, like hearing, seeing and touching. Besides, by allowing the children to be able to touch and manipulate elements of the installation to create their own play activity, the play-based learning experience is enhanced.

> *"I want children to discover their senses. [...] It's about the combination of playing and discovering."*
> Teacher

## Implementation

- Trigger multiple senses, using visual, audio and tactile
- Use easy to manipulate materials such as sand or water



9

Acknowledgement

## Reflect everyday life

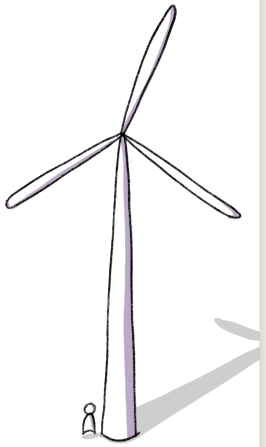
Children are seeking the experience of everyday life. They want to feel that they are taken seriously by being allowed to experience the real deal, like handling specialised equipment, supplies and materials. Allowing children to explore and experiment with these resources instils a sense of pride, as they experience a unique opportunity to step in the shoes of an expert and handle their activities. Besides, by confronting the children with the materials and methods that are also used in everyday life they become more aware of the world around them outside of the museum.

> *"I would like to see real solar panels. Why is that? Than you can see how it really works"*
> Boy age 9

> *"Is a windmill big? [...] I want to see how big it is."*
> Boy age 10

## Implementation

- Let children pretend to step in the life of an expert
- Present real materials and equipment



10

Pleasure

## Utilise humour

Using humour can increase the engagement with an installation and it opens the way for play. Children often use humour to make an activity playful. In addition, humour can help to make sense of an experience, thus boosting the learning process. Besides stimulating the play-based learning experience, laughter, which is often the result of humour, also has many benefits, such as reducing stress, improving the mood of the child and enhancing creativity.

*"I think the bird is carrying the monkey. Haha I like that, you got some humour! I like funny things."*

Girl age 9

## Implementation

- Show bizarre things
- Make something unexpected






Beauty

## Aesthetics promote involvement

Aesthetics can play a significant role in catching the child's attention. If a child sees something they experience as beautiful, they are more likely to approach and explore it. By using the aesthetics of the child in the installations, the child can be provoked to engage with the installation.

*"I like multicolour I think that will be beautiful. [...] It will create some scenery."*

Boy age 10

*"I want a big blue door [...] It is beautiful, I think people will want to enter it now."*

Boy age 6

## Implementation

- Consider scale, colour and texture
- Make something unique, like a mythical creature



# PART 2
# Design

*Glossary*

**Design goal**
A statement which formulates the main target to be reached by the design, without limiting the solution space.

**Geotricity**
The concept developed in this project aimed to provide a play-based learning experience to the target group through an interactive installation that educates children about the applicability of renewable energy. Detailed in Chapter 8: Final concept.

**Board**
Refers to the playing field of Geotricity on which the projection is positioned. The board represents a landscape.

**Elements**
This refers to the interactive elements used in the concept of Geotricity that are representatives of the different power plants. The children are expected to place these elements on the playing field after which a projection appears on it.



# 6. Design focus

THE DESIGN PHASE IS STARTED BY FORMULATING THE DESIGN GOAL, THE INTERACTION VISION AND DESIGN CRITERIA.

# 6.1 Design goal

Based on the findings in the exploration phase the following design goal is formulated:

“The design goal is to design an interactive installation that first triggers children of age 9 to 11 in the Nairobi metropolitan area to actively engage with the installation. Through engaging with the installation they will be able to playfully explore, experiment and reflect on the implementation of renewable energy, contrasting the different energy sources. After which they will leave the installation with a sense of pride, due to the gained learning experience.”

# 6.2 Interaction vision

## *The treasure chest*

Interacting with the installation should feel like trying to open a treasure chest. As soon as you see a treasure chest, you are **drawn to** see what is inside. You attempt to open the chest, but it is locked. You try all kinds of ways, and although you **keep learning new skills** about opening objects, you can't get the chest to open. You look for new methods and **experiment with different possibilities**. And then, after a long process of investigation, you finally **discover** how to open the chest. Even though there is no big treasure inside, the **pride** you feel about being able to open the box is significant. And looking back you’ve managed to learn a lot about opening objects when you tried to open the treasure chest.

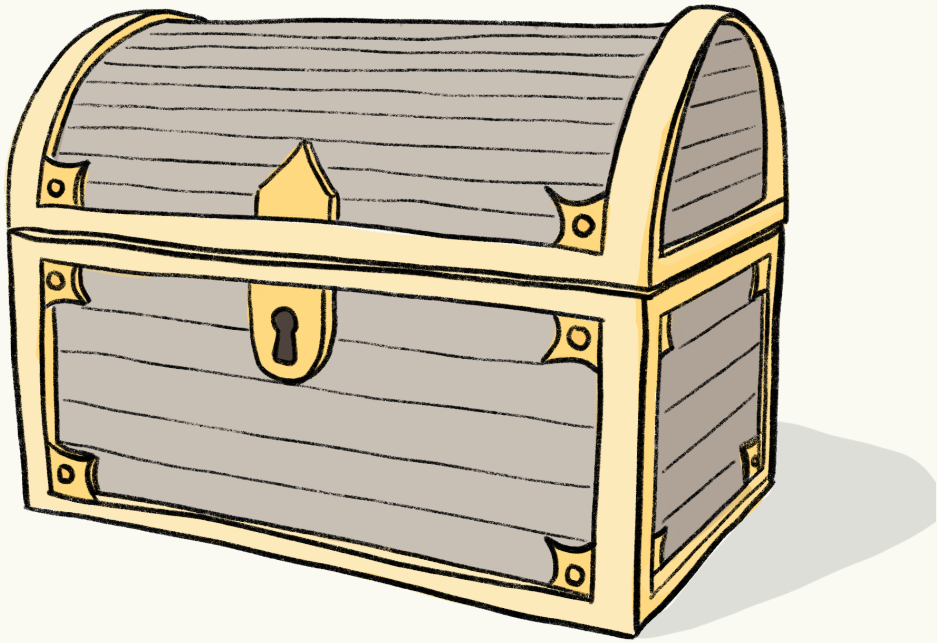


*Figure 27: Visual representation of the interaction vision: the treasure chest*

# 6.3 Design criteria

The design criteria are the result of the findings in the exploration phase and are used in a later stage to determine whether the proposed design meets the design goal. The criteria are divided into three categories based on the customer journey presented in 5.2: Exhibition journey: become interested, experiential learning and finalise experience.

## Become interested

- It is clear to the child what play activity needs to be conducted.
- The play activity is feasible to conduct for the child.
- The child experiences a sense of curiosity to engage with the installation.

## Experiential learning

- The child feels in control.
- The child experiences the installation as playful.
- The child experiences the interaction with the installation as a spontaneous activity.
- The child experiences the process as more important than a specific outcome.
- The child is aware of the signals of the created pseudo-reality.
- The child feels supported to process and practice their gathered knowledge.

## Finalise experience

- The child believes that their knowledge of renewable energy increased.
- The child experiences the exhibition as a form of relaxation.
- The child has a feeling of pride after using the installation.



# 7. Ideation

THIS CHAPTER DISCUSSES THE STEPS TAKEN DURING THE IDEATION PHASE. IT PRESENTS THE METHODS USED FOR IDEA GENERATION, SIX DESIGN DIRECTIONS AS A RESULT OF THE IDEA GENERATION AND THE SELECTION OF AN IDEA. NEXT IT DISCUSSES THE ITERATIONS OF DESIGN PROPOSAL.

# 7.1 Ideation approach

Various ideation methods and techniques were used during the design phase of the project to generate ideas. The methodology of the various methods will be briefly described in this section.

## Braindump

Throughout the project, ideas that emerged during the research or ideas that were suggested by the participants were noted down. These ideas function as a starting point for the ideation. Besides, writing the ideas down helped to make room for new ideas.

## Museum drawings by the children

In addition, at the start of the ideation process the drawings made during the creative session with children were reviewed (see 1.6: Methodology). The focus during this review was mainly on the vision of the target group on how the museum could educate the children about energy & resources in a playful way.

## Creative brainstorm with peers

A brainstorming session was organised with a total of 7 participants, all related to The MuseumFutures lab. The MuseumFutures lab is a part of Delft University of Technology and "studies the design of meaning-making experiences for researchers and museum audiences" (Vermeeren, 2022). The participants were asked to answer How-Tos based on the playful experience (PLEX) cards (Lucero & Arrasvuori, 2010), which correspond with the guidelines mentioned in Chapter 5: Findings exploration. The PLEX cards are a set of 22 cards based on various play and game theories and models that present playful human experiences.  See Appendix O for the result of the brainstorm.

## Guidelines inspiration

For each guideline, inspiration was gathered from already existing museums, experiences and interiors. An overview of this inspiration can be found in Appendix N. This inspiration was used during the ideation, by combining various elements into an idea. An impression of the ideation phase is given in Figure 28.




*Figure 28: Impression of ideation as part of the design phase*

# 7.2 Selection design direction

Based on the ideation methods mentioned in 7.1, 6 design directions were developed. The design directions are the result of several cycles of ideation in which promising aspects of ideas were combined into the design directions. These design directions are briefly highlighted by means of a visual and a short explanation.

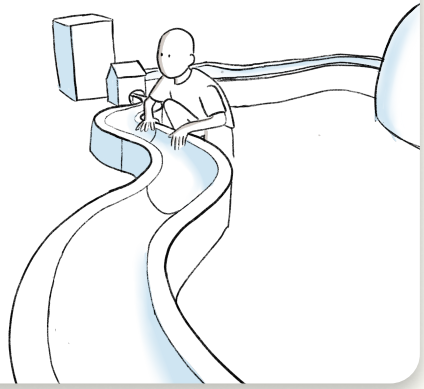
These design directions were reviewed by means of the speed dating method (Zimmerman & Forlizzi, 2017). The speed dating method is developed as a way to test possible ideas with stakeholders in order to validate the proposal. In speed dating, a panel of stakeholders is presented with several design directions. The panel is asked to imagine the experience in which the design direction is used. After imagining all the experiences, the panel is asked to critically reflect on the design directions by explaining what they do and do not want to experience.

For this project the panel of stakeholders consisted of two Design for Interaction students, who both have experience designing for children, and two parents with children in the age bracket of 9-11 years old who frequently visit children's museums.

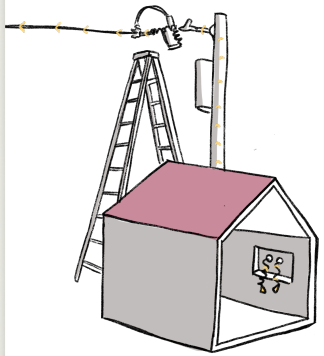
The design directions, as they were also proposed to the panel, are presented with the corresponding reflection of the panel, sorted into pros and cons.

### 1. Build a circuit

The child connects factories that supply energy to houses that need energy. It is like a puzzle where the elements have to be placed in the right combination. By using large building elements they can solve the puzzle and ensure that all buildings receive energy.



+ *Children are involved by building it themselves and if they manage to solve the puzzle, they will get a feeling of satisfaction.*
- *The goal is less about renewable energy. There is also a clear right and wrong which hinders the exploration.*



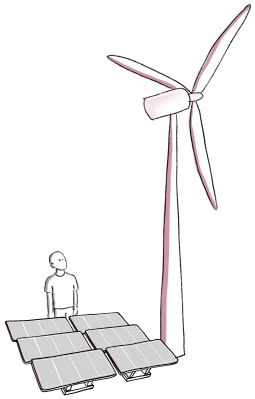
### 2. Follow the power

Starting from the factory, the child follows the energy running through the electricity wires all the way to a house. On the route, they complete small activities, such as connecting the wires in order to learn about the risks and applicability of electricity.

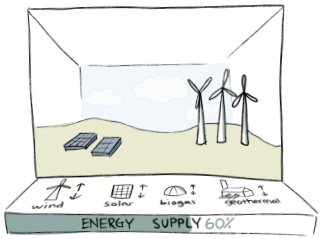
+ *Several small experiments that contribute to the same narrative.*
- *Less is needed for the same experience and there are concerns about the safety of this design direction.*

## 3. The real deal

The child takes a look at how real energy is generated. They can influence factors to experience the effect this has on energy generation. For example: the child can manipulate the shadow to sun ratio to experience the influence of shadow on a solar panel.



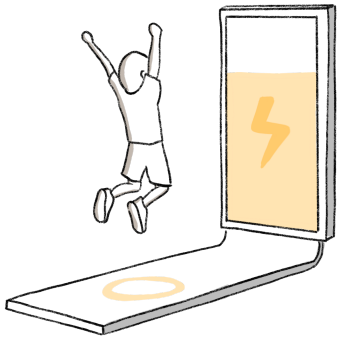
+ *Children will find it imposing and be impressed by what it looks like in real life up close.*
- *The children do not have a clear goal or role in the installation, which makes it very static and the attention span will therefore be short.*




## 4. Environment revision

The child explores how the world changes due to different energy resources. To generate enough energy they choose which energy resource they want to use, which then influences the environment. The aim is to make the child aware of the effect of implementing different energy resources.

+ *There is no right or wrong but rather children can contribute to the discussion and influence the outcome themselves.*
- *To make it more interesting, something like a game or puzzle element could be incorporated.*



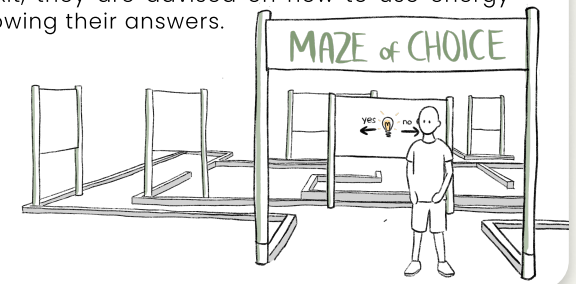
## 5. Power pressure

The child has to balance both consuming and generating energy. Different installations generate energy, but as soon as the child uses energy, this is deducted from their total. The aim is providing insight into the effort required to generate energy and to prevent wastage.

+ *By relating the installation to the children's own body, it becomes understandable, in which being tired can be a metaphor for the use of energy.*
- *Measuring per visitor will be difficult. 'Spending' energy should be playful to make it more entertaining.*

## 6. Maze of choice

The child has to make choices regarding renewable energy. Based on their choices they follow a path through the maze. Once they find the exit, they are advised on how to use energy more sustainably following their answers.




+ *Raising awareness by children thinking about their individual energy consumption in a playful way.*
- *The choices for the signs should not be too much reading, is there a possibility to make it visual? It is less interactive.*

In addition to the reflection of the panel, the design directions were assessed based on the design criteria, with the help of a Harris profile (Figure 29). A Harris profile is a method to evaluate design directions by making a visual representation of the strengths and weaknesses (Van Boeijen et al., 2013). The design criteria as mentioned in 6.3 are ranked in order of priority, whereby the top criteria in the Harris profile is considered to be the most important.

The combination of the speed dating and Harris profile shows that design direction 4 “Environment revision” has the most potential, especially with regard to the learning objective about renewable energy. As described in the design goal, the learning experience is an important aspect of the installation. The learning aspect of this design direction will therefore be used as a starting point for the next phase of designing.

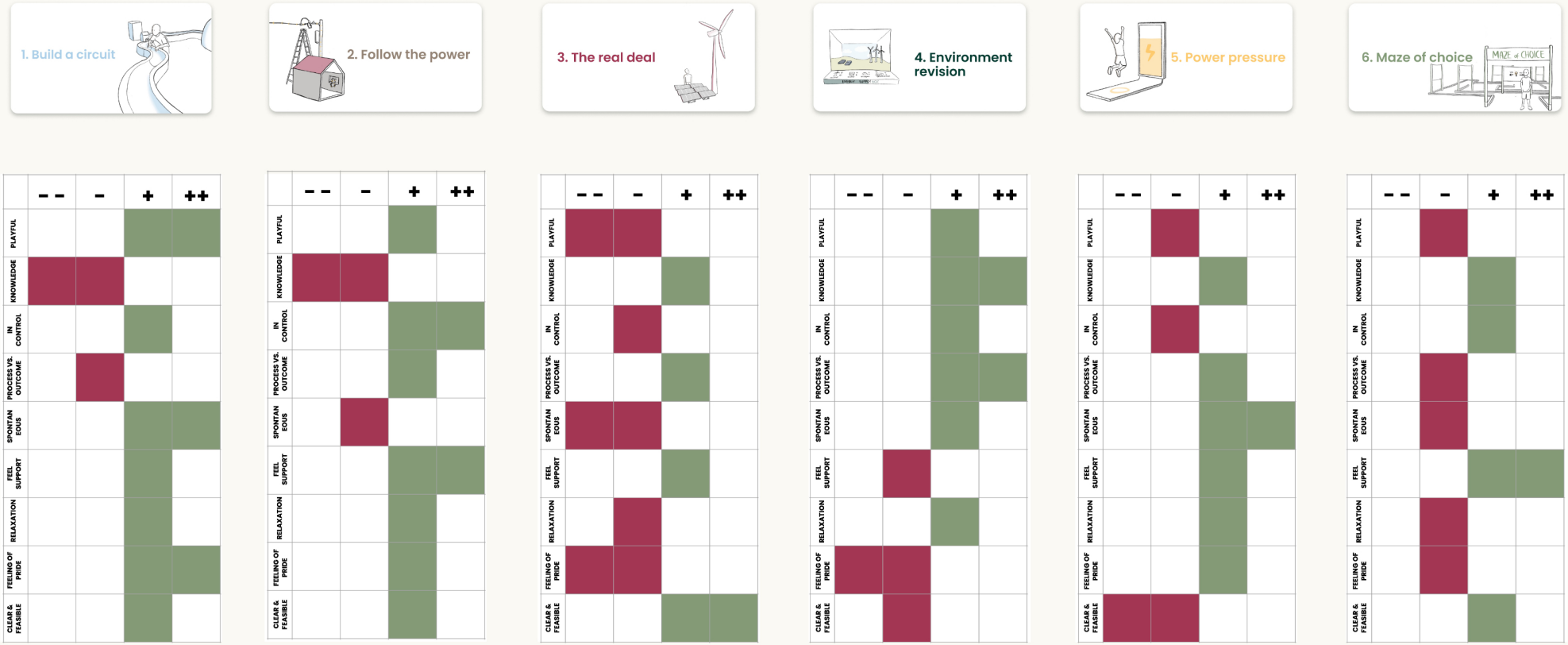



*Figure 29: Harris profile of the six design directions with the rows representing the design criteria and the columns the score.*

During the speed dating, however, it was indicated that this design direction could be made more playful. Specifically design direction 1 “Build a circuit” scores high on playfulness with the puzzle element as a powerful element. It not only contributes to the playfulness, but also gives a feeling of pride once the puzzle is solved.
However, a drawback with the puzzle element as described in “Build a circuit” is that there is only a right or wrong within this design. All of this was taken into account for the next phase of design.

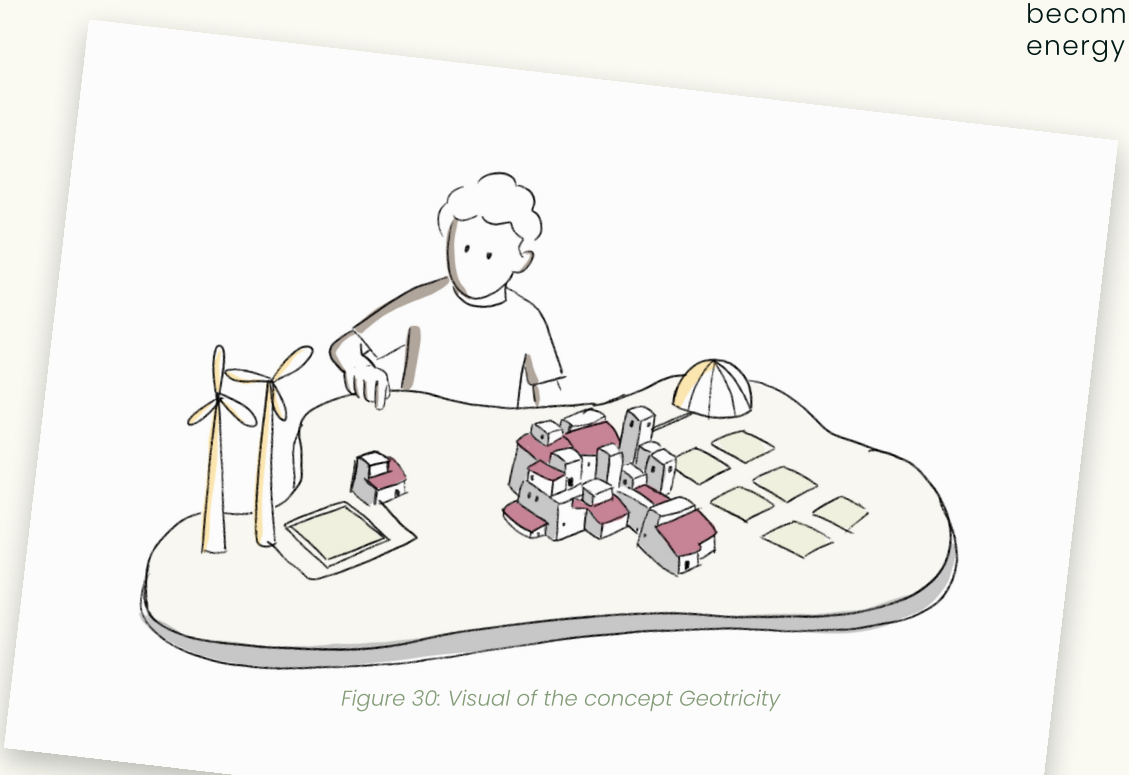


*Figure 30: Visual of the concept Geotricity*

# 7.3 Design proposal

Based on the speed dating and Harris profile, a short ideation session was performed in which the playful element of design direction 1 "Build a circuit" was combined with the learning objective of design direction 4 "Environment revision".

The result of this ideation session is “Geotricity” (Figure 30). Geotricity is a table on which an environment with houses is projected. The aim is to provide the houses in the area with energy by placing power plants. The child can physically place elements that represent a renewable energy power plant. Once the child places an element, the projection and with that the environment will change accordingly. Based on the position of the element it is determined whether the houses are provided with energy. For example, a hydro dam cannot be placed close to a village, and a windmill works better on the mountain than behind it. This way the child can become aware of the implementation of different renewable energy resources.

# 7.4 Iterations

After defining the basic concept of Geotricity, some iterations were made based on the guidelines. For each guideline a short brainstorming session was held on how the guideline could be applied or enhance the design. The most important iterations are discussed.

## Fellowship

To encourage fellowship between children, it is implemented within the design that the children receive feedback based on the placed elements, see Figure 31. This feedback can reach any player. By randomising who will receive the feedback, children are encouraged to interact with each other and share their ideas. The bright colours used for the feedback make them stand out on the board and allow children to remind each other of the feedback.

## Humour & risks

To make the experience more interesting, risky and humorous scenarios have been incorporated into the installation. For example, an entire village can be flooded if the hydro power plant is placed incorrectly on the board.

## Trigger the senses

In order to stimulate multiple senses, a visual projection is used on which the child can place elements (tactile). By using animations instead of static images, the senses are stimulated even more. In addition, the choice was made not to project the houses onto the board but to use actual scale models in which a light turns on as soon as the house is supplied with energy. This feature offers an extra dimension to the installation, to trigger the children's imagination.

## Reflect everyday life & in control

By giving children the task of supplying all the houses with energy at the start of the game and indicating that they are in charge, they get a sense of autonomy and competence (Figure 31). To reinforce this feeling, a recognisable scale model with mountains and houses is used, as they might encounter in their daily life.




*Figure 31: Start message and feedback when using Geotricity.*

# 7.5 Feedback design proposal

In order to get an impression whether the concept resonates with the target group, a number of stakeholders, consisting of a teacher, three parents and a designer, were asked for feedback on the concept based on a short pitch given by the designer with the help of the visual in Figure 32. This feedback is given in an informal setting. A couple of responses are listed.

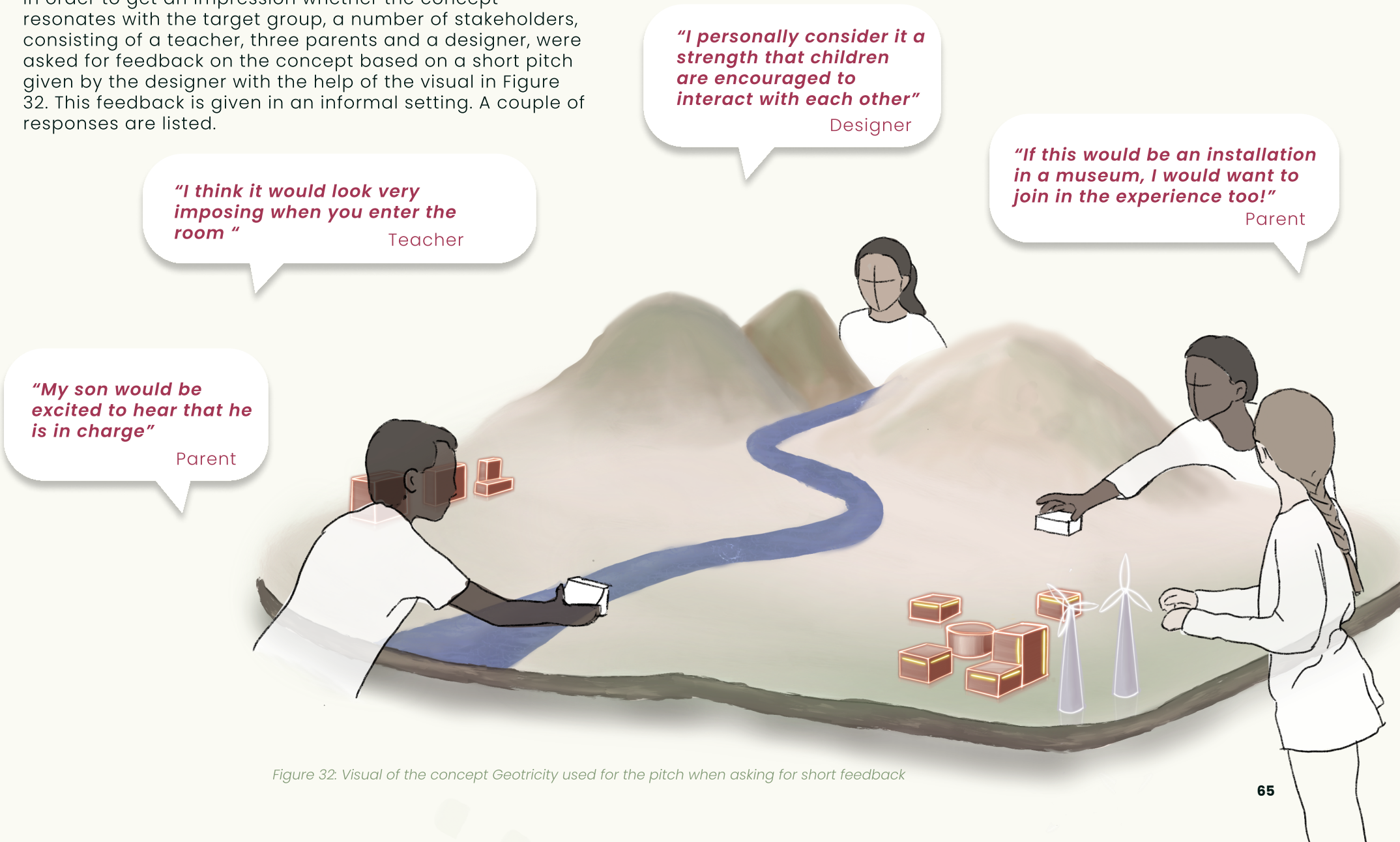
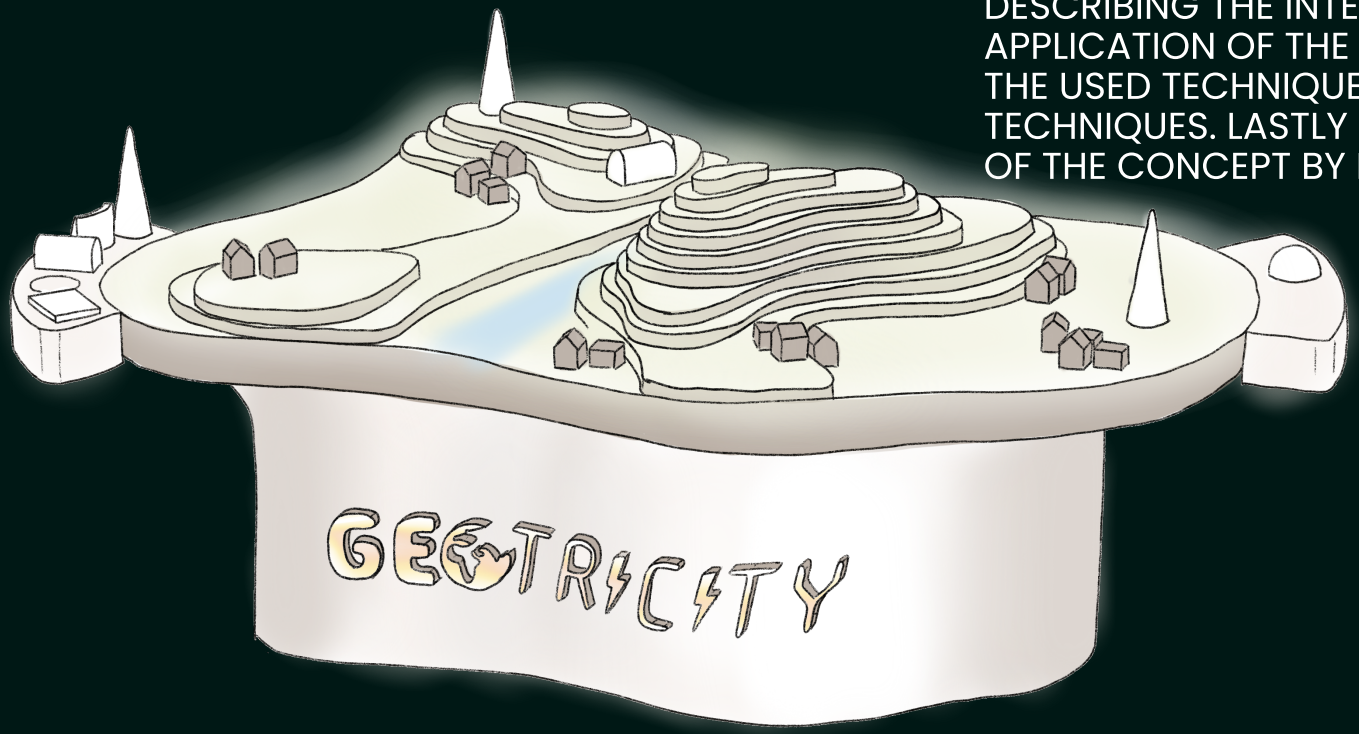



*Figure 32: Visual of the concept Geotricity used for the pitch when asking for short feedback*

# 8. Final concept

THIS CHAPTER PRESENTS THE FINAL CONCEPT: GEOTRICITY. IT STARTS BY DISCUSSING ITS AIM. NEXT THE INTERACTION IS ELABORATED BY PRESENTING A STORYBOARD AND DESCRIBING THE INTERACTIVE ENVIRONMENT. THE APPLICATION OF THE DESIGN IS HIGHLIGHTED BY DESCRIBING THE USED TECHNIQUE AND POSSIBLE PRODUCTION TECHNIQUES. LASTLY THE CHAPTER PRESENTS THE VALIDATION OF THE CONCEPT BY MEANS OF AN EVALUATION TEST.



# 8.1 Geotricity explained

Geotricity is an interactive installation designed to educate children about the applicability of renewable energy resources using a playful approach (Figure 34). The aim at Geotricity is to provide the houses on the board with electricity by supplying power plants. Through experimentation, the children can provide energy to the houses. Each energy resource has its own implementation, making it a challenging task.

The children are allowed to touch and move the identified elements. By doing so they receive feedback from the environment with the help of light projection and with textual messages on the board. The feedback stimulates collaboration between the children.

There is a risk involved for the users: if they place an object in an improper place, the houses can overflow or the residents might become angry, which in turn can results in humorous scenes.

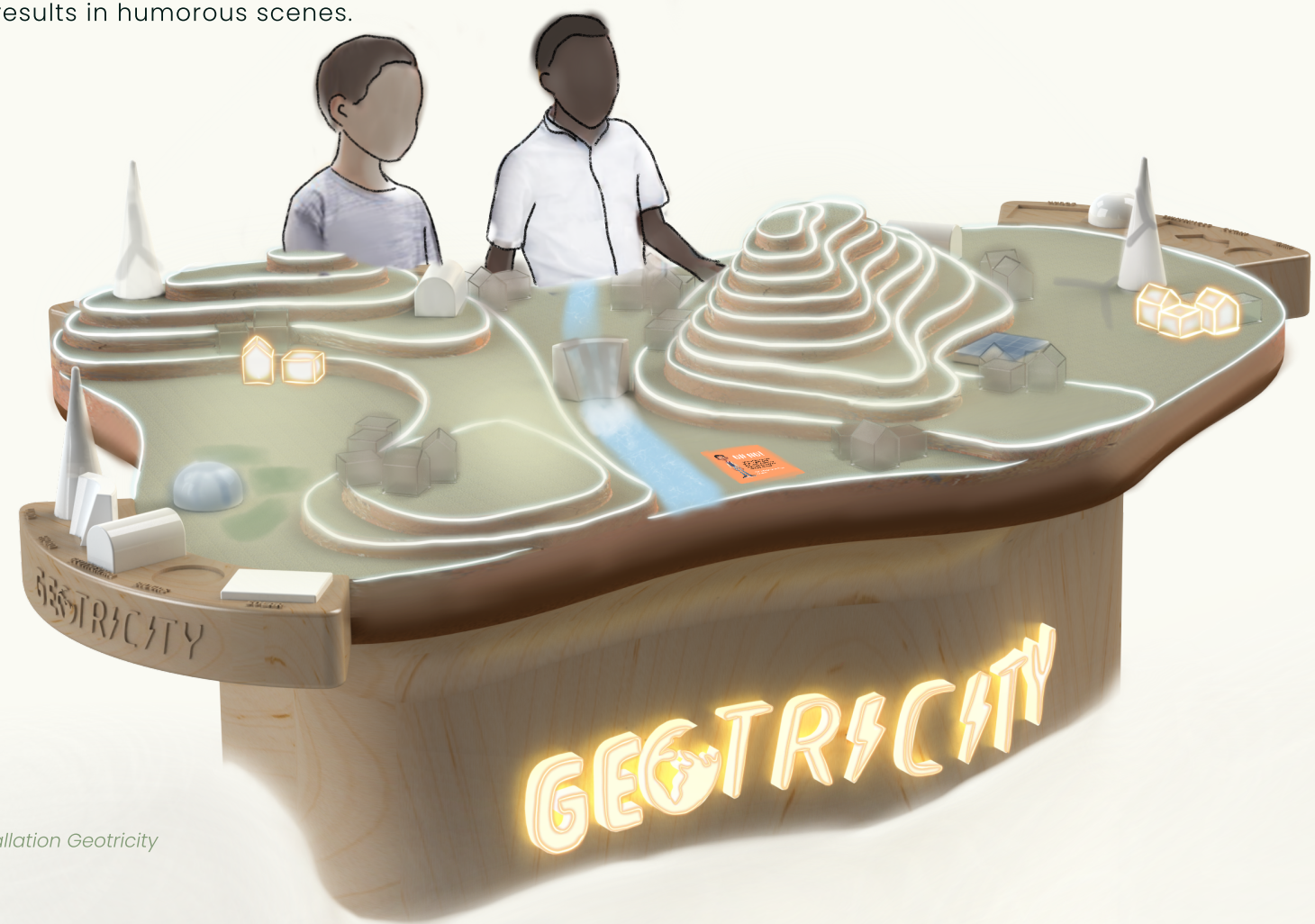
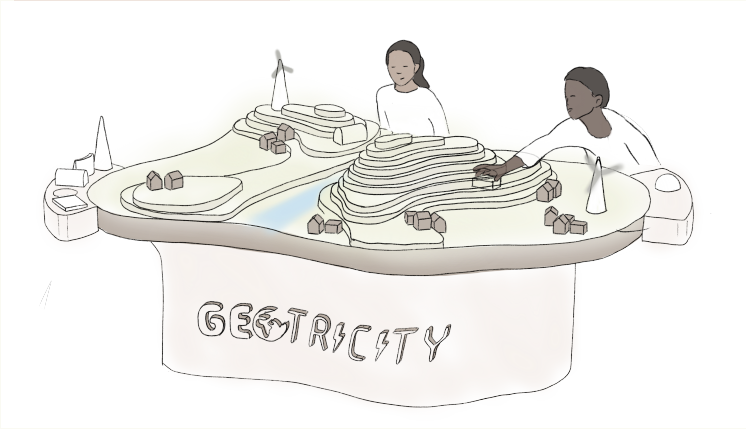
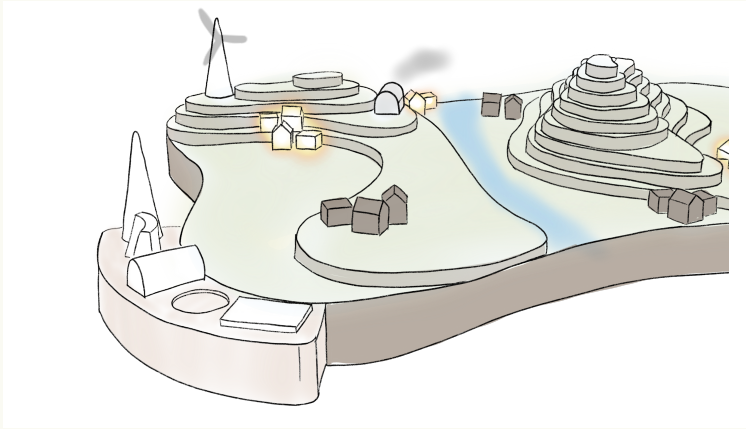



*Figure 33: Visual of the installation Geotricity*

# 8.2 Storyboard



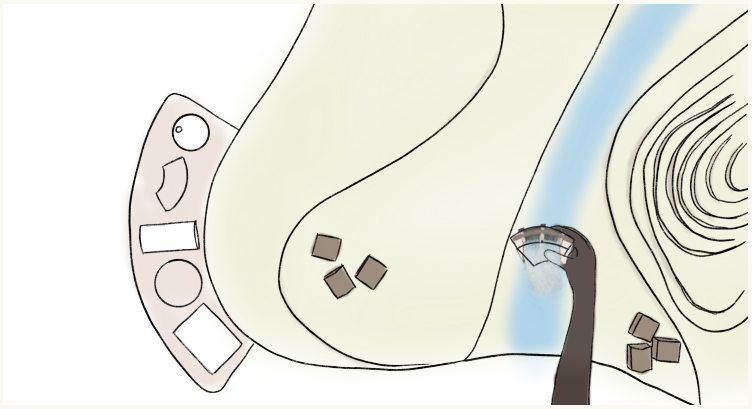

1. Imagine you are on a trip at the Green Kids' Museum. You walk into the theme of Energy & Resources. In the middle of the room stands a large table with several children around it, it immediately catches your attention.



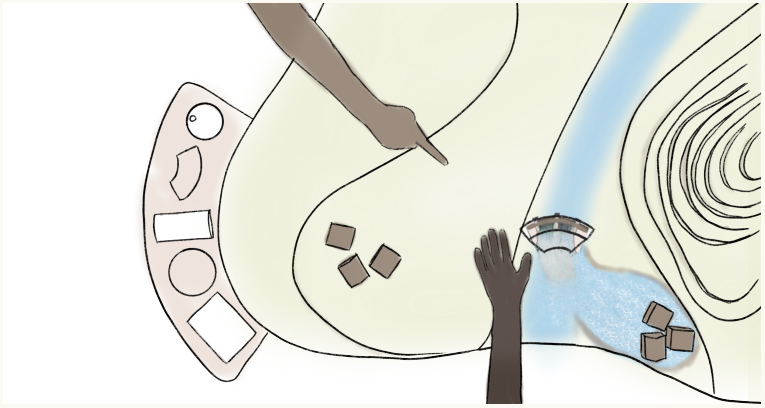
2. As soon as you get closer you realise that it is a large landscape on which an environment is projected. Some of the houses in the landscape have lights on and you wonder why others do not. A message pops up in front of you.



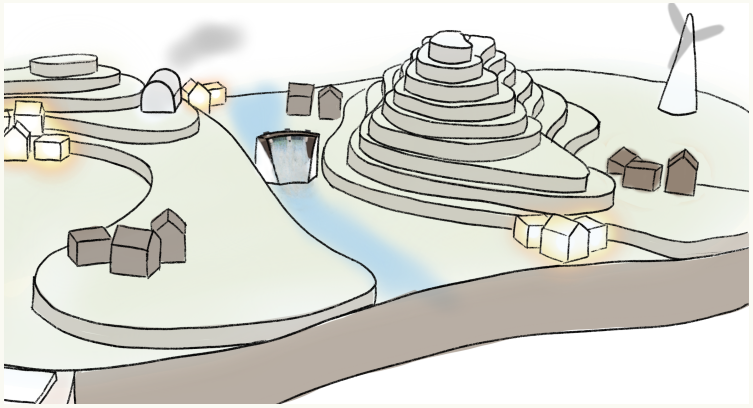

3. You read the message and want to get started right away, feeling responsible to provide power to as many houses as you can. You look around and see that the other children are using the elements from the container attached to the table.



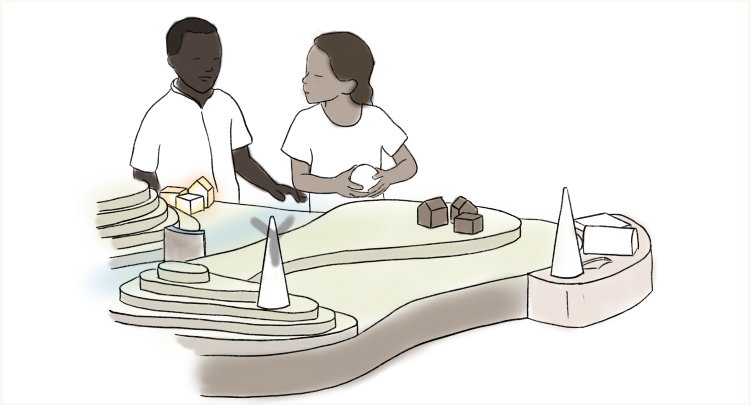
4. You also pick up an element and place it on the board. As soon as you position the element it turns into a hydro dam. You take a closer look and try to move the element, you realise the projection follows the element.



5. All of a sudden, the projection changes and it looks like an entire village is getting flooded. The other children see this as well and come to the rescue.



6. One of the children explains that the hydro dam is too close to the village. You follow the instructions to move it and the flooding goes away while the lights in the houses start to turn on.



7. Now that you have provided one of the villages with light you get a message on the board that more villages would like electricity. You explore the other energy resources by placing them on the table.




8. Along the way you become aware of the implementation of the different energy resources. You leave the table with a feeling of pride, because you have been able to supply a number of villages with energy. Now it is up to the other players.

# 8.3 Shape & size

The shape of the board is organic to resemble an island and encourage collaboration. To stimulate collaboration even more, it was desirable that the board is large enough for several children to play at the table at the same time. However, the children must be able to reach everything on the board. The average arm length of a child between 9 and 11 years is 59 cm (DINED, 2018). During the design of the board, it was taken into account that the entire board is accessible from the edge (Figure 34).

To ensure that children can easily reach the elements, containers have been added to the edge of the board in which the elements can be placed if they are not on the board. To prevent children from only using up one kind of power plant, for example only windmills, but to also have enough elements for several children, it was decided to use three containers, further research needs to be conducted in order to determine if this is a sufficient amount.

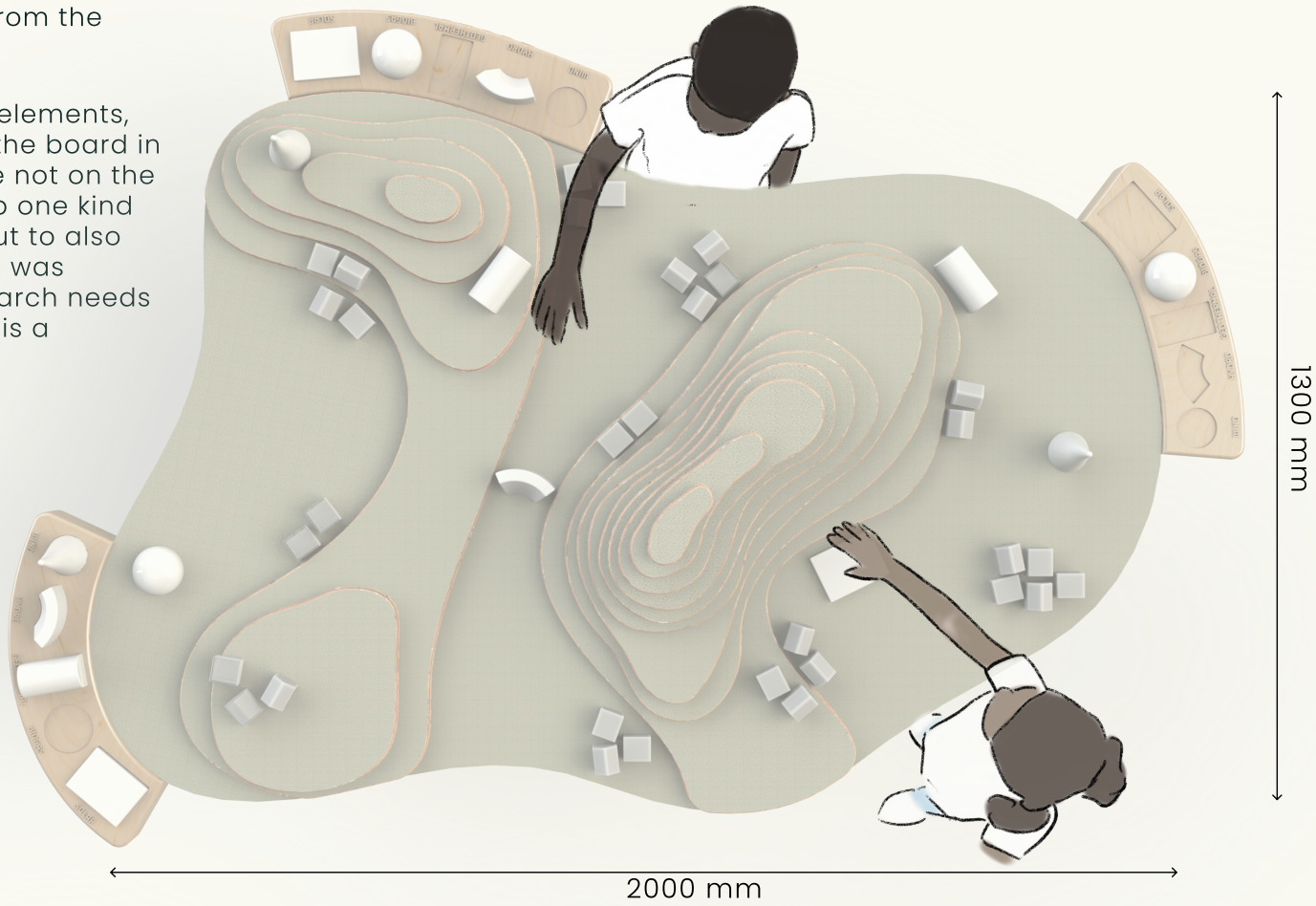



*Figure 34: Geotricity from above with children as a reference*

# 8.4 Interactive environment

As described in 8.1: Geotricity explained, the environment changes based on the actions of the child. This section describes the set-up to create that interaction, what the interactive environment looks like based on the power plants and finally explains the mechanism to determine how the interactive environment should change.

## Set-up

Figure 35 is a visual representation of the set-up of Geotricity. The projector above the installation projects the interactive environment onto the board. With the help of the camera the elements can be detected. Based on the type of power plant and the coordinates, the corresponding feedback is projected in the interactive environment. Once an element is placed in a correct spot (see “Location” on the next page), the Arduino underneath the table is signalled, which in turn lights the Neopixels in the corresponding houses.

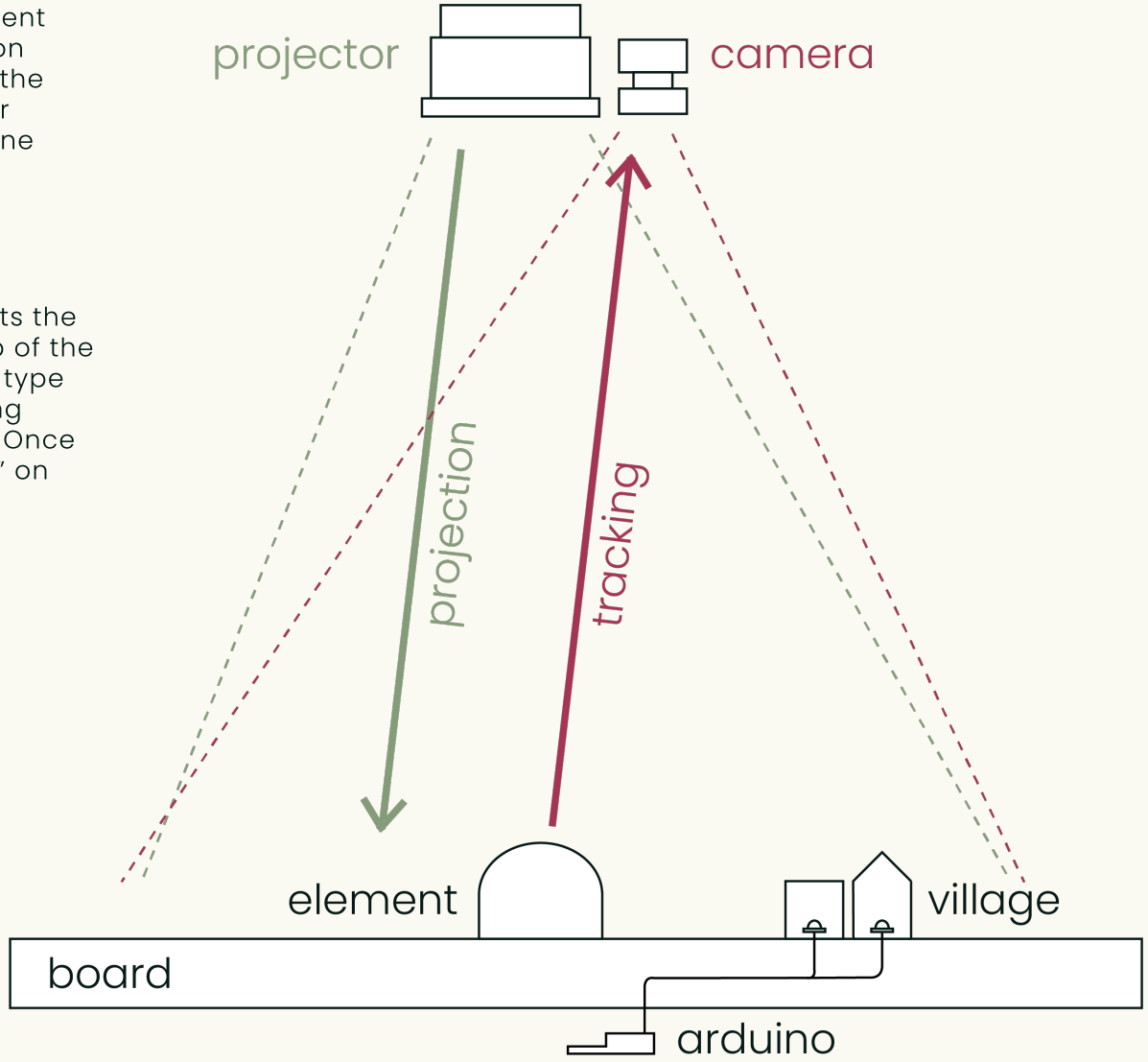



*Figure 35: Set-up of Geotricity*

## Power plants

In order to ensure that the correct learning experience is imparted into the design, research has been conducted into the various energy resources and their implementation. Figure 36 on the next page gives an overview of the different energy resources by presenting the element, corresponding projection, applicability, board indications, scenarios and feedback.

In consultation with the Green Kids' Museum, it was decided to focus only on renewable energy resources. This decision is based on the importance to keep it clear and comprehensible for the children and to also support the message of the museum to create a sustainable future in which non-renewable energy does not play a role.

It was also decided to exclude ocean power plants as research shows that the costs do not yet outweigh the benefits (Onundo & Mwema, 2017). In addition, this form of energy generation is not as relevant to the target group because it is only suitable at the coast and this covers only a small part of Kenya, not close to Nairobi.  Finally, it would bring limitations to the design because the board has to be provided with an ocean.

## Location

As described, the effectiveness of power plants depends on a number of factors. In order to incorporate this aspect into the design, topography maps for each energy resource were created (Figure 37). The red areas are the optimal conditions for the power plant which means that all the houses closest to the element will light up. Orange means that a small number of houses will be provided with power and yellow only 1 house. As soon as the child puts an element in the grey area, they will receive the feedback as presented in Figure 36. It was taken into account that the houses are distributed across the board and all have the possibility of being supplied by multiple energy resources.

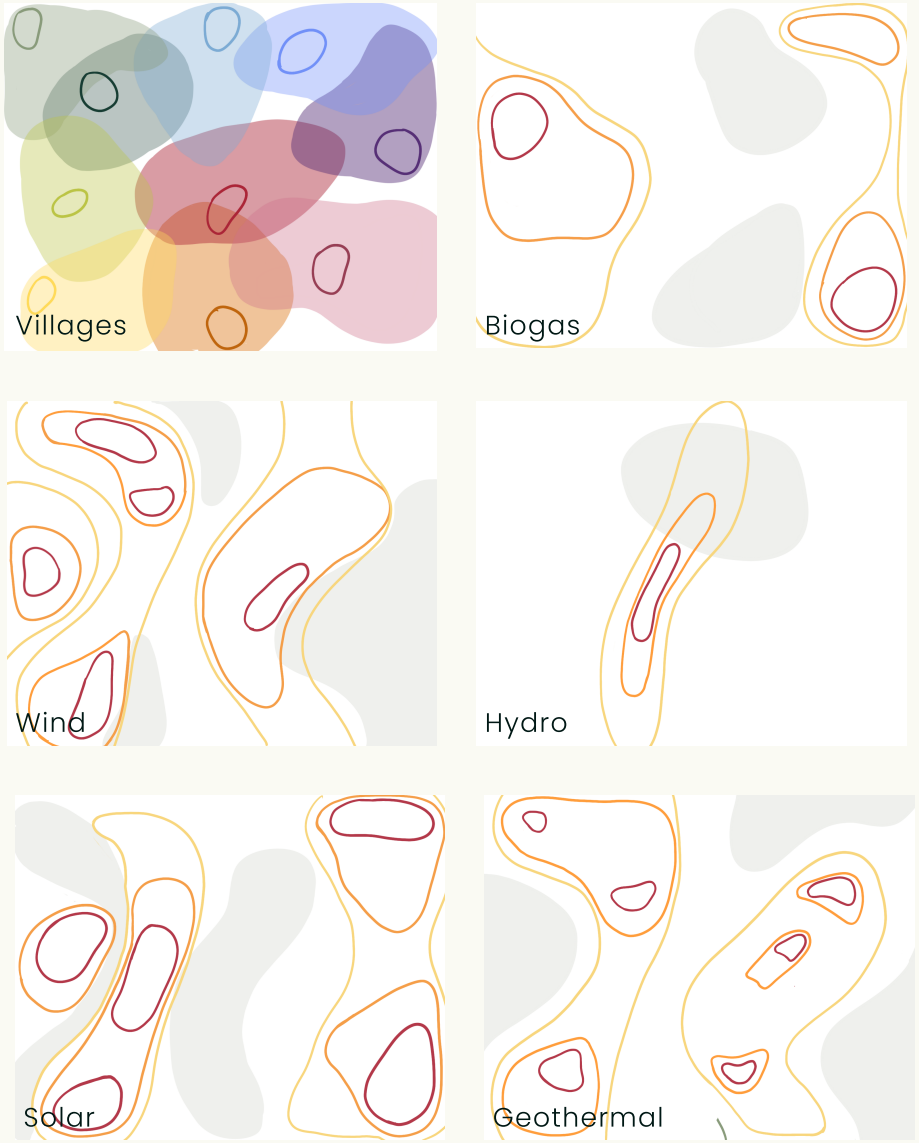



*Figure 37: Typography maps Geotricity per energy source*

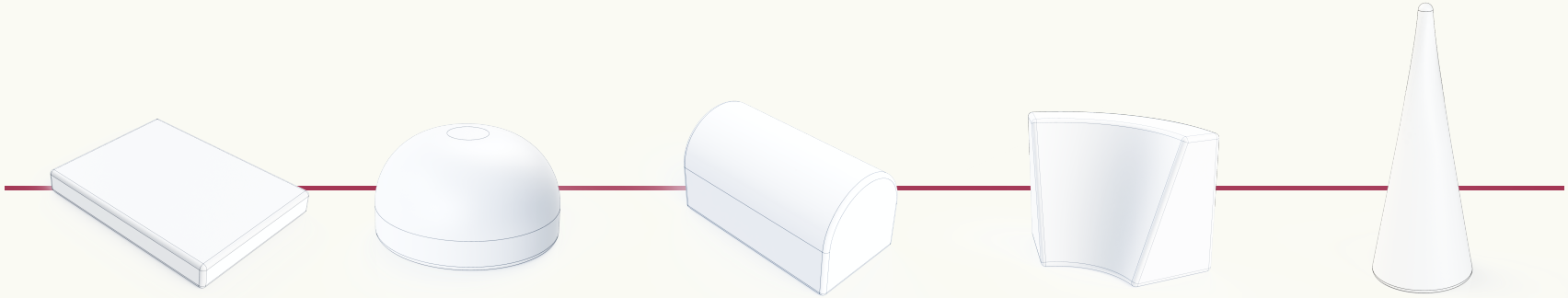
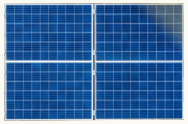
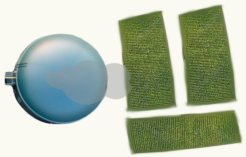
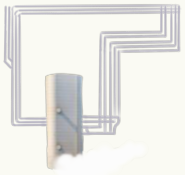
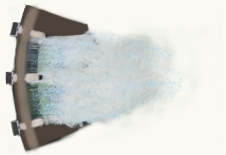
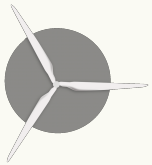
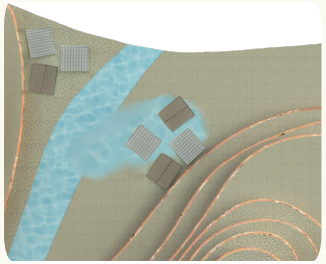
| | Solar | Biogas | Geothermal | Hydro | Wind |
|---|---|---|---|---|---|
| **Implementation** | Solar panels take up a lot of space and require full sunlight, ideally they should be placed in a large open area. | A biogas plant is best located in rural areas due to the needed large amount of raw material. Besides, a foul odor emerges during the process. | Geothermals are stable and reliable however they are location restricted and it is expensive to establish the power plant. | A hydro power plant should be placed by ( flowing) water. Placing a hydro dam can increase the risk of both floods and droughts. | Windmills are an effective way of land use however they do depend on the amount of wind and they can cause noise pollution. |
| **Element** |  | | | | |
| **Board indications** | Slowly moving shadows behind the mountains on the board are projected. | In addition to the projection on the element itself, farmyards appear surrounding the biogas power plant to show that it requires space. | Sporadically, a cloud of steam is projected, mainly in the vicinity of the mountains, which indicates it is a suitable place for a geothermal plant. | Based on the location of the hydro dam, the water will flow faster or slower. | Wind clouds are depicted on the board moving in a certain direction. In addition, the turning of the blades gives an indication of the suitability of the spot. |
| **Projection** |  |  |  |  |  |
| **Scenario/ feedback** |  |  |  |  |  |

*Figure 36: Overview of the projection and implementation of the different energy resources*

# 8.5 Technology

To demonstrate the feasibility of the technology, an interactive prototype was created, representing a small part of the concept. The structure of this interactive prototype is discussed. The prototype is a simplified version of the concept in which a number of factors have been left out of consideration:

- only the red, orange and grey areas of the topography maps were taken into account;
- The interplay between power plants is not taken into account;
- a limited number of scenarios were implemented.

Figure 38 depicts a visual of the interactive model.

## Object detection

Various techniques have been analysed to create the experience. It was decided to work with the Python programming language, in which openCV machine learning was used, in particular the object detection model of YOLOv5. With the support of a collection of images of the element, the model was trained. The training ensured that the software is synchronised with the elements, allowing the camera to detect them. Once the object has been detected and coordinates on the board are determined, the corresponding image is projected onto the object.

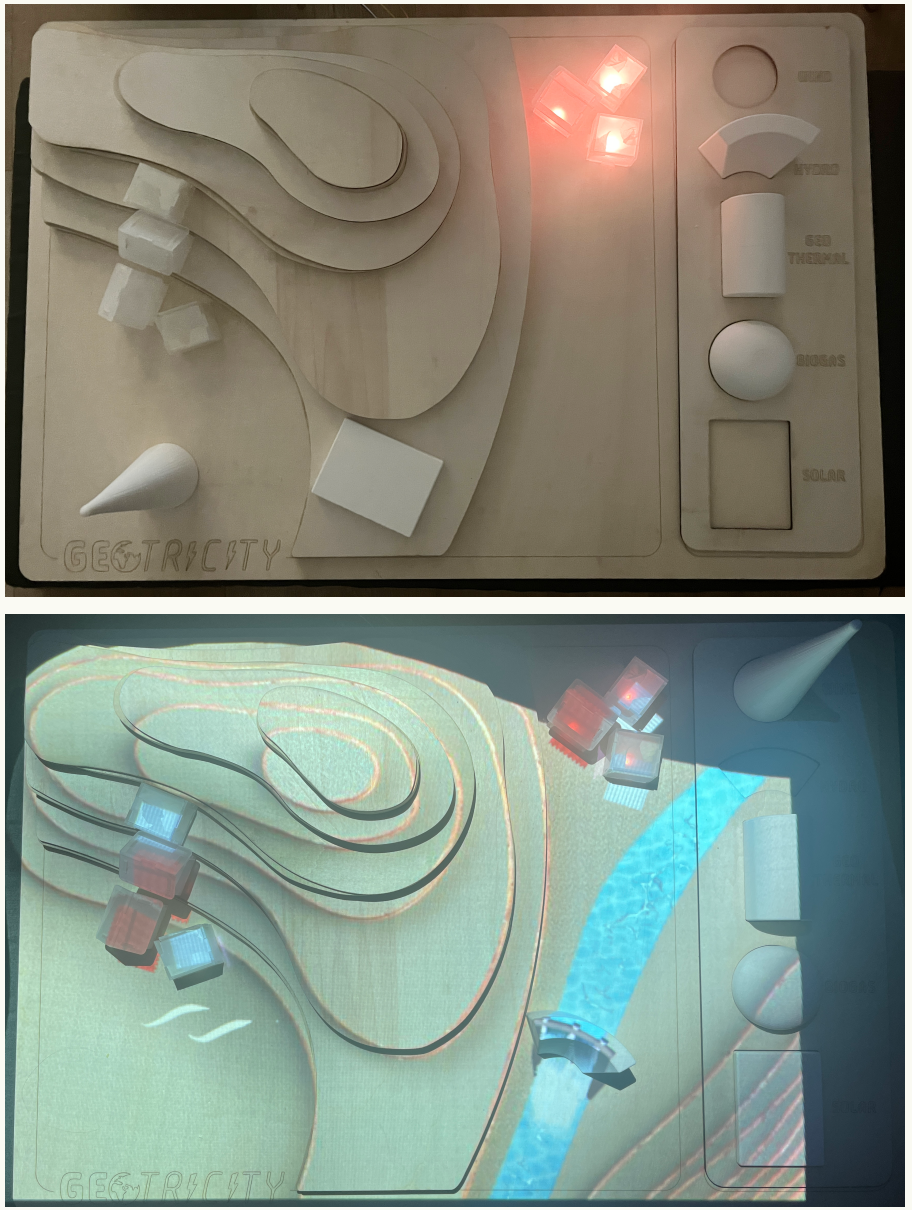



*Figure 38: Interactive prototype with the picture on the top the setting without the projection, and the bottom one of the projection on an element and the wind indication.*

## Arduino

It is desired that the board is accessible from all sides. This way children can easily walk around the installation and work together. Above the table the projection is managed and the elements are tracked. Under the table the lights in the houses are controlled. Bluetooth is used to create a connection between the projector and camera above the table and the Arduino under the table. The projector and camera are connected to the laptop that runs the program. As soon as an element is placed in the correct spot, the program sends a signal via Bluetooth to the Arduino under the table. The Arduino receives this signal and based on the message it lights the corresponding houses.

## Flowchart

Figure 39 represents a flowchart of the interaction between the user and the interactive prototype, presenting the build-up of the programmed code.

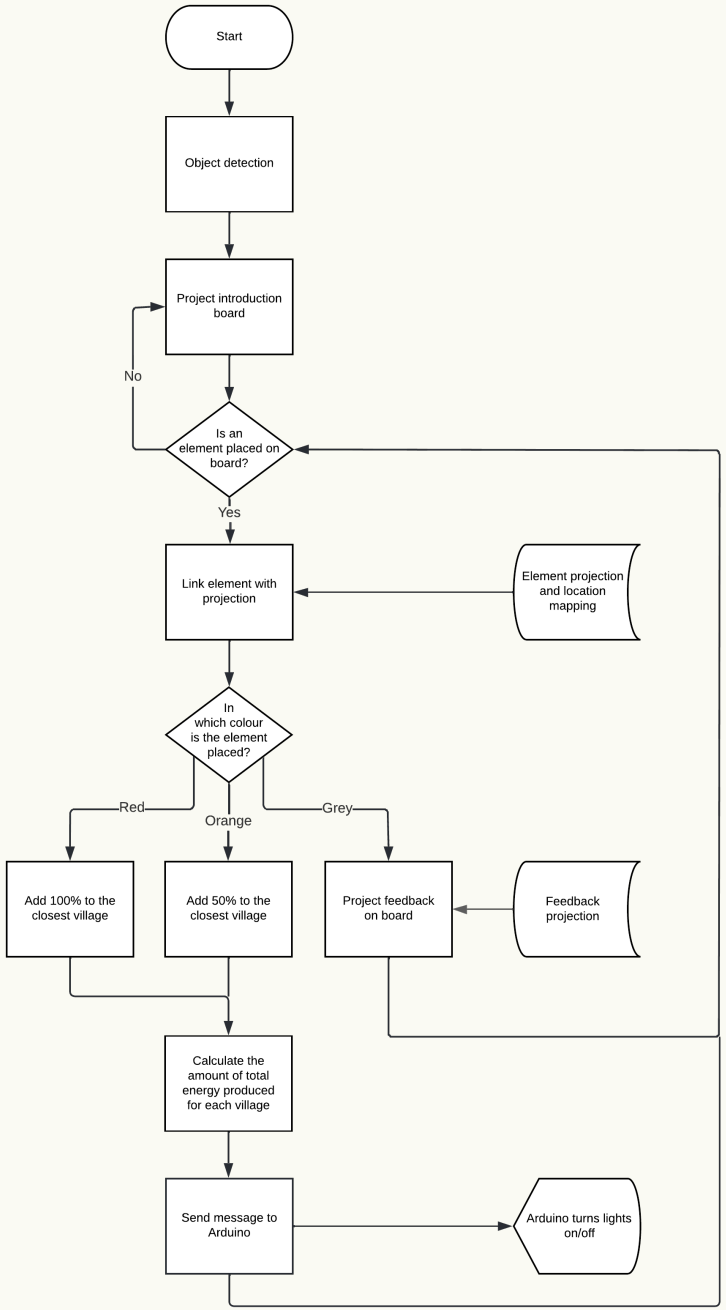



*Figure 39: Flowchart interaction between user and Geotricity*

# 8.6 Production technique

To give a complete picture and to help the Green Kids' Museum implement the design, a proposal for the production of the design is included.
This part is meant more as a recommendation as opposed to a fully thought out production process.

During the evaluation of the production techniques extra attention was paid to ensuring that it also contributes to the overall goal of the museum: sustainability.

For the production of the concept it is recommended to collaborate with the organisation Plastiki Rafiki. This is a non-profit organisation set up and run by (design) students and its mission is "Cleaning up our local environment and empowering communities to earn a living through plastic recycling and creative product design" by processing plastic waste from nature into new products using proprietary machines (Plastiki Rafiki, 2019). These machines are developed using the open-source plastic recycling community Precious Plastic. During the development of these machines they also consciously take into account the impact by using 100% locally available materials and components.

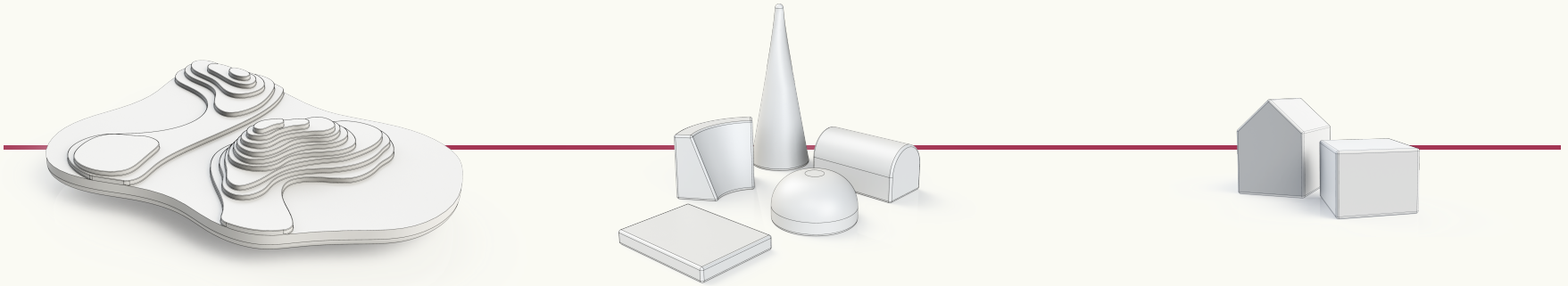
A collaboration with this company provides:

- a local supplier, keeping the ecological impact of transport low.
- sustainable use of materials, by using only plastic waste found in the environment of Kenya.
- support to local communities.

In addition, a collaboration between the Green Kids' Museum and Plastiki Rafiki contributes to the message that the museum wants to spread: Anyone can be a change maker and we need to empower people to become one.

It is important to note that there are certain facilities of Plastiki Rafiki that run exclusively on renewable energy, the museum can specify that the parts may only be made at these facilities to ensure that the production of the installation also has a minimal ecological footprint.

In a conversation with one of the leaders of a design team from Plastiki Rafiki, it transpired that they were interested in working together. Potential ways to make the different parts of Geotricity were also discussed. Figure 40 on the next page highlights the most important components by presenting the requirements, suitable production technique and additional considerations. Plastiki Rafiki is familiar with all these (and more) production processes.

| | Board | Elements | Houses |
|---|---|---|---|
| **Visual** |  | | |
| **Requirements** | • The surface must be smooth and have a light colour in order to show the projection.<br>• The table should be sturdy in case children climb on the table. | As the elements are the components that are constantly touched, it is important that the material is:<br>• Durable<br>• Easy to clean | The houses are fixed on the table and must show a light when powered correctly, therefore it is important that the material is:<br>• Translucent<br>• Sturdy |
| **Production** | Creating sheets with an oven press machine after which the sheets can be cut into shape.<br>• Easy process<br>• Solid | Injection moulding using a resin mould.<br>• Small sample size<br>• Shape flexibility | Sheets made in the oven press machine, cut into shape using a CNC-machine.<br>• Precise<br>• Easy assembly |
| **Considerations** | Consider using a special polyurea coating:<br>• enhance projection<br>• prevent damage from the large number of visitors<br>*Based on "'Waterkracht" in Science Center NEMO Amsterdam (Kunststof Coatings Nederland, 2015)* | Anti-slip component on the bottom:<br>• prevent from sliding too easily on the table<br>• less sustainable | Using a CNC machine, the parts of the hollow body can be clicked together (Appendix Q). However, it should be noted that children may be able to take them apart, therefore it is recommended to secure the connection for example by using glue or a melting technique. |

.

*Figure 40: Recommended production techniques per component of Geotricity*

# 8.7 Evaluation test set-up

In order to validate the intended interaction, an evaluation test was conducted. Within the scope of the project, it was not feasible to test the concept with the original target group of 9 to 11 year old children living in the Nairobi metropolitan area. In order to still gain an impression of whether the concept fits in with the 9 to 11 year old age group, a test was carried out at a Dutch school called "Het Atelier" with children in group 6 (age 10).

## Goal of test

The purpose of the test was to gain insight into whether Geotricity meets the design goal as described in 6.1 and to find possible points of improvement as part of the recommendations. In the user test, specific attention was paid to the following questions:

- To what extent do the children experience the installation as a playful experience?
- To what extent does the installation invite the children to explore, experiment with and reflect on the application of renewable energy?
- To what extent do the children understand what is expected of them with the installation?

## Test plan

In order to create overview and consistency between the various tests, a test plan was created. For the complete test protocol see Appendix P.
The test was conducted in groups of 2 to 3 children, in order to stimulate interaction between the children but also small enough for the researcher to manage all the insights.

The test consisted of 4 sessions with a total of 11 children. Each group of children went through the following steps in about 45 minutes:

First, the children were given a short introduction to clarify the purpose of the test and to remove some of the tension. Next, the children were presented with a scenario in which they were told that the installation would be in a museum such as NEMO. After the short explanation, the children started to test the prototype.

Because building a complete prototype was beyond the scope of the project, a representation of the design was used. A projection was made on the ground, where children could place the elements (Figure 41, next page). As soon as the children put down or moved an element, the projection was changed manually by the researcher. This is a different prototype from the interactive prototype described in 8.7: Technology, which was intented to demonstrate the feasibility of the concept.

After the prototype had been tested, the children were asked a number of questions in order to, in addition to the observations, get insight into the research questions.

The children were thanked for their time and escorted back to their classroom.

Immediately after the test, the researcher took the time to note down insights. This was not done during the test to avoid giving children the idea that they were being judged. In addition, this gave the researcher the opportunity to fully focus on the test as the projection needed to be changed manually.

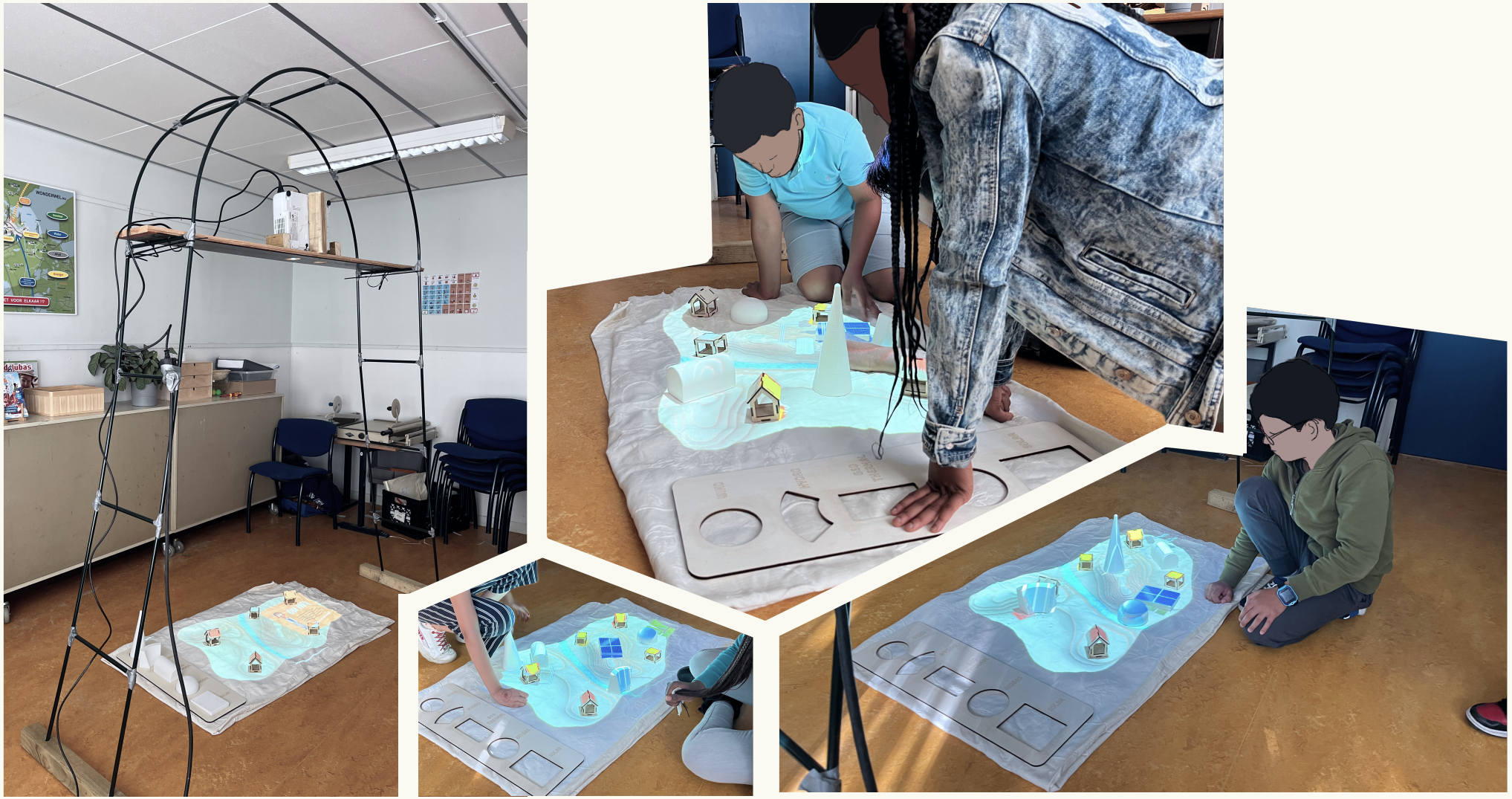


*Figure 41: Impression of the evaluation test with the left picture presenting the test setup*

# 8.8 Evaluation test findings

Based on observations and the questions during the evaluation test, several insights were gained. These insights are briefly discussed on the basis of the research questions mentioned in 8.5: Evaluation test set-up. Next, based on the design criteria, it is determined whether the concept has achieved the design goal.

## Playful experience

- A general impression of the head researcher is that the concept was well received by the children. A number of groups were keen to do the test again after it had actually finished.
- The children mentioned they liked that once they placed an object the projection made it come to life. Besides, they liked that the projection followed their movement providing a feeling of being in control.
- The moving animation, rather than a static image, was experienced as engaging.

## Explore, experiment & reflect

- The children were especially focused on the houses, experimenting with several configurations to try to get the light in the houses turned on, feeling a sense of pride when they succeeded, expressed by clapping and cheering.
- The indications given on the board were clearly picked up and gave guidance in placing the objects. Especially the indication of wind.
- In all groups, the participants engaged in a fruitful dialogue, trying to turn the lights in the houses on and sharing their ideas on how to do so. It is important to mention that the children were already acquainted with each other because they attend the same class, in a museum the peers are often strangers.
- The children sometimes felt frustrated when the projection did not change quickly enough or when they did not understand why a village was flooded. It must therefore be clear to children why particular events happen.
- The children attributed extra value to the feedback they received. When asked about their goal, the feedback was often explicitly mentioned, for example: “We had to make sure that everyone had power but also that they had enough space” (after feedback from the biogas plant). This shows that it is an effective way to instruct the children, however, a balance needs to be established between how much attention the feedback gets in relation to the play itself.

## Understandable

- In the beginning children were under the impression that if they placed the element correctly, a projection would appear. A possible explanation for this is that the manual projection sometimes took long to get in the right place. However, this lasted for a few minutes, after which children understood that the projection followed the element.
- When asked afterwards what the children’s goal was, they often answered along the lines of: “Taking care of electricity”. This shows that they were aware of the aim of the installation.
- In one session, the start message was not read, and the group did not know what to do as a result. This shows that the first message is an important aspect and should be emphasised.
- As a point for improvement, the children indicated that they would like to have more insight into which house is connected to which power plant. A possible solution would be to create a power line between the two.

## Design criteria

To determine whether the design goal has been reached, the design criteria were assessed. Each criterion is marked with a + or −. If the evaluation test has shown that the criterion is met by the design, it is indicated with a + . The criteria that have not yet been properly incorporated in the design or if no conclusion could be drawn based on the evaluation test are marked with a − .
The assessment was done by the head researcher based on her impressions during the evaluation test.

The test showed that not all children understood what was expected of them, some children were not aware of the created pseudo-reality. As indicated earlier, the start message is an important component with regards to this criterion. It is therefore recommended to improve the way the message is delivered to the child.

Because the evaluation test was a planned session, it was not possible to test whether the children experienced the play with the installation as a spontaneous activity and if it provides a form of relaxation. Further research needs to be conducted in order to assess these criteria.

The criterion "The child believes that their knowledge of renewable energy increased" also requires further research to determine whether it is met. It was decided to leave this out of the scope of the evaluation test because the prior knowledge of the Dutch children from the test can differ significantly from that of the target group.

### Become interested

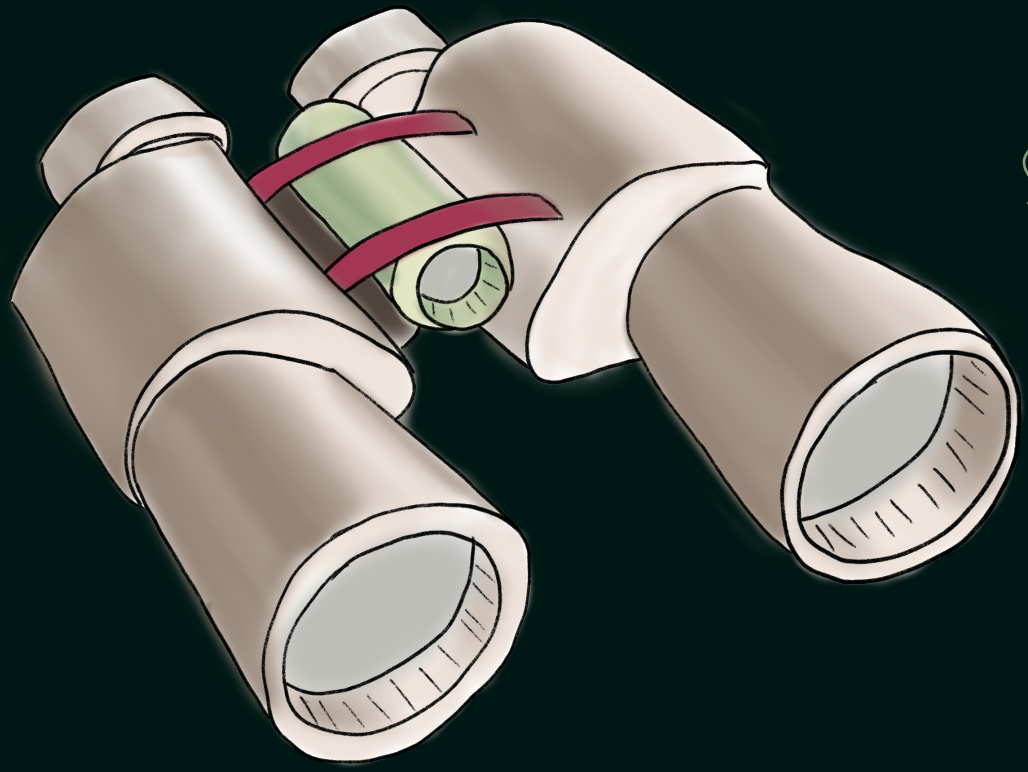
- − It is clear to the child what play activity needs to be conducted.
- + The play activity is feasible to conduct for the child.
- + The child experiences a sense of curiosity to engage with the installation.

### Experiential learning

- + When engaging with the installation the child feels in control
- + The child experiences the installation as playful.
- − The child experiences the interaction with the installation as a spontaneous activity.
- + The child experiences the process as more important than a specific outcome.
- − The child is aware of the signals of the created pseudo-reality.
- + The child feels supported to process and practice their gathered knowledge.

### Finalise experience

- − The child believes that their knowledge of renewable energy increased.
- − The child experiences the exhibition as a form of relaxation.
- + The child has a feeling of pride after using the installation.



# 9. Conclusion

THIS CHAPTER PRESENTS THE MAIN FINDINGS OF THE PROJECT AND EVALUATES IF THE DESIGN GOAL IS MET. LASTLY, RECOMMENDATIONS ARE MADE BASED ON THE INSIGHTS GAINED WITHIN THE PROJECT.

# 9.1 Conclusion

In part 1: Exploration, research was carried out in relation to play-based learning. It was concluded that this is an effective way for the museum to ensure that children enjoy themselves while also having an educational value. Kolb's (1974) experiential learning model was used to describe the process of learning through experience: The child has an experience, reflects on it, and then tries to make sense of it, which can then be tested by experimentation. This cycle keeps repeating itself multiple times.

To ensure that the installation connects with the target group, a set of 12 guidelines has been developed, in which each guideline is a way to support the play-based learning experience.

In addition, the research has shown that children at the age of 9 to 11 years living in the Nairobi metropolitan area already have some basic knowledge about energy. For example, they can list some energy resources. In order to ensure that the museum matches the children's previous knowledge while at the same time providing a learning experience, the project focused mainly on contrasting different energy resources.

The insights from the Exploration have been compiled into the following design goal in the Design part:
"The design goal is to design an interactive installation that first triggers children of age 9 to 11 in Nairobi metropolitan area to actively engage with the installation. Through engaging with the installation they will be able to playfully explore, experiment and reflect on the implementation of renewable energy, contrasting the different energy sources. After which they will leave the installation with a sense of pride, due to the gained learning experience."

Based on the design goal and using the guidelines, the concept of Geotricity was developed. This installation gives children the challenge to supply energy to the houses on the board by placing power plants. An interactive environment is projected on the board, which changes according to the placement of the power plants by the children. The different types of energy with corresponding power plants all have a different implementation, leaving it up to the children to find out the applicability and conditions of the different energy resources, by exploring, experimenting and reflecting on their activities.

The evaluation test and the interactive prototype were used to determine if the design goal was met. The evaluation test showed that the changing projection based on the child's input is an engaging element. Besides, the projected feedback and indications supported the children in exploring and reflecting on the implementation of the renewable energy resources. During the test the children worked together and shared their insights which led to an enhanced learning experience. The immediate feedback from the houses in which the light did or did not turn on was considered an effective way to experiment and test the child's findings. Once they managed to turn one or multiple lights on, they felt a sense of pride expressed by clapping and cheering.

The evaluation session demonstrated that the design of Geotricity mostly corresponds with the design goal, However, the evaluation test could not determine whether the children actually became more aware of renewable energy, follow-up research will have to show whether this is the case.  In addition, the evaluation test showed that there is still room for improvement, especially in terms of how understandable the design is for the children.

# 9.2 Recommendations

If the Green Kids' Museum decides to implement the concept, improvements still need to be made beforehand. The most essential recommendations are listed.

During testing, it transpired that the children lacked an understanding of which power plant supplied electricity to which houses. Therefore, it is recommended to clarify this by making it visible to the children. This can be done, for example, by projecting an electrical wire from the houses to the power plant.

In the evaluation session, the start message was found to be an important element in understanding the purpose of the installation. It is recommended that this message is made more prominent to make sure that children are aware of it.

Another important aspect to consider is the performance of the installation when it is in the museum for a day. If a child leaves the installation in the ideal conditions (with all the lights in houses turned on), the next visitor will not have the same opportunity to explore, experiment and reflect on the experience. A possible solution would be to constantly change the conditions of the board, for instance the direction of the wind can shift, and the shadow can move to the other side of the mountain. This way, the game continues to develop and new challenges will arise for the next children.

# 9.3 Limitations

Like any project, the research has some limitations. And while some limitations keep the project manageable and focused, there are also some that limit the insights of the project. Most limitations are highlighted in the report in the corresponding section. However the two most important limitations are briefly highlighted.

Within the project there was limited contact with the target group of 9 to 11 year old children living in the Nairobi Metropolitan area. As described in 8.7: Evaluation test set-up, it was not possible to test the concept with the original target group. In order to get an impression of whether the design goal has been achieved, it was tested with Dutch children of the same age. However, these children are, unlike the target group, already familiar with interactive children's museums like NEMO Science Museum, they have another baseline of knowledge and differ in culture and view on the world.

In addition, the project was carried out by a Dutch student who had no specific knowledge about or experience with Nairobi, Kenya prior to the project. In efforts to close this gap, the head researcher frequently contacted people living in Nairobi and consciously took into account her own cultural background and bias. However, it cannot be eliminated that there are unconscious preconceptions made within the project or design of Geotricity, with which the target group does not identify.

Although the report mentions that parents and teachers play an important role in the play-based learning process of the target group, they were not included in the design. Follow-up research could be conducted to investigate the role the parents and teachers play in the museum and how this affects the design of Geotricity.

# 9.4 Future work

Follow-up research could focus on the guidelines by assessing their applicability when designing an exhibition for children, especially with regard to the implementation of the guidelines for other target groups.

With regard to the design of Geotricity, first and foremost the design should be tested with the target group to determine whether it is a suitable concept to provide a play-based learning experience for them. The evaluation test should specifically focus on whether the installation matches the current knowledge level of the target group, to what extent they experience the design as playful and to what extent they understand what is expected of them. This test can also be used to assess whether the children learn about renewable energy by means of the installation. It is advisable to test the concept with the target group as soon as possible to identify barriers at an early stage in order to take them into account during the development.

In addition, the projection should be further developed to include all possible scenarios. Within the scope of this project, only a small number of possibilities were covered, but the database should be expanded if the installation will be implemented in the museum.

# References


## A

Apter, M. J. (2007). Danger: Our quest for excitement. Oneworld Publications Limited.

## B

Bär, E., & Boshouwer, S. (2018). Worlds of Wonder: Experience Design for Curious People. BIS Publisher.

Barnett, L. A. (1990). Developmental benefits of play for children. Journal of Leisure Research, 22(2), 138-153.

Begisheva, A. (2018). Kenya becomes a pioneer in green energy. KfW. https://www.kfw.de/stories/environment/renewable-energy/kenia-green-energy/

Bourke, T. M., & Sargisson, R. J. (2014). A Behavioral Investigation of Preference in a Newly Designed New Zealand Playground. American Journal of Play, 6(3), 370-391.

## C

Cook, D. A., & Artino Jr, A. R. (2016). Motivation to learn: an overview of contemporary theories. Medical education, 50(10), 997-1014.

## D

Damon, W. (1984). Peer education: The untapped potential. Journal of applied developmental psychology, 5(4), 331-343.

Darwin, C. (1872). The Expression of the Emotions in Man and Animals. Oxford University Press.

Davis, J. (2010). Early childhood education for sustainability: Why it matters, what it is, and how whole center action research and systems thinking can help. Journal of Action Research Today in Early Childhood, 2010(April), 35-44.

DINED. (2018). DINED Anthropometric Database. Retrieved July 29, 2022, from https://dined.io.tudelft.nl/en/database/tool

## E

Ebbens, S., & Ettekoven, S. (2013). Effectief leren. Derde druk. Groningen: Noordhoff Uitgevers.

Eberle, S. G. (2014). The elements of play: Toward a philosophy and a definition of play. American Journal of Play, 6(2), 214-233.

Eckstein, D., Künzel, V., Schäfer, L., & Winges, M. (2019). Global climate risk index 2020. Who Suffers Most from Extreme Weather Events? Weather-Related Loss Events in 2018 and 1999 to 2018. (Report No. 20-2-01e). Germanwatch e.V. https://www.germanwatch.org/sites/default/files/20-2-01e%20Global%20Climate%20Risk%20Index%202020_16.pdf

Evy van Weezendonk (n.d.). Info [LinkedIn page]. LinkedIn. Retrieved February 8, 2022, from https://www.linkedin.com/in/evy-van-weezendonk/

## G

Government of Kenya. (2016). Green Economy Strategy and Implementation Plan 2016 – 2030. Retrieved February 10, 2022 from https://www.greengrowthknowledge.org/sites/default/files/downloads/policy-database/KENYA%29%20Improving%20Efficiency%20in%20Forestry%20Operations%20and%20Forest%20Product%20Processing%20in%20Keyna_0.pdf

Green Kids Museum. (2021). Framework and Methodology for Learning Outcomes. Nairobi.

Gurholt, K. P., & Sanderud, J. R. (2016). Curious play: Children's exploration of nature. Journal of Adventure Education and Outdoor Learning, 16(4), 318-329.

## H

Hassed, C. (2001). How humour keeps you well. Australian Family Physician, 30(1), 25-28.

Henderson, T. Z., & Atencio, D. J. (2007). Integration of play, learning, and experience: What museums afford young visitors. Early Childhood Education Journal, 35(3), 245-251.

## I

International Renewable Energy Agency. (2021). Energy profile Kenya. Retrieved March 3 2022, from https://www.irena.org/IRENADocuments/Statistical_Profiles/Africa/Kenya_Africa_RE_SP.pdf

## J

Jahreie, C. F., Arnseth, H. C., Krange, I., Smørdal, O., & Kluge, A. (2011). Designing for play-based learning of scientific concepts: Digital tools for bridging school and science museum contexts. Children Youth and Environments, 21(2), 236-255.

## K

Karabon, A., & Steiner, A. (2020). Risk taking during play: ecological influences and behavioral outcomes of young children's appraisal of risks in outdoor spaces. International Journal of Play, 9(3), 318-330.

Kathambi, B. E., Mā, H., & Mutembei, I. (2020). PERCEPTIONS ON ACCELERATED TRANSITION TO RENEWABLE ENERGY IN NAIROBI, KENYA. International Journal of Social Sciences, 2(1).

Kemple, K. M., Oh, J., Kenney, E., & Smith-Bonahue, T. (2016). The power of outdoor play and play in natural environments. Childhood education, 92(6), 446-454.

Kisirkoi, F. K., & Mse, G. (2016). Curriculum Implementation: Strategies for Improved Learning Outcomes in Primary Schools in Kenya. Journal of Curriculum and Teaching, 5(1), 19-26.

Kolb, D.A. (1984) Experiential Learning: Experience as the Source of Learning and Development. Prentice-Hall, Inc. Englewood Cliffs, NJ.

Kunststof Coatings Nederland. (2015, September 1). Science Center NEMO - Strijd tegen water (tafel gecoat met polyurea). YouTube. Retrieved July 8, 2022, from https://www.youtube.com/watch?v=XWXlh04Yxhk

## L

Lawson, D. F., Stevenson, K. T., Peterson, M. N., Carrier, S. J., Strnad, R., & Seekamp, E. (2018). Intergenerational learning: are children key in spurring climate action?. Global Environmental Change, 53, 204-208.

Lawson, D. F., Stevenson, K. T., Peterson, M. N., Carrier, S. J., L Strnad, R., & Seekamp, E. (2019). Children can foster climate change concern among their parents. Nature Climate Change, 9(6), 458-462.

Lever-Tracy, C. (Ed.). (2010). Routledge handbook of climate change and society (p. 228). London: Routledge.

Lindholm, M. (2018). Promoting curiosity?. Science & Education, 27(9), 987-1002.

Lovorn, M. G. (2008). Humor in the home and in the classroom: The benefits of laughing while we learn. Journal of Education and Human Development, 2(1).

Lucero, A. & Arrasvuori, J. (2010). PLEX Cards: a source of inspiration when designing for playfulness. In Proc. of Fun and Games '10. ACM, 28-37.

## M

Makau, A. M., Mukundi, J. B., Ochiengâ, A., Gichuhi, M. W., & Wesonga, J. (2018). Perception and mitigation preferences on climate change among residents of Nairobi City County. African Journal of Environmental Science and Technology, 12(7), 244-257.

Masson-Delmotte, V., Zhai, P., Pörtner, H. O., Roberts, D., Skea, J., Shukla, P. R., ... & Waterfield, T. (2018). Global warming of 1.5 C. An IPCC Special Report on the impacts of global warming of, 1(5).

## O

Onundo, L. P., & Mwema, W. N. (2017). Estimating Marine Tidal Power Potential in Kenya. International Journal of Energy and Environmental Engineering, 10(7), 1013-1017.

Our world in data. (2019). Kenya: Energy Country Profile. Retrieved March 4 2022, from https://ourworldindata.org/energy/country/kenya

## P

Plastiki Rafiki - About. (2019). Plastiki Rafiki. Retrieved July 27, 2022, from https://plastikirafiki.com/about/

## R

Rix, C., & McSorley, J. (1999). An investigation into the role that school-based interactive science centres may play in the education of primary-aged children. International Journal of Science Education, 21(6), 577-593.

## S

Sanders, L., & Stappers, P. J. (2012). Convivial Toolbox: Generative Research for the Front End of Design (1st ed.). BIS.

Smith, N., & Leiserowitz, A. (2014). The role of emotion in global warming policy support and opposition. Risk Analysis, 34(5), 937-948.

## U

Under the sea. (2019). [Photograph]. Village Market Kenya. https://villagemarket-kenya.com/store/under-the-sea/

UNESCO International Bureau of Education, Njeng'ere, D., & Ji, L. (2017, June). The Why, what and how of competency-based curriculum reforms: the Kenyan experience (IBE/2017/WP/CD/11). https://unesdoc.unesco.org/ark:/48223/pf0000250431

UNFCCC. (n.d.) Education and Training under Article 6. Retrieved February 10, 2022 from https://unfccc.int/topics/education-and-outreach/workstreams/education-and-training

United Nations. (n.d.). What is renewable energy? Retrieved March 7, 2022, from https://www.un.org/en/climatechange/what-is-renewable-energy

## V

Van Boeijen, A.G.C. (2015). Crossing Cultural Chasms: Towards a culture-conscious approach to design. Doctoral Thesis, Delft University of Technology, Delft.

Van Boeijen, A., Daalhuizen, J., Zijlstra, J., & van der Schoor, R. (2013). Delft Design Guide: Vol. 3rd printing 2016 (revised 2nd ed.). BIS Publishers.

Van der Bijl, W.M. (2000). Bio play-along [Graduation report].

Vedder, R. (1977) Observatie van kinderen. Groningen: Wolters-Noordhoff.

Vermeer, E.E.A. (1972) Spel en spelpedagogische problemen. Utrecht: Bijleveld.

Vermeeren, A. (2022, January 4). About - MuseumFutures Lab. Delft Design Labs. Retrieved June 28, 2022, from https://delftdesignlabs.org/museum-futures-lab/about/

Verstraete, I., & Nijman, K. (2018). Handboek leren leren voor het voortgezet onderwijs: 5 krachtige leerprincipes vertaald naar de praktijk. Pica.

## Z

Zimmerman, J., & Forlizzi, J. (2017). Speed dating: providing a menu of possible futures. She Ji: The Journal of Design, Economics, and Innovation, 3(1), 30-50.

Zuilkowski, S. S., Piper, B., Ong'ele, S., & Kiminza, O. (2018). Parents, quality, and school choice: Why parents in Nairobi choose low-cost private schools over public schools in Kenya's free primary education era. Oxford Review of Education, 44(2), 258-274.