

Exploring the impact of infographics and non-digital interactive design elements on the behavioral engagement of primary school children in science exhibitions

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12-10-2023

Abstract

Fostering children's engagement with science is crucial for nurturing a positive attitude toward the subject. Museums can offer an ideal environment for achieving this goal, providing children with an informal and interactive introduction to science. However, the effectiveness of museums in promoting children's engagement in science exhibitions is often hindered by insufficient information and poor integration of hands-on activities. Consequently, there is a need for research aimed at developing engaging science exhibitions for children. In recent years, research has largely focused on the use of high-tech exhibits to engage children. This has led to a gap in the understanding of the effectiveness of simpler elements, such as pictures or button presses, in engaging children within a science exhibition. Therefore, the aim of this study is to investigate the impact of infographics and non-digital interactive design elements (N-DIDE) on the behavioral engagement of primary school children in two science exhibitions located at the Museumfabriek in Enschede. This research consists of three phases. First, the analysis and exploration phase, where preliminary research was conducted to understand children's current engagement behavior with the exhibitions. Second, the design and construction phase, involving the development of infographics and N-DIDE. Third, the evaluation and reflection phase, where the impact of these infographics and N-DIDE on children's engagement behavior were investigated. Throughout the study, 240 observations were conducted to investigate the engagement behavior. The results revealed several significant impacts of the infographics and N-DIDE on the engagement behavior of primary school children. Nevertheless, there were also no statistically significant differences that were of interest and therefore require further investigation.

Keywords: engagement behavior, primary school children, science exhibitions

Table of contents

1. Introduction	5
2. Theoretical framework	8
2.1. Behavioral engagement	8
2.2. Infographics for immediate apprehendability	14
2.3. Non-digital interactive design elements for physical interactivity.....	16
2.4 Research question.....	17
3. Research design	18
4. Analysis and exploration	19
4.1. The exhibitions.....	19
4.1.1. Thunder and Lightning exhibition (exhibition A)	19
4.1.2. World Traveler exhibition (exhibition B).....	19
4.2. Method	20
4.3. Participants.....	20
4.4. Instrumentation Exhibition A.....	20
4.5. Instrumentation Exhibition B.....	21
4.6. Procedure	21
4.7. Data analysis exhibition A	22
4.8. Data analysis exhibition B.....	23
4.9 Results Exhibition A	23
4.9.1. Descriptive statistics.	23
4.9.2. Frequency statistics.	24
4.9.3. Pearson’s correlation.....	26
4.10. Results Exhibition B.....	26
4.10.1. Descriptive statistic.....	26
4.10.2. Frequency statistics	27
4.11. Discussion of results.....	28
4.11.1. Exhibition A.....	29
4.11.2. Exhibition B	30
5. Design and construction	32
5.1. Ideation.....	32
5.1.1. Skeleton design.....	32
5.1.2. Brainstorming	33
5.2. First ideas.....	34
5.3. Feedback and evaluation ideas	36
5.4. Sketches and feedback	36
5.4.1. Feedback sketch Kelvin’s Druppelaar	36
5.4.2. Feedback sketch orb	37
5.5. Final infographics and N-DIDE.....	37
6. Evaluation and reflection	38
6.1. Method	38

6.2. Participants.....	38
6.3. Instrumentation Exhibition A.....	38
6.4. Instrumentation Exhibition B.....	39
6.5. Procedure.....	39
6.6. Data analysis study I.....	39
6.7 Data analysis study II.....	40
6.8. Results Study I exhibition A.....	40
6.8.1. Descriptive statistics.....	40
6.8.2. Frequency statistics.....	41
6.8.3. Pearson's correlation.....	43
6.8.4. Comparative analysis.....	43
6.8.5. Comparative analysis.....	45
6.9. Results Study I exhibition B.....	47
6.9.1. Descriptive statistics.....	47
6.9.2. Frequency statistics.....	48
6.9.3. Comparative analysis: independent t-test.....	49
6.9.4. Comparative analysis: frequency table.....	50
6.10. Results study II exhibition A.....	50
6.10.1. Descriptive statistics.....	50
6.10.2. Frequency statistics.....	51
6.10.3. Comparative analysis: Independent t-test.....	53
6.10.4. Comparative analysis: frequency table.....	54
6.11. Results study II exhibition B.....	56
6.11.1. Descriptive statistics.....	56
6.11.2. Frequency statistics.....	57
6.11.3. Pearson's correlation.....	58
6.11.4. Comparative analysis: Independent t-test.....	59
6.11.5. Comparative analysis: frequency table.....	60
7. Discussion.....	63
7.2 Study II.....	64
7.3. Limitations and recommendations.....	66
References.....	68
Appendices.....	72
A: Photos exhibition A and exhibition B.....	72
B: Observation and coding scheme exhibition A.....	74
C: Observation and coding scheme exhibition B.....	78
D: Color scheme Museumfabriek.....	81
E: Brainstorming session mind maps.....	82
F: First ideas.....	84
G: Finalized ideas.....	86
H: Sketches infographic and N-DIDE.....	88
I: Final elements infographics.....	92
J: Final elements N-DIDE.....	99
K: Added components observation and coding scheme study II.....	105

1. Introduction

Science museums are an important informal learning environment for children, providing them with opportunities for exploration, play, and learning with science-related activities (Andre et al., 2017; Baran et al., 2019; Eshach, 2006). Engaging children in science at a young age has several benefits: (1) developing positive attitudes towards science (2) better understanding of scientific concepts (3) developing scientific thinking (4) supporting their interest in exploring the world (Eshach & Fried, 2005, pp. 332 - 333). Moreover, children's confidence in scientific thinking can be enhanced by engaging them in science-related activities such as science exhibitions (Patrick et al., 2009, pp. 182–183).

The study by Lee et al. (2021) found that students who were behaviorally engaged were more likely to actively participate. It is therefore crucial to investigate this finding in the context of a museum setting. Behavioral engagement in a museum can be recognized when 'the visitor pays attention to an exhibit by looking at it, reading accompanying labels/directions, touching, or manipulating the exhibit, or discussing the exhibit with another person' (Boisvert & Slez, 1995, p. 504). Meaning that being behavioral engaged involves actively looking, reading, touching, and talking about the exhibit. Furthermore, the study by Emerson et al. (2020) highlights the significant influence of engagement on visitors' attitudes toward the information presented in museums, as well as the knowledge they acquire during their visit. When all the benefits of engagement are considered, it can be said that engagement is an important aspect of science learning. In fact, engagement has been described as 'the holy grail of learning' (Sinatra et al., 2015, p1).

However, the effectiveness of science museums in fostering children's engagement is often hindered by insufficient information and poor integration of hands-on activities (Allen, 2004). In addition, according to Hall and Bannon (2005, p. 62) exhibits that lack interactivity are more likely to lose children's interest because they can quickly become disengaged by simply observing objects or reading information without any interactive involvement. These issues create challenges, as both insufficient information and lack of interactivity contribute to disengagement. It is therefore crucial for museums to prioritize effective strategies to increase children's engagement within science museums. To tackle this issue, Allen (2004) emphasizes the importance of science exhibits meeting the criteria of immediate apprehendability: ensuring that exhibits are easy to understand. This is crucial because a lack of information about the objects on display can lead to frustration and hinder visitor engagement. In addition, poorly explained hands-on activities can reduce children's engagement as both caregivers and

children may struggle to use them effectively (Allen, 2004). In addition, Allen (2004) suggests that physical interactivity, also referred to as hands-on activities, is another important factor in creating a successful exhibit. These physical interactivities allow children to actively interact with the exhibition and engage with the various objects, artifacts, and artworks on display (Wood & Wolf, 2008). By incorporating physical interactivity, museums can provide a more participatory experience for visitors, increasing their behavioral engagement and understanding.

Thus, in theory by integrating immediate apprehendability and physical interactivity into an exhibition, the engagement behavior of children can be enhanced. However, it is important to research exhibition design that aim to effectively engages visitors (wood & Wolf, 2008). In the context of immediate apprehendability, studies have found that infographics (information graphics) can contribute to immediacy due to their use of visual representations (Dunlap & Lowenthal, 2016; Smiciklas, 2012). In addition, it is even said that infographics are suitable for a museum (Tan & Çelebi, 2017). Therefore, the current study will examine the impact of infographics on behavioral engagement within two science exhibitions. Furthermore, in today's rapidly changing technology, researchers are primarily focusing on interactive technology-based design elements to enhance the physical interaction between visitors and exhibitions. Think about game-based learning (Hsu et al., 2018), digital exhibitions (Li et al., 2022), and augmented reality (Hsu & Liang, 2017). This results in a lack of recent research on the effectiveness and accessibility of non-digital interactive design elements (N-DIDE) on children's behavioral engagement with science exhibitions. Therefore, in the context of physical interactivity, this study aims to fill this gap in the literature by investigating the impact of N-DIDE on children's behavioral engagement with two science exhibitions.

The non-digital interactive design elements and infographics will be created as part of this study. These elements will be implemented in science exhibitions at the Museumfabriek in the Netherlands. The Museumfabriek describes its collection as follows: "there is a large natural history collection, a collection relating to the textile industry and life and work in Twente, and a large cultural history collection" (Museumfabriek, 2023). This study aims to contribute to the knowledge of the impact of infographics and N-DIDE on the engagement behavior of primary school children. This study will begin by observing primary school children's current engagement behavior with the two science exhibitions. The infographics and N-DIDE will then be introduced separately to assess their impact on engagement behavior. Finally, the study aims to identify any differences in engagement

between primary school children who visit exhibitions with these elements and those who do not.

2. Theoretical framework

This section provides an overview of the concepts, definitions, and models relevant to this study. As the current study examines the engagement behavior of primary school children, it is important to clarify the term “behavioral engagement”. In addition, this section will present a relevant model and framework from various studies relating to behavioral engagement in the exhibition context. Subsequently, the study aims to investigate the impact of infographics and non-digital interactive design elements (N-DIDE) on behavioral engagement. Therefore, definitions of “infographics” and “N-DIDE” are provided in this section.

2.1. Behavioral engagement

Encouraging children to engage in science-related activities is a crucial aspect of fostering their scientific development (Bulunuz, 2013; Eshach & Fried, 2005). Besides from the cognitive gains, Barriault and Pearson (2010) emphasize the importance of measuring the level of engagement that influences science learning outcomes, since engagement is a significant factor of interpretation and learning. Engagement, however, is a complex term with multiple meanings that can be applied in a variety of ways in the field of science learning (Wood & Wolf, 2008). Engagement in general can be defined as “a multidimensional relational concept featuring psychological and behavioral attributes of connection, interaction, participation, and involvement, designed to achieve or elicit an outcome at individual, organization, or social levels” (Jonhston, 2018, p. 1). The study by Sinatra et al. (2015) also mentions that there are generally cognitive, behavioral, and/or emotional components to engagement. Their study delves deeper into the meaning of engagement from a psychological point of view. According to Sinatra et al. (2015), someone that is engaged shows or feels characteristics of attention, metacognitive awareness, positive or negative feelings. Furthermore, they specify that characteristics such as motivation and emotion are additional factors that can influence an individual's engagement in science learning (Sinatra et al., 2015). The psychological part, however, addresses the side of cognitive engagement, while this study focuses on the behavioral engagement.

Studying behavioral engagement allows children to be observed in their natural actions and interactions without interference, providing a full understanding of their actual behavioral engagement during their museum visit. Boisvert and Slez (1995) specifically defines behavioral engagement in a museum and states that “in a museum, engagement is

indicted when the visitor pays attention to an exhibit by looking at it, reading accompanying labels/directions, touching, or manipulating the exhibit, or discussing the exhibit with another person” (Boisvert & Slez, 1995, p. 504). A more recent study that focuses on behavioral engagement is by Ben-Eliyahu et al. (2018), they generally define engagement as “the intensity of productive involvement with an activity” and suggests that behavioral engagement can be observed by looking at individuals' actions. However, the focus of their study is on the engagement behavior of students in the classroom. Therefore, Boisvert and Slez's definition is most relevant to the current study. Their description of engagement emphasizes the visitor's behavioral engagement with an exhibit by noting characteristics such as looking and touching.

According to Boisvert and Slez (1995) model of engagement levels (Table 1), engagement can be divided into three groups: involved time (level 1), positive interaction (level 2) and instructional time (level 3). This model indicates that the engagement level "involved time", is the lowest form of engagement, where an individual only looks at an exhibit and does not engage with the exhibition such as reading or touching the exhibit. The engagement level named “positive interaction” indicates that an individual is engaging with the exhibit by reading information, performing actions on the exhibit, and encouraging others to engage with the exhibit by helping them to understand the information and the actions. The engagement level “instructional time” indicates when an individual seeks more information about the exhibit from a museum staff member.

Table 1

Behaviors indicative of Engagement Levels

Type of Engagement	Behavior
Involved time (level 1)	<i>Visitor:</i> Stands in front of and/or looks at exhibit but does not read directions or try it; watches another person use exhibit but does not take part in any way; uses exhibit but not as it is intended to be used.
Positive interaction (level 2)	<i>visitor:</i> Reads labels and/or directions for exhibit; uses exhibit in way it is intended to be use; helps another person use exhibit by reading directions, demonstrating its use, or manipulating part of the exhibit so another person can Use it as intended.
Instructional Time (level 3)	<i>Visitor:</i> Has volunteer/staff member explain how to use exhibit or what exhibit is about; discusses meaning of exhibit? with volunteer/staff member; shares personal information related to exhibit with volunteer/staff member.

Note. From “The relationship between exhibit characteristics and learning-associated behaviors in a science museum discovery space.”, by Boisvert & B.J. Slez, 1995, *Science Education*, 79(5), 503–518. (<https://doi.org/10.1002/sce.3730790503>). In the public domain

This model symbolizes the behavioral engagement of visitors in a museum and is therefore used in this study. However, it's important to note that this model does not consider children's behavioral engagement, whereas the current study does. To address this gap, the model is integrated with findings from a more recent study that focuses on children's behavioral engagement in a museum.

According to Rennie and Howitt (2020) the engagement of children in science-related activities is just as important as that of adults. Their framework (Table 2) focuses on all types of children's engagement behaviors with science exhibitions, including play.

Table 2*Children's behavioral framework from Rennie & Howitt (2020)*

Behavior	Engagement level	Example types of activities
EPISTEMIC. Centered on knowledge and information and is associated with new learning. What does this object do?	<i>Initiation (activities providing entry point to learning, not yet deeply involved in learning experience)</i>	
	Doing the activity or watching others engage with it.	Looks at pump and inspects it. Observes others using the pump. Explores pump and tries to work it. Enjoys watching others pump or trying to pump. Manages to pump after watching or with help but does not continue exploration.
	<i>Transition (becoming more committed to the learning experience)</i>	
	Repeating the activity, expressing positive emotion and motivation to engage.	Uses pump successfully and watches outcomes carefully. Enjoys using pumps; points to objects moving. Explores effects of pumping but without experimentation.
LUDIC. Centered on self-amusement and associated with imaginative and enjoyable behavior. What can I do with this object?	<i>Breakthrough (takes full advantage of learning opportunity, committed to meaningful learning)</i>	
	Experimenting with the activity, seeking and sharing information, engaged and involved.	Communicates with others about how pump works. Continues using pump and experiments with different ways of pumping, e.g., faster/slower; full pumps or half pumps. Looks for different outcomes of tube contents. Competes with others.
	<i>Symbolic (pretence or fantasy play)</i>	
	Engagement in pretence play.	Treats pump or pump components as other objects, such as using pump as pretend horse. Smiling, enjoys using pump in fantasy ways.
<i>Repetition (repeating behavior for enjoyment, no novel features, and no new learning)</i>		
Using components of exhibit in repetitive manner with enjoyment.	Varies playing with pump repeating actions, but no novel or investigative actions. Uses pump(s), paying no attention to outcome. Repetitive manipulation of the pump or other parts of pump station without apparent purpose.	

Note. From “The Children’s Engagement Behaviour Framework: describing young children’s interaction with science exhibits and its relationship to learning”, by L.J. Rennie & C. Howitt, 2020, *International Journal of Science Education*. 10(1), 1-21. P. 374 (doi.org/10.1080/21548455.2020.1851425). In the public domain.

Rennie and Howitt based their framework on the work of Hutt (1981) and, Barriault and Pearson (2010). The framework shows two types of behaviors: epistemic and ludic behavior. Epistemic behavior shows signs that a child is gaining knowledge and information through exploration, interaction, and communication. Ludic behavior is based on playful behavior where a child performs repetitive actions without apparent purpose. As the current study focuses on behavioral engagement, such as actively looking, reading, touching, and talking about the exhibit, the current study focuses only on epistemic behavior. The framework shows that epistemic behavior has three type of engagement levels: ‘(1) *initiation behaviors*: doing the activity; spending time watching others engaging in the activity, (2) *transition behaviors*: repeating the activity; expressing positive emotional responses in reaction to engaging in the activity, (3) *breakthrough behaviors*: referring to past experiences while engaging in the activity; seeking and sharing information with others; engaged and involved)’.

The following framework (Table 3) is developed based on the model of Boisvert and Slez (1995) and framework of Rennie and Howitt (2020). The framework shows four different types of behaviors: exploration behavior, social behavior, reading behavior and, question asking. Each of these behaviors are associated with specific types of engagement. For example, exploration behavior includes types of engagement such as looking at objects, exploring by touching different objects, and interacting with interactive elements. In addition, some engagement types indicate the level of engagement, for example, whether someone has skimmed or actively read the information. This ensures that a distinction can be made in the way a child carries out the type of engagement.

Table 3

Framework children's behavioral engagement with exhibitions

Type of behavior	Type of engagement	Example types of activity
Exploration behavior	Looking at objects and images (<i>Skimming or actively looking</i>).	Skimming: a child is skimming the exhibitions by quickly looking at some of the objects and images. Actively: a child is actively looking at all the objects and images

Social behavior

Exploring by touching various objects (orb not included) <i>(Passively or actively touching).</i>	Passively: a child is using their hands to quickly feel various objects but is distracted or does not pay attention while touching the object.
Interacting with interactive elements <i>(Passively or actively).</i>	Actively: a child is using their hands to investigate various objects and is paying attention while touching the objects Passively: a child is interacting with an interactive element but does not pay attention to their actions.
Interacting with caregiver while engaging with exhibition.	Actively: a child is actively interacting with an interactive element and purposely want to succeed the outcome. A child interacts with a caregiver in the exhibit by talking about the exhibition or looking at objects together.
Caregiver stimulates/guide child to look at the objects.	A caregiver leads the child through the exhibit, encouraging the child to look at the different objects and guiding the child by explaining information about the objects.
Caregiver stimulates/guide child to read the information Child seeks for guidance from caregiver.	A caregiver stimulates the child to read the information that belongs to a specific object A child asks for help while looking/touching or reading in the exhibit.
Interacting with peers while engaging with exhibition.	A child interacts with a peer in the exhibit by touching various objects together or talking about the exhibition.
Shares experiences with caregiver or peer.	A child talks about their experience in the exhibition by mentioning what they see or feel. “Feel the objects, it gets warm when I touch it” or “look at that machine, it think it so big!”
Interacting with caregiver while engaging with exhibition.	A child interacts with a caregiver in the exhibit by talking about the exhibition or looking at objects together.

	Shares experiences with caregiver or peer.	A caregiver leads the child through the exhibit, encouraging the child to look at the different objects and guiding the child by explaining information about the objects.
Reading behavior	Reading labels, signs or information displayed in the exhibition <i>(Skimming or actively).</i>	Skimming: a child is skimming the information quickly next to the several objects displayed in the exhibition. Actively: a child actively reads all the information next to the several objects displayed in the exhibition.
	Too young to read the information.	A child is too young to read the information that is displayed in the exhibition.
Question asking	Expressing curiosity through questioning.	A child asks their caregiver or peer, “ what happens when I touch this?” while pointing at an object.

2.2. Infographics for immediate apprehendability

According to Allen (2004), developing science exhibits that are engaging and educational is a complex task. The study mentioned several important factors that contribute to the success of a science exhibition, including immediate apprehendability (making the exhibit easy to understand), physical interactivity (allowing visitors to interact with the exhibit), conceptual coherence (ensuring the exhibit is logically structured), and diversity of learning modes (appealing to different types of learners). As stated in the problem statement, the current study focuses on immediate apprehendability and physical interactivity. First, immediate apprehendability will be discussed. Immediate apprehendability refers to the quality of an exhibit that allows people to understand its purpose, scope, and characteristics quickly and easily without much effort. A quick understanding of the theme of the exhibition and the nature of the objects on display may enhance visitor engagement (Allen, 2004). However, according to Allen (2004), many museums fall short of this standard by presenting an overload of objects and hands-on activities in their exhibits. In addition, these objects or

hands-on activities lack simple directions or information to help visitors understand their purpose or meaning. This overload and complexity can have a negative impact on the visitor experience and can also make it difficult for parents to guide their children. Therefore, Allen (2004) suggests the use of labels, information, or signs to clarify the exhibit. The current study therefore focuses on the usage of infographics (information graphics) to quickly express the purpose of an object. Huang and Tan (2007) define infographics as “ visual representations of information, data, or knowledge”. Expanding on this definition, the study by Smiciklas (2012) presents a broader perspective, describing infographics as “a visualization of data or ideas that tries to convey complex information to an audience in a manner that can be quickly consumed and easily understood”. In addition, Dunlap and Lowenthal (2016) add on this by highlighting the power of visuals as a communication tool, emphasizing that they have the potential to be more effective than text or verbal explanations. When used correctly, visuals can help people understand complex material, even when confronted with unfamiliar topics. According to Dunlap and Lowenthal (2016) infographics can even contribute to immediacy through their clear examples and visual representations which connects to immediate apprehendability.

According to Dunlap and Lowenthal (2016) powerful infographics have the following characteristics:

- Use visuals to express relationships and context, rather than text.
- Maintain clarity by conveying one learning objective or a small collection of related objectives.
- Keep infographics to 1-2 pages in length to ensure consistency and avoid overwhelming the audience.
- To engage and captivate the audience, consider incorporating unexpected aspects such as humor, metaphor, narrative, or personal anecdote.
- Use basic visuals rather than high-definition pictures to keep the focus on the important aspects of the message. that focus on the important aspects of the message.

In short, a key factor of a successful exhibition is immediate apprehendability, which means that exhibitions should be easy to understand. Infographics can contribute to immediacy through their ability to convey information in an understandable way using visualizations. Therefore, infographics are well-suited for museum contexts (Tan & Çelebi, 2017). When designing an infographic, it is important to keep in mind that the information presented needs to be related to a primary objective or a sequence of connected minor

objectives, ensuring clarity for the audience. Furthermore, to engage the audience within an infographic it can be beneficial to incorporate memorable elements such as humor or a narrative.

2.3. Non-digital interactive design elements for physical interactivity

In addition to immediate apprehendability, another significant factor contributing to a successful exhibition is physical interactivity (Allen, 2004). As defined by Allen (2004), the concept of physical interaction within exhibits refers to the ability of an exhibit to respond to visitor actions. Importantly to note is that this type of interactivity increases visitor engagement (Allen, 2004). In addition, Allen (2004) emphasizes that this type of interaction is especially important in science and children's museums. Furthermore, another important finding is from the study by Witt and Kimple (2008). Their study mentions that exhibits with hands-on activities can contribute to children's scientific knowledge. This claim is supported by the fact that these activities can help children to maintain their attention for a longer period and become more engaged in the learning process (Witt & Kimple, 2008).

Already in 20th century, studies highlighted the importance of physical interactivity as a critical aspect in exhibits by showing that museum visitors want to do more than just look at objects and read information. According to Caulton (1998) visitors want to engage with exhibits through interactions that are not only educational, but also enjoyable. Exhibitions characterized by interactive elements, are often referred to as "hands-on exhibitions". The study of Caulton (1998) describes hands-on exhibits as "visitors physically interact with an exhibit whether it is simply pushing buttons, using a computer keyboard, or engaging in a more complex activity with a multiplicity of outcomes". These hands-on experiences can encourage visitors to engage with the exhibitions more actively (Caulton 1998). Their study also revealed that hands-on exhibits do not necessarily require advanced technology or touching actual museum artifacts to be effective. In addition, the study of Allen (2004) mentions that "more is not necessarily better". This insight emerged when they discovered no significant difference in the experience of visitors who engaged with a more interactive version compared to those who engaged with a less interactive one. This suggests that interactive elements do not need to be very advanced to have a significant impact on engagement behavior.

2.4 Research question

Based on the problem statement and theoretical framework the following main research question is formulated:

“Do infographics and/or non-digital interactive design elements have an impact on the behavioral engagement of primary school children with science exhibitions in museums?”

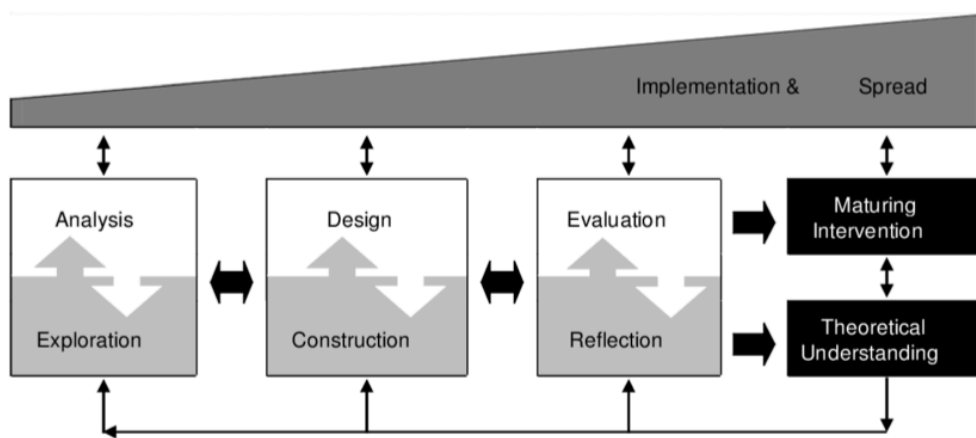
The main research question is divided into three sub-questions:

1. What is the current engagement behavior of primary school children within two science exhibitions?
1. What is the impact of infographics on the engagement behavior of primary school children within two science exhibitions?
2. What is the impact of N-DIDE on the engagement behavior of primary school children within two science exhibitions?

3. Research design

For the development of the infographics and the non-digital interactive design elements, design-based research was carried out. Design-based research enables the development of educational products based on a theoretical foundation (McKenney & Reeves, 2018, p. 6). This study used the generic model for conducting educational design research from McKenney and Reeves (2018) (Figure 1). Their model includes three phases: analysis & exploration, design & construction, and evaluation & reflection. The first phase: analysis & exploration, focuses on investigating the current engagement behavior of primary school children towards the two exhibitions. The second phase: design & construction, focuses on developing infographics, and non-digital interactive elements by adopting processes and activities from the generic model from McKenney and Reeves (2018). The third phase, evaluation & reflection: investigates the engagement behavior of primary school children after the implementation of the infographics and after the implementation of the N-DIDE.

Figure 1
Generic model for conducting educational design research.



Note. From *Conducting Educational Design Research* (p.83) By S. Mckenney & T. Reeves, 2019, Routledge (<https://doi.org/10.4324/9781315105642>). In the public domain.

4. Analysis and exploration

The analysis and exploration phase served as preliminary study and focused on getting insight into the current engagement behavior and perception of primary school children regarding two existing science exhibitions. In this section the two science exhibitions are described. Furthermore, qualitative research was conducted to examine the engagement behavior.

4.1. The exhibitions

4.1.1. Thunder and Lightning exhibition (exhibition A)

The exhibition named Thunder and Lightning, contains objects and information about electricity and weather conditions such as rain and thunder. The exhibition includes several interactive elements, displayed objects, text information, sound effects and videos showing weather conditions. The first interactive elements in the exhibition are two orbs. These orbs can be touched. The second interactive element is a machine that makes the sound of wind when the paddle is pressed. There are also several non-interactive objects that can be touched. In addition, there are a few objects that cannot be touched and therefore presented behind glass. Some of the objects have textual information on placards. The exhibition also has a sound effect that plays the sound of thunder and lightning every few minutes. At the back of the exhibition there are several video's showing different weather conditions, such as rain and snow. In Figure A1 (appendix A), a photo of the exhibition can be found. Throughout the study the Thunder and Lightning exhibition is referred to as exhibition A.

4.1.2. World Traveler exhibition (exhibition B)

The World Traveler exhibition contains objects found all over the world. Some of these objects come with textual information. The exhibition includes objects such as a camera, a backpack and items called 'souvenirs'. There are also stuffed animals such as birds, a panther, and a platypus. Moreover, there are no interactive elements in the exhibition, so visitors can only look and read about the objects. Photos of the exhibition can be found in Figure A2 (appendix A). Throughout the study the World Traveler exhibition is referred to as exhibition B.

4.2. Method

Qualitative research was conducted to gather data on the current engagement behavior of primary school children within exhibition A and B. The research consists of observations, including an observation and coding scheme that focused on engagement behaviors relevant to this study.

4.3. Participants

The preliminary study sample consisted out of primary school children (N = 80) visiting the Museumfabriek. The participants were selected using convenience sampling, as the participants were available at the museum attending the relevant exhibitions.

4.4. Instrumentation exhibition A

The following instruments were used in the preliminary study:

Observation scheme. To investigate the current engagement behavior of primary school children in exhibition A, an observation scheme was developed (Table B1, Appendix B). This observation scheme is developed based on the framework in Table 3 in Section 2.1 Behavioral engagement. The observation scheme focuses on characteristics of behavioral engagement such as, ‘stand in front of the exhibit and inspect it by looking at objects and images’ or ‘interacts with a caregiver while engaging with the exhibition’. Furthermore, the scheme includes additional components that specifically focus on the interaction between participants and interactive elements within the exhibition such as, ‘actively touches the orb’. Moreover, to indicate the participant's level of engagement, some behavioral activities are scaled under 'passive' or 'active'.

Coding scheme exhibition A. A coding scheme is developed in alignment with the observation scheme (Table B2, Appendix B) This coding scheme is structured around five different categories: (1) Participants (2) exploration behavior, (3) social behavior, (4) reading behavior, and (5) question asking. Each category has specific codes assigned to them. For example, within the category ‘exploration behavior’ specific behaviors are coded as follows:

1. Looking at objects and images - skimming or actively looking.
2. Exploring by touching various objects - passively or actively touching.
3. Interacts with orb by touching it - passively or actively touching.
4. Interacts with wind machine by pressing down the paddle - passively or actively pressing down.

The coding scheme will be used during the data analysis where specific behaviors of the participants will be coded.

4.5. Instrumentation Exhibition B

Observation scheme. When compared to exhibition A, exhibition B has different characteristics. Therefore, another observation scheme is created for this exhibition to investigate the current engagement behavior of primary school children in exhibition B (Table C1, Appendix C). This observation scheme is also developed based on the model of Boisvert and Slez (1995) and the framework of Rennie and Howitt (2020). Given the absence of interactive elements in the exhibition, this observation scheme does not include components that focus on the interaction between participants and interactive elements. However, identical to the observation scheme of exhibition A, this scheme focuses on characteristics of behavioral engagement such as, ‘stand in front of the exhibit and inspect it by looking at objects and images’ or ‘interacts with a caregiver while engaging with the exhibition’.

Coding scheme World. The coding scheme for exhibition B is also structured into the same set of five categories (Table C2, Appendix C). This coding scheme has excluded the interactive components. Therefore, the category "exploration behavior" has only the following code assigned to it:

1. Looking at objects and images – skimming or actively looking

This coding scheme will also be used during the data analysis.

4.6. Procedure

Prior the research, ethical approval was obtained from the BMS ethics commission of the University of Twente.

The data collection was located at the Museumfabriek in Enschede during the May holiday. The data collection took approximately eight days and consisted out of observations. First, 40 participants visiting exhibition A were observed using a structured observation scheme and coding scheme. Second, 40 participants visiting exhibition B were also observed using a structured observation scheme and coding scheme. The observations focused on gaining insight into participants' engagement behavior, time spent in the exhibitions and time spent touching interactive elements. The data collection resulted in a total of 80 observations, which were all processed anonymously.

4.7. Data analysis exhibition A

Following data collection, data analysis was carried out to investigate the current engagement of primary school children with exhibition A. IBM SPSS Statistics 28 was selected as the analytical tool to process the collected data. This dataset included a sample of 39 participants and variables related to behavioral engagement with an exhibition. Due to the presence of categories with different values, it was necessary to construct dummy variables to effectively integrate all values. A total of twenty dummy variables were created, each associated with specific categories. These categories included: (1) exploration behavior, (2) social behavior (3) reading behavior (4) question asking (5) did not visit the exhibition. The category 'reading behavior' serves as an example, where two different dummy variables were created:

- **Reading Exhibits – Skimmed:** indicates whether the participant skimmed through the information content without doing any substantial reading. A value of 0 indicates that the content was skimmed, 1 if not, and 2 if the participant was considered too young to read.
- **Reading Exhibits – Actively:** Indicates whether the participant was actively reading the textual content. A value of 0 indicates active reading, 1 if not, and 2 if the participant is considered too young to read.

The entire sample was included in the data analysis to ensure a complete assessment of participants' engagement behavior. For example, it is important to note that not all participants engaged with the wind machine. However, to gain a comprehensive knowledge of general interaction patterns and to avoid bias, this variable was not removed from the dataset of children who did not interact with the wind machine. Instead, the time values were set to 00:00, indicating no interaction, and were included in calculating the average time. This decision was made to provide a holistic view of engagement behaviors and to minimize bias arising from the exclusion of non-interactive participants. However, one respondent was excluded from the dataset due to a specific case where the participant was unable to interact with the exhibit because it was too crowded. Therefore, the dataset went from 40 participants to 39 participants. By excluding this respondent from the analysis, the results are intended to focus on those who had the opportunity to interact with the exhibit.

4.8. Data analysis exhibition B

An additional round of data analysis was carried out to investigate the current engagement behavior of primary school children with exhibition B. The procedure for this analysis is identical to that used for exhibition A. The dataset has a sample of 40 participants and included dummy variables to capture all values. A total of thirteen dummy variables were assigned to the categories (1) exploration behavior, (2) social behavior (3) reading behavior (4) question asking (5) did not visit the exhibition. There were no participants excluded from this dataset.

4.9 Results exhibition A

The results show the outcomes of the analysis from both exhibitions. First, descriptive statistics are presented to show the mean time participants spent in the exhibition. Second frequency statistics are presented to show the observed engagement behavior of the participants. The results of the exhibitions will be presented separately, starting with exhibition A, followed by exhibition B.

4.9.1. Descriptive statistics.

Table 4 presents the descriptive statistics of the participants in exhibition A. The Table shows the number of participants (*N*), minimum (*MIN*), maximum (*MAX*), mean (*M*) and standard deviation (*SD*) values of the total time spent by the participants at the exhibition ((Exhibition Time), the time of participants touching the orb, and the time of participants pressing down the pedal of the wind machine (Time Pressing Down Wind Machine).

Table 4
Descriptive statistics exhibition A

	N	MIN	MAX	M	SD
Exhibition Time	39	.00	7.22	2.34	1.37
Time Touching the Orb	39	.00	4.35	1.21	.57
Time Pressing Down Wind Machine	39	.00	.30	.04	.08

Note. N = 39

4.9.2. Frequency statistics

The current engagement behavior is presented in Table 5. Various main findings were found in the table. First, almost every observed participant visited the exhibition. In addition, there were participants who skimmed and actively looked the objects. Second, few participants touched the displayed objects (orb and wind machine not included), but most participants actively touched the orb. Third, most participants interacted with their caregiver. However, not every caregiver guided or stimulated their children's looking or reading. Fourth, few participants read the information in the exhibition. Lastly, participants showed their curiosity by asking questions to their caregivers.

Table 5

Frequency table engagement behavior exhibition A

	Frequency	Per cent
Participants		
Passes the exhibition		
No	38	97.4%
Yes	1	2.6%
Exploration behavior		
Exploration looking		
Actively looked at all the objects and images	14	35.9%
Skimmed the objects and images	15	38.5%
Does not look at the objects at all	9	23.1%
Passes the exhibition	1	2.6%
Exploration touching		
Actively touching various objects (orb not included)	2	5.1%
Passively touching various objects (orb not included)	4	10.3%
Does not touch various objects (orb not included)	33	84.6%
Passes the exhibition	1	2.6%
Exploration orb		
Actively touching orb	34	87.2%
Passively touching orb	3	7.7%
Does not touch orb	1	2.6%
Passes the exhibition	1	2.6%
Exploration wind		
Actively pressed down the paddle	5	12.8%
Passively pressed down the paddle	3	7.7%
Does not pressed down the paddle	30	76.9%
Passes the exhibition	1	2.6%
Social behavior		
Social interaction caregiver		
Interacting with caregiver while engaging with exhibition	36	92.3%

Does not interact with caregiver while engaging with exhibition	2	5.1%
Passes the exhibition	1	2.6%
Social interaction stimulates looking		
Caregiver stimulates/guides child to look at the objects	19	48.7%
Caregiver does not stimulates/guides child to look at the objects	19	48.7%
Passes the exhibition	1	2.6%
Social interaction stimulate reading		
Caregiver stimulates/guides child to read the information	7	17.9%
Caregiver does not stimulates/guides child to read the information	31	79.5%
Passes the exhibition	1	2.6%
Social interaction guidance		
Child seeks for guidance from caregiver	22	56.4
Child does not seek for guidance from caregiver	16	41%
Passes the exhibition	1	2.6%
Social interaction peers		
Interacting with peers while engaging with exhibition	19	48.7%
Does not interact with peers while engaging with exhibition	19	48.7%
Passes the exhibition	1	2.6%
Social interaction sharing		
Shares experience with caregiver or peer	26	66.7%
Does not share experience with caregiver or peer	12	30.8%
Passes the exhibition	1	2.6%
Reading behavior		
Reading exhibits		
Actively reading labels, signs and information displayed in the exhibition	2	5.1%
Skimmed trough labels, signs or information displayed in the exhibition	4	10.3%
Does not read the labels, signs or information displayed in the exhibition	23	58.9%
Too young to read	9	23.1%
Passes the exhibition	1	2.6%
Questions		
Question asking caregiver		
Expressing curiosity trough asking question to a caregiver	25	64.1%
Does not express curiosity trough asking question to a caregiver	13	33.3%
Passes the exhibition	1	2.6%
Question asking peer		
Expressing curiosity trough asking question to a peer	2	5.1%

Does not express curiosity through asking question to a peer	36	92.3%
Passes the exhibition	1	2.6%

Note. N = 39.

4.9.3. Pearson's correlation.

To investigate the influence of the time spent at touching the orb and wind machine on the total time spent at the exhibition, Pearson's correlation analysis is performed. It is important to note that the significance level is 10% ($\alpha = 0.10$). This level of significance allows this analysis to be exploratory with this relatively small sample. The analysis revealed a strong significant positive correlation between the variables "Exhibition Time" and "Orb Time" $r(37) = .77, p < .001$. In addition, Pearson's correlation revealed a moderate positive correlation between the variables "Exhibition Time" and "Wind Machine" $r(37) = .33, p = .04$.

4.10. Results Exhibition B

This section aims to investigate the engagement behavior within exhibition B.

4.10.1. Descriptive statistics

The data analysis revealed an outlier in the dataset. This participant spent significantly more time at the exhibition than the other participants. As the outlier is not an error but has an impact on the average time spent at the exhibition, the data are presented with and without the outlier. Table 6 presents the descriptive statistics with the outlier. The Table shows the number of participants (N), minimum (MIN), maximum (MAX), mean (M) and standard deviation (SD) values of the total time spent by the participants at the exhibition ((Exhibition Time).

Table 6

Descriptive statistics exhibition B (with outlier)

	N	MIN	MAX	M	SD
Exhibition Time with outlier	40	.00	5.12	.35	.55
Exhibition Time without outlier	40	.00	1.50	.28	.33

Note. Exhibition Time with outlier N = 40, Exhibition Time without outlier N = 39

Due to the relatively short duration of the participants' visit to the exhibition, a difference of seven seconds could have an impact on the study. Therefore, the descriptive statistics without outlier are used in this study.

4.10.2. Frequency statistics

Table 7 shows the current engagement behavior in a frequency table. The table shows several main findings. First, not every participant observed visited the exhibition. Also, few participants actively looked at the objects. Second, few caregivers encouraged or guided their children to look or read. Third, few participants read the information displayed. Finally, few participants showed their curiosity by asking their caregivers questions about the exhibition.

Table 7

Frequency table engagement behavior exhibition B

	Frequency	Percent
<i>Participants</i>		
Passes the exhibition		
No	26	65%
Yes	14	35%
<i>Exploration behavior</i>		
Exploration looking		
Actively looked at all the objects and images	3	7.5%
Skimmed the images and objects	19	47.5%
Does not look at the objects at all	4	10%
Passes the exhibition	14	35%
<i>Social behavior</i>		
Social interaction caregiver		
Interacting with caregiver while engaging with exhibition	19	47.5%
Does not interact with caregiver while engaging with exhibition	7	17.5%
Passes the exhibition	14	35%
Social interaction stimulates looking		
Caregiver stimulates/guides child to look at the objects	8	20%
Caregiver does not stimulates/guides child to look at the objects	18	45%
Passes the exhibition	14	35%
Social interaction stimulate reading		
Caregiver stimulates/guides child to read the information	1	2.5%
Caregiver does not stimulates/guides child to read the information	25	62.5%
Passes the exhibition	14	35%

Social interaction guidance		
Child seeks for guidance from caregiver	9	22.5%
Child does not seek for guidance from caregiver	17	42.5%
Passes the exhibition	14	35%
Social interaction peers		
Does not interact with peers while engaging with exhibition	26	65%
Passes the exhibition	14	35%
Social interaction sharing		
Shares experience with caregiver or peer	10	25%
Does not share experience with caregiver or peer	16	40%
Passes the exhibition	14	35%
Reading behavior		
Reading exhibits		
Actively reading labels, signs and information displayed in the exhibition	1	2.5%
Skimmed through labels, signs or information displayed in the exhibition	1	2.5%
Does not read the labels, signs or information displayed in the exhibition	19	47.5%
Too young to read	5	12.5%
Passes the exhibition	14	35%
Questions		
Question asking caregiver		
Expressing curiosity through asking question to a caregiver	6	15%
Does not express curiosity through asking question to a caregiver	20	50%
Passes the exhibition	14	35%
Question asking peer		
Does not express curiosity through asking question to a peer	26	65%
Passes the exhibition	14	35%

Note. N = 40.

4.11. Discussion of results

This section aims to answer the following sub-question: “What is the current engagement behavior of primary school children within the two science exhibitions?”. Therefore, the results of the previous section will be discussed by putting them into perspective and providing a deeper understanding of their implications. The results of exhibition A will be discussed first, followed by exhibition B.

4.11.1. Exhibition A

The descriptive statistics showed that the average total time spent at the exhibition was 02:34 minutes. Participants spent approximately 01:21 minutes touching the orb and approximately 00:04 seconds pressing the paddle of the wind machine. Pearson's correlation showed a strong significant positive correlation between the variables "exhibition time" and "orb time". This suggests that as the time spent touching the orb increased, the total time spent in the exhibition increased. Given the strength of the correlation, it is unlikely to be due to chance, but rather a meaningful correlation between the two variables. Moreover, Pearson's correlation was also performed between the variables "exhibition time" and "wind machine". The results revealed a moderate positive correlation between the variables, indicating that as the use of the wind machine increased, the exhibition duration also increased. The strength of the relationship implies a potentially relevant correlation between these two variables.

The frequency statistics showed some important findings. First, out of the 39 participants who were observed, 38 of them visited the exhibition. Indicating that participants are curious to visit the exhibition and explore the displayed objects. However, only 14 participants were engaged enough to actively examine all the objects. The remaining participants either skimmed the objects (N=15) or did not look at them at all (N=9). This may suggest that their interests were not triggered enough to actively explore the exhibition. Second, several objects in the exhibition could be touched (orb and wind machine not included). However, only four participants passively touched these objects and only two participants actively touched these objects. This suggests that participants were not curious enough to touch them, or that it was not clearly indicated that these objects could be touched. Third, the orb was the main attraction of the exhibition. Almost all participants interacted actively with the orb (N= 34). During the observations, it was noticeable that most of the participants first touched the orb and then went on to explore the rest of the exhibition. Fourth, most participants (N=36) interacted with a caregiver within the exhibition. 19 of these caregivers guided or stimulated their child to look at the objects, only seven of them guided or stimulated their child to read. It is important to note that parents can have a significant impact on children's engagement behavior when exploring an exhibition (Braham et al., 2018; Callanan et al., 2020). This suggests that their stimulation or guidance may encourage children to look, read or interact more actively. However, there were 22 children who sought guidance from their caregivers. Looking at the number of caregivers providing this guidance, it can be said that not every caregiver had the intention or time to guide or stimulate their

child through the exhibition. Fifth, almost half of the participants interacted with a peer. This interaction could have a positive influence on the engagement behavior as it enables the exchange of knowledge, ideas, or experiences (Rennie & Howitt, 2020). Sixth, nine children were considered unable to read because of their age. This leaves 30 children who could read. Only four of them skimmed the labels, signs, or information and only two of them actively read the labels, signs, and information. This indicates that children are not interested in reading the information or that the information provided is not suitable for primary school children. Lastly, more than half of the participants (N=25) asked their caregivers questions about the exhibition. These questions showed, for example, that the children wanted to know how something worked or what it was made of.

In short, the observations showed that children were curious enough to visit the exhibition. Most children were drawn to the exhibition due to the displayed orbs and actively engaged with them for a relative long time. However, children engaged less with the other displayed objects. Most of their behavior consisted of skimming the objects, not touching the other displayed objects, and not reading the information. This indicates that the children's engagement behavior was enhanced by the interactive elements and that children are not interested in reading the information. Furthermore, caregivers played an important role in the exhibition. Children sought guidance from their caregiver and asked questions to them. In addition, their guidance or stimulation may have a positive influence on the engagement behavior of children.

4.11.2. Exhibition B

Descriptive statistics showed an outlier in the dataset. This outlier spent 05:12 minutes in the exhibition while the average time is 00:35 seconds. The analysis showed that the outlier interacted with a caregiver and was stimulated or guided to look at the objects and to read the information. In addition, the outlier showed curiosity by asking questions and sharing their experience of the exhibition with a caregiver. This suggests that the exhibition will not be of interest to every child, but that there is a chance that a child will be deeply fascinated by the objects in the exhibition because of their interests. The total time spent at the exhibition without the outlier is 00:28 seconds, with a maximum visit of 01:50 minutes. The mean time spent at the exhibition is relatively short. This could be due to the lack of interactive elements, the lack of information or the way the information is presented.

The frequency table revealed some noteworthy findings. First, 14 of the 40 participants walked past the exhibition. This may suggest that these participants were not

interested in visiting the exhibition. The participants who visited the exhibition mainly skimmed the objects (n=19), and only three participants actively looked at all the objects. Moreover four participants did visit the exhibition for a short time but did not look at the displayed objects. These findings indicate that the participants' interest was not sufficiently triggered to actively engage with the exhibition. Second, 19 participants interacted with their caregiver while visiting the exhibition. However, only eight caregivers stimulated or guided their children's looking and only one caregiver stimulated or guided their children's reading. This may suggest that the caregivers themselves were not stimulated enough to guide or stimulate their children throughout the exhibition. In addition, none of the participants interacted with a peer. This could be a coincidence, but it could also indicate that participants did not ask a peer to join them at the exhibition. Third, five children were considered too young to read the information. Moreover, only one participant actively read all the information in the exhibition and one participant skimmed through the information. This suggests that the participants were not interested in reading the information.

In short, the observations showed that the children were less curious to visit the exhibition. They also spent a relatively short time in the exhibition. Almost every child quickly looked at the objects and then left the exhibition. Furthermore, the children did not read the information and none of the children interacted with a peer. Some children sought guidance, but a relatively small group received guidance or were stimulated by their caregiver.

5. Design and construction

During the design and construction phase, ideas were brought to life using various techniques of the generic model from McKenney and Reeves (2018). This phase took a different approach from the norm of the generic model, as the design elements (infographics and N-DIDE) that address the problem had already been defined during the problem statement. According to McKenney and Reeves (2018), there is no universal set of steps to address different design challenges. This provided an opportunity to adopt processes and activities that were particularly relevant and beneficial to this study. The design part consists out of ideation, where ideas for the infographics and the N-DIDE were generated, considered, and checked. Moreover, core features of the infographics were defined in a skeleton design. The construction phase consists out of creation, where prototypes and actual designs of the infographics and N-DIDE were created.

5.1. Ideation

Ideation is the process of generating, developing, and communicating ideas (Jonson, 2005). According to Jonson (2005), these ideas can be visual, concrete, or abstract. The current study used both visuals and concrete text to develop and communicate ideas. Before ideation began, a skeleton design was created to identify key design requirements. Based on these requirements, further ideas were generated through brainstorming. The ideas that emerged from this brainstorming session were then shared with the employee from the museum's education department.

5.1.1. Skeleton design

In collaboration with the employee of the Museumfabriek's education department, a skeleton design was created for the infographics (Table 8). The skeleton design shows that the Museumfabriek had few design criteria. The only design requirements for the infographics were to incorporate some colors from their color scheme (Appendix E), to create an infographic specifically for one of their machines in exhibition A, and to create an infographic to stimulate conversation about souvenirs in exhibition B. There were no design requirements for the N-DIDE.

Table 8*Skeleton design infographics*

Design element	Materials	Design requirements
Exhibition A <i>Infographics</i>	<ul style="list-style-type: none"> • Infographics made in Illustrator. 	<ul style="list-style-type: none"> • Using the Museumfabriek's color specifications • Create an illustration of "Professor Fred" that gives the explanation in the infographics. • Designing an infographic for Kelvin's Druppelaar (self-built machine)
Exhibition B <i>Infographic</i>	<ul style="list-style-type: none"> • Infographics made in Illustrator 	<ul style="list-style-type: none"> • Using the Museumfabriek's color specifications • Ask children about their souvenirs

5.1.2. Brainstorming

Brainstorming is an important ideation process that generates ideas in a creative and non-judgmental way (McKenney & Reeves, 2018). Throughout the brainstorming session, the mind-mapping technique was used. Mind mapping is the process of writing down words and ideas that revolve around a primary keyword and can be used by one person. This technique offers the opportunity to capture a holistic view of all the words involving around the main subject. It also helps to establish relationships between words and concepts (Buzan, 2018; Mandal, 2014). According to Buzan (2018) the three essential characteristics of a mind map are: (1) having a central image or word that describes the main subject (2) including themes that revolve around the main subject (3) adding words or ideas that are related to these themes. In addition, Buzan (2018) mentions that the use of color is important. These characteristics were kept in mind when using this brainstorming technique. This technique was used to generate ideas for N-DIDE as well as the infographics for both exhibitions. The

process resulted in a total of four mind maps, which can be found in appendix E (Figures E1 through E4).

5.2. First ideas

The brainstorming session resulted in the development of several concepts for the infographics and N-DIDE, which are presented in a Table in Appendix F. The table contains concepts for two infographics and one N-DIDE for exhibition A and for one infographic and one N-DIDE for exhibition B. These concepts are developed based on the results from the preliminary study, the mind maps, and the skeleton design.

First, the concepts for exhibition A are discussed. The first concept, shown in the table, proposes the themes and design requirements for the infographics in exhibition A. The preliminary research led to the first suggestion, which is to design an infographic for the orb. The preliminary study revealed that the orb was the main attraction of the exhibition. This is an opportunity to provide additional information about something that has piqued the participants' curiosity. In addition, the mind map showed that the orb was top of mind when brainstorming. Furthermore, based on the skeleton design, all infographics will be designed using some of the colors in the color scheme. The second suggestion is based on the request from the employee of the education department. The concept proposes the idea to create an infographic for the object: Kelvin's Druppelaar. This object shows the working of thunder using water and magnetic rings. Someone named Fred created Kelvin's Druppelaar, which led to the request to include an illustration of a professor named Fred explaining the workings of the machine. Both infographics will be placed in the exhibition at the same time, so it is important that the infographics match. Therefore, both concepts suggest including an illustration of Professor Fred. Furthermore, the mind map inspired to explain how Kelvin's Druppelaar works, step-by-step. The way the machine works is complex and therefore difficult to explain clearly, the step-by-step explanation must make the explanation easier to understand. The aim of the infographics is to promote conversations between caregivers and children, to encourage children to look at and think about the objects, and to make the workings of these objects understandable to children.

The second concept proposes the concept for the N-DIDE in exhibition A. The mind map inspired to incorporate questions in the non-digital interactive design element, which led to the idea of asking suggestive questions about the objects in the exhibition. This concept would look like the following: children could interact with these questions by reading them and then responding with a physical interaction: lifting a sign labeled 'yes' or 'no' in response

to each question given. Below the signs is an explanation of whether their answer is correct or incorrect.

To bring this idea to life, a simple but effective mechanism needs to be built. Therefore, the N-DIDE is going to be made from wood, which gives the opportunity to create a system where signs can be lifted up and down. This concept can be further enriched by introducing a color-coding aspect. When the children answer a question correctly, they are given a number. This number corresponds to a particular color on their coloring sheet. The participants can fill in the empty spaces with the correct color, which is indicated by a number. Eventually, as they continue to answer questions correctly and fill in the colors, a thunder illustration will become visible. The aim of this N-DIDE is to stimulate curiosity and encourage active participation among the participants.

The third concept proposes the concept for the infographic in exhibition B. The preliminary study showed that the exhibition did not have much space to place infographics. Therefore, the maximum size of an infographic is A5. Based on the skeleton design, the concept proposes to develop an infographic that asks children questions about their souvenirs. Furthermore, the mind map inspired the inclusion of an illustration of a world explorer named Wiecher. This concept came from the exhibition's narrative, which revolves around the remarkable journey of the world explorer Wiecher in his search for uranium around the world. The aim of the infographic is to encourage children to think about their travels, to encourage them to look at the objects in the exhibition and to encourage conversations between caregivers and children.

The final concept proposes the concept for the N-DIDE in exhibition B. The mind map inspired the idea of developing a small activity to encourage children to explore the exhibition. The preliminary study showed that about half of the participants walked past the exhibition without looking. Therefore, the N-DIDE must be something that stands out in the exhibition and attracts children and their caregivers to the exhibition. This led to the idea of adding a touchable globe at the beginning of the exhibition. To encourage participants to look around the exhibition an assignment will be included. This assignment will look like the following: next to the globe are stickers representing various objects in the exhibition. These stickers can be attached to the globe using Velcro. The task is to match each object with the country in which it is found. In addition, participants will have the opportunity to record their discoveries on flyers located next to the globe. These flyers not only allow them to record their findings, but also provide fun facts about the objects on display in the exhibition, adding an element of fun and learning to the experience. Thus, participants must explore the

exhibition, identify the objects, and determine their country of origin. The aim of this N-DIDE is to encourage children to look at the objects in the exhibition, to provide interaction for children, to encourage caregivers to interact with their children while carrying out the task, and to attract children and caregivers to the exhibition.

5.3. Feedback and evaluation ideas

The proposed concepts were sent to the Education Department staff member. After these ideas were sent, a meeting was arranged to discuss them together. During the meeting it became clear that the ideas were received positively, but there were a few suggestions for adjustments. First, it was mentioned that the proposed idea of adding a color assignment to the N-DIDE in exhibition A would be difficult to implement in practice due to the supervision required. Therefore, the idea to elaborate the N-DIDE with a color assignment will not continue. Second, the flyers in the N-DIDE for the Exhibition B will be replaced by an infographic due to the reason that an infographic looks neater.

Practical matters were also discussed. First, it was agreed that the final designs of the infographics would be sent to their designer for font adjustments and any additional final refinements if necessary. Second, the museum's technical department is busy and that it would take a long time for them to assist in designing the wooden planks, therefore it was decided to develop them without their assistance. Third, the Museumfabriek will print the infographics so that they match their decor. Last, they offered to order the globe for the N-DIDE. This feedback moment resulted in finalized ideas shown in Appendix G.

5.4. Sketches and feedback

After the finalized ideas were approved, the first sketches of the infographics were created in Canva. The sketches can be found in Appendix H, which contains sketches for two infographics (Figures H1 and H2) and an N-DIDE (Figure H3) for exhibition A, and a sketch for the infographic (Figure H4) and N-DIDE (Figure H5) for exhibition B. The sketches were sent to the employee of the education department for feedback. The following feedback was received:

5.4.1. Feedback sketch Kelvin's Druppelaar

- The name of the object needs to be added (Kelvin's Druppelaar).
- There were some typos that needed to be corrected.

- Replace ‘Donder en Bliksem’ (Thunder and Lightning) for ‘Donder & Bliksem’ (Thunder & Lightning).

5.4.2. Feedback sketch orb

- The text needs to be shortened.
- In the last box, add that touching the sphere is not painful or dangerous.
- Add an explanation of why the electrons move to the hand.

5.5. Final infographics and N-DIDE

After receiving feedback, the final infographics were developed in Illustrator and sent to the Museumfabriek designer. The designer made a few minor adjustments, including the font. The infographics were then printed by the Museumfabriek. Appendix I (Figures I1 through I7) shows the infographics, including photos of the infographics displayed in both exhibitions. In addition, Appendix J (Figures J1 through J6) shows photos of the N-DIDE displayed in both exhibitions.

6. Evaluation and reflection

The evaluation and reflection phase focused on gaining insight into the engagement behavior and perceptions of primary school children towards the two exhibitions after the implementation of the infographics and the N-DIDE. These developed elements were implemented separately. The process of the evaluation and reflection phase is almost identical to the preliminary study in the analysis and exploration phase.

6.1. Method

Qualitative research was used to collect data. In line with the preliminary study, the research consists out of observations using an observation and coding scheme. As the infographics and N-DIDE were implemented separately, the evaluation and reflection phase is divided into two studies: study I investigated the influence of infographics on engagement behavior, while study II focused on the impact of N-DIDE.

6.2. Participants

The evaluation and reflection phase consisted out of 160 participants ($N=160$) visiting the Museumfabriek. The participants were selected using convenience sampling, as the participants were available at the museum attending the relevant exhibitions. All participants were observed.

6.3. Instrumentation exhibition A

Observation and coding scheme infographics. The same observation and coding scheme as in the preliminary study will be used to study the impact of infographics on the engagement behavior. For a description of the observation and coding scheme, see section 'Instrumentation' in the 'Analysis and exploration' phase.

Observation and coding scheme N-DIDE. To study the impact of N-DIDE on the engagement behavior, an additional component is added to the existing observation scheme: "interacts with wooden planks". This results in the following extension to the coding scheme (Appendix K):

- Interacts with wooden planks - passive or active.

6.4. Instrumentation Exhibition B

Observation and coding scheme infographics. The same observation and coding scheme as in the preliminary study will be used to study the impact of infographics on the engagement behavior. For a description of the observation and coding scheme, see section 'Instrumentation' in the 'Analysis and exploration' phase.

Observation and coding scheme N-DIDE. To study the impact of N-DIDE on the engagement behavior, additional components are added to the existing observation scheme: ‘‘ interacts with the world globe’’ and ‘‘time interacting with world globe’’. This results in the following extension in the coding scheme (Appendix K):

- Interacts with globe - passive or active.

6.5. Procedure

The data collection took place at the Museumfabriek in Enschede during the summer holidays. Collecting the data took approximately 21 days and consisted of two rounds of observations. The infographics and N-DIDE were implemented separately to examine the impact of the infographics on the participants behavioral engagement and the impact of N-DIDE on the participants behavioral engagement. Therefore, two rounds of observations were carried out. The first round took place after the implementation of the infographics in both exhibitions. The observations consisted of 80 participants. 40 participants were observed in exhibition A and 40 participants in exhibition B. Identical to the preliminary study, the observations focused on the participants' engagement behavior, the time they spent in the exhibition and the time they spent touching the interactive elements. The second round took place after the implementation of the N-DIDE. This round was identical to the first round.

The data collection resulted in a total of 160 observations, of which 60 children were interviewed. The data were anonymized.

6.6. Data analysis study I

Data analysis was conducted to investigate the impact of infographics on the engagement behavior of the participants, by both exhibition A and B. This process of the data analysis was identical to the preliminary study. However, no participants were excluded from this dataset. For a description of the data analyses see section ‘‘4.7. Data analysis exhibition A, and 4.8. Data analysis exhibition B’’.

To study the impact of the infographics on the engagement behavior, the results from study I and the preliminary study were compared. Therefore, both datasets were merged in SPSS.

6.7 Data analysis study II

Data analysis was conducted to investigate the impact of N-DIDE on the engagement behavior of the participants, by both exhibition A and B. This process of the data analysis was identical to the preliminary study. For a description of the data analyses see section ‘‘4.7. Data analysis exhibition A, and 4.8. Data analysis exhibition B’’. Identical to study I, both datasets were merged to investigate any differences between the preliminary study and study II.

6.8. Results Study I exhibition A

This section investigates the impact of infographics within exhibition A. Therefore, descriptive statistics and frequency statistics are presented. Furthermore, the results will be compared with those of the preliminary study.

6.8.1. Descriptive statistics.

Table 9 present the descriptive statistics of the participants in exhibition A. The Table shows the number of participants (*N*), minimum (*MIN*), maximum (*MAX*), mean (*M*) and standard deviation (*SD*) values of the total time spent by the participants at the exhibition ((Exhibition Time), the time of participants touching the orb (Time Touching The Orb), and the time of participants pressing down the paddle of the wind machine (Time Pressing Down Wind Machine).

Table 9*Descriptive statistics exhibition A study I*

	N	MIN	MAX	M	SD
Exhibition Time	40	.00	8.09	3.11	1.49
Time Touching the Orb	40	.00	4.54	1.08	.52
Time Pressing Down Wind Machine	40	.00	.34	.06	.09

*Note. N = 40***6.8.2. Frequency statistics**

Table 10 shows the engagement behavior following the implementation of the infographics. There were several key findings. First, almost every participant observed visited the exhibition. In addition, there were participants who skimmed the objects and actively looked at the objects. Second, few participants touched the objects (orb and wind machine not included), but most participants actively touched the orb. Third, most participants interacted with a caregiver. However, not every caregiver stimulated or guided their children's looking or reading. Fourth, there were more participants who skimmed the information than actively read the information. Lastly, participants showed curiosity by asking questions of their caregivers.

Table 10*Frequency table engagement behavior exhibition A (infographics)*

	Frequency	Percent
Participants		
Passes the exhibition		
No	39	97.5%
Yes	1	2.5%
Exploration behavior		
Exploration looking		
Actively looked at all the objects and images	19	47.5%
Skimmed the objects and images	12	30%
Does not look at the objects at all	8	20%
Passes the exhibition	1	2.5%

Exploration touching

Actively touching various objects (orb not included)	6	15%
Passively touching various objects (orb not included)	7	17.5%
Does not touch various objects (orb not included)	26	65%
Passes the exhibition	1	2.5%

Exploration orb

Actively touching orb	37	92.5%
Passively touching orb	2	5%
Does not touch orb	0	0%
Passes the exhibition	1	2.5%

Exploration wind

Actively pressed down the paddle	13	32.5%
Passively pressed down the paddle	1	2.5%
Does not pressed down the paddle	25	62.5%
Passes the exhibition	1	2.5%

Social behavior**Social interaction caregiver**

Interacting with caregiver while engaging with exhibition	33	82.5%
Does not interact with caregiver while engaging with exhibition	6	15%
Passes the exhibition	1	2.5%

Social interaction stimulates looking

Caregiver stimulates/guides child to look at the objects	27	67.5%
Caregiver does not stimulates/guides child to look at the objects	12	30%
Passes the exhibition	1	2.6%

Social interaction stimulate reading

Caregiver stimulates/guides child to read the information	22	55%
Caregiver does not stimulates/guides child to read the information	17	42.5%
Passes the exhibition	1	2.5%

Social interaction guidance

Child seeks for guidance from caregiver	24	60%
Child does not seek for guidance from caregiver	15	37.5%
Passes the exhibition	1	2.5%

Social interaction peers

Interacting with peers while engaging with exhibition	19	47.5%
Does not interact with peers while engaging with exhibition	20	50%
Passes the exhibition	1	2.5%

Social interaction sharing

Shares experience with caregiver or peer	30	75%
Does not share experience with caregiver or peer	9	22.5%
Passes the exhibition	1	2.5%

Reading behavior**Reading exhibits**

Actively reading labels, signs and information displayed in the exhibition	4	10%
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Skimmed trough labels, signs or information displayed in the exhibition	12	30%
Does not read the labels, signs or information displayed in the exhibition	14	35%
Too young to read	9	22.5%
Passes the exhibition	1	2.5%
Questions		
Question asking caregiver		
Expressing curiosity trough asking question to a caregiver	26	65%
Does not express curiosity trough asking question to a caregiver	13	32.5%
Passes the exhibition	1	2.5%
Question asking peer		
Does not express curiosity trough asking question to a peer	39	97.5%
Passes the exhibition	1	2.5%

Note. N = 40.

6.8.3. Pearson's correlation

Pearson's correlation was performed to investigate the influence of the time participants spent touching the orb and touching the wind machine on the total time participants spent in the exhibition. The analysis revealed a moderately strong significant positive correlation between the variables "exhibition time" and "orb time" $r(38) = .65, p < .001$. In addition, Pearson's correlation showed a moderate weak positive correlation between the variables "exhibition time" and "wind machine" $r(38) = .33, p = .037$.

6.8.4. Comparative analysis: independent t-test

Table 11 shows the values of the total time spent at the exhibition of the preliminary study and of study I.

Table 11
Descriptive statistics (preliminary study and study II)

	N	MIN	MAX	M	SD
Preliminary study Exhibition time	39	.00	7.22	2.34	1.37
Study I Exhibition time	40	.00	8.09	3.11	1.49

Note. Preliminary study N = 39, Study I N = 40

To investigate if the infographics influenced the total time spent at the exhibition, an independent t -test is conducted. Important to note is that the significance level is 10% ($\alpha = 0.10$). The chosen significance level allows the analysis to take on an exploratory nature, which is particularly appropriate for the current study given the relatively small sample sizes. The following hypothesis is formulated: ‘Participants who attend exhibition A with infographics will exhibit a significantly longer mean total time spent in the exhibition compared to those who attend the exhibition without infographics’.

H₀: *There is no significant difference in the mean total time spent in exhibition A between participants who visited the exhibition with infographics and those who visited the exhibition without infographics.*

$$\mu(\text{With infographics}) = \mu(\text{Without infographics})$$

H_A: *Participants who visited exhibition A exhibition with infographics spent a significantly longer mean total time in the exhibition than those who visited the exhibition without infographic.*

$$\mu(\text{With infographics}) > \mu(\text{Without infographics})$$

First, the assumption of equal variance was tested, and the results indicated that this assumption was met (Levene’s test = 1.37, $p = 0.245$). This indicates that the variances of the two groups compared in the independent t -test are not significantly different. Second, an independent t -test was conducted. The results show that participants ($N=40$) who visited the exhibition with infographics ($M = 3.11$, $SD = 1.49$) spent a significantly longer mean total time in the exhibition than those who visited the exhibition without infographic ($N=39$) ($M = 2.34$, $SD = 1.37$), $t(77) = -1.6$, $p = .059$. Therefore, the null hypotheses can be rejected.

In addition, the independent t -test was conducted to determine if there was a significant difference in the mean time spent ‘touching the orb’ and ‘pressing down the wind machine’ between study I and the preliminary study. First, equal variance was assumed for both variables. There were no significant differences in the mean time spent ‘touching the orb’ between study I ($M = 1.14$, $SD = .05$) and the preliminary study ($M = 1.21$, $SD = .57$) $t(77) = 1.1$, $p = .277$, as well as in the mean time spent ‘pressing down the wind machine’ between study I ($M = .06$, $SD = .09$) and the preliminary study ($M = .04$, $SD = .08$) $t(77) = -1.01$, $p = .314$.

6.8.5. Comparative analysis: frequency table and G-test

To examine the differences in engagement behavior between participants with and without infographics, the frequency tables from the preliminary study and study I are compared. Table 12 shows the categories with the main differences in engagement behavior, highlighted in bold. First, fewer participants in Study I skimmed the objects in the exhibition. However, more participants actively looked at the objects. Second, in study I more caregivers stimulated or guided their children's looking and reading. Third, in study I more participants skimmed the information. Finally, not many more participants in study I actively read the information.

Table 12

Key differences preliminary study and study I (exhibition A)

	preliminary study		study I	
	Frequency	Per cent	Frequency	Per cent
<i>Exploration behavior</i>				
<i>Exploration looking</i>				
Actively looked at all the objects and images	14	35.9%	19	47.5%
Skimmed the objects and images	15	38.5%	12	30%
Does not look at the objects at all	9	23.1%	8	20%
Passes the exhibition	1	2.6%	1	2.5%
<i>Social behavior</i>				
<i>Social interaction stimulates looking</i>				
Caregiver stimulates/guides child to look at the objects	19	48.7%	27	67.5%
Caregiver does not stimulates/guides child to look at the objects	19	48.7%	12	30%
Passes the exhibition	1	2.6%	1	2.6%
<i>Social interaction stimulate reading</i>				
Caregiver stimulates/guides child to read the information	7	17.9%	22	55%
Caregiver does not stimulates/guides child to read the information	31	79.5%	17	42.5%
Passes the exhibition	1	2.6%	1	2.5%
<i>Reading behavior</i>				
<i>Reading exhibits</i>				
Actively reading labels, signs and information displayed in the exhibition	2	5.1%	4	10%
Skimmed trough labels, signs or information displayed in the exhibition	4	10.3%	12	30%
Does not read the labels, signs or information displayed in the exhibition	23	58.9%	14	45%
Too young to read	9	23.1%	9	22.5%
Passes the exhibition	1	2.6%	1	2.5%

Note. Preliminary study (N = 39), study I (N = 40). Frequency and per cent

highlighted in bold and italic are key differences between the preliminary study and study I.

Since the assumptions of the chi-square test were violated, the likelihood ratio chi-square test (G -test) was used to test whether these differences were significant. The following hypotheses were formulated: ‘‘there are significant differences in the engagement behavior between participants who visited the exhibition in the preliminary study and those who visited the exhibition in study I’’.

***H₀:** There are no significant differences in the engagement behavior between participants who visited the exhibition without infographics and those who visited the exhibition with infographics.*

$$\mu(\text{Without infographics}) = \mu(\text{With infographics})$$

***H_A:** There are significant differences in the engagement behavior between participants who visited the exhibition without infographics and those who visited the exhibition with infographics.*

$$\mu(\text{Without infographics}) \neq \mu(\text{With infographics})$$

The G -test showed that there is a significant difference between the preliminary study and study I regarding the social interaction ‘stimulate reading’ $G^2(2, N = 79) = 12.3, p = .002$. In the preliminary study, seven caregivers guided or stimulated their child to read. In Study I, 22 caregivers guided or stimulated their child to read. Therefore, the null hypothesis can be rejected, and it can be said that there is a significant difference in the engagement behavior between participants who visited the exhibition without infographics and those who visited the exhibition with infographics.

6.9. Results Study I exhibition B.

This section aims to investigate the impact of infographics on the engagement behavior of primary school children within exhibition B.

6.9.1. Descriptive statistics

Table 13 present the descriptive statistics of the participants in Exhibition B.

Table 13*Descriptive statistics Exhibition B study I*

	N	MIN	MAX	M	SD
Exhibition Time	40	.00	2.10	.22	.30

*Note. N = 40***6.9.2. Frequency statistics**

The results of the observed engagement behavior following the implementation of the infographics are presented in Table 14. Several key findings were identified. First, not every participant observed visited the exhibition. Second, more participants skimmed the exhibition than actively looking. Third, few participants interacted with a caregiver. In addition, few caregivers stimulated or guided their children's reading. Fourth, no participants actively read the information, and a few skimmed the information. Finally, few participants showed curiosity by asking questions of their caregivers.

Table 14*Frequency table exhibition B study I (infographics)*

	Frequency	Per cent
Participants		
Passes the exhibition		
No	20	50%
Yes	20	50%
Exploration behavior		
Exploration looking		
Actively looked at all the objects and images	2	5%
Skimmed the images and objects	15	37.5%
Does not look at the objects at all	3	7.5%
Passes the exhibition	20	50%
Social behavior		
Social interaction caregiver		
Interacting with caregiver while engaging with exhibition	12	30%
Does not interact with caregiver while engaging with exhibition	8	20%
Passes the exhibition	20	50%
Social interaction stimulates looking		
Caregiver stimulates/guides child to look at the objects	1	2.5%
Caregiver does not stimulates/guides child to look at the objects	19	47.5%
Passes the exhibition	20	50%
Social interaction stimulate reading		

Caregiver stimulates/guides child to read the information	1	2.5%
Caregiver does not stimulates/guides child to read the information	19	47.5%
Passes the exhibition	20	50%
Social interaction guidance		
Child seeks for guidance from caregiver	5	12.5%
Child does not seek for guidance from caregiver	15	37.5%
Passes the exhibition	20	50%
Social interaction peers		
Interacting with peers while engaging with exhibition	4	10%
Does not interact with peers while engaging with exhibition	16	40%
Passes the exhibition	20	50%
Social interaction sharing		
Shares experience with caregiver or peer	8	20%
Does not share experience with caregiver or peer	12	30%
Passes the exhibition	20	50%
Reading behavior		
Reading exhibits		
Actively read labels, signs, and information	0	0%
Skimmed trough labels, signs or information displayed in the exhibition	2	5%
Does not read the labels, signs or information displayed in the exhibition	14	35%
Too young to read	4	10%
Passes the exhibition	20	50%
Questions		
Question asking caregiver		
Expressing curiosity trough asking question to a caregiver	6	15%
Does not express curiosity trough asking question to a caregiver	14	35%
Passes the exhibition	20	50%
Question asking peer		
Does not express curiosity trough asking question to a peer	20	50%
Passes the exhibition	20	50%

Note. N = 40.

6.9.3. Comparative analysis: independent *t*-test

Table 15 shows the descriptive statistics of the preliminary study and study I. The descriptive statistics already show that the infographics did not have a significant effect on the total mean time spent in the exhibition, as the mean time is lower than in the preliminary study. Therefore, no independent *t*-test is performed.

Table 15*Descriptive statistics (preliminary study and study I)*

	N	MIN	MAX	M	SD
Preliminary study Exhibition Time	40	.00	1.50	.28	.33
Study I Exhibition Time	40	.00	2.10	.22	.30

6.9.4. Comparative analysis: frequency table

When comparing the frequency table from the preliminary study and the frequency table from Study I, no significant differences were found.

6.10. Results study II exhibition A

This section investigates the impact of N-DIDE within exhibition A. Therefore, descriptive statistics and frequency statistics are presented. Furthermore, the results will be compared with those of the preliminary study.

6.10.1. Descriptive statistics

The descriptive statistics are shown in Table 16.

Table 16*Descriptive statistics exhibition A study II*

	N	MIN	MAX	M	SD
Exhibition Time	40	.00	6.14	3.01	1.19
Time Touching the Orb	40	.00	3.02	1.11	.47
Time Pressing Down Wind Machine	40	.00	.54	.03	.10

Note. N=40

6.10.2. Frequency statistics

Table 17 shows the engagement behavior after the implementation of N-DIDE. Several key findings were identified. Firstly, most participants visited the exhibition. Second, more participants actively looked at the objects than skimmed over them. Third, few participants touched the objects in the exhibition (orb, wind machine and N-DIDE not included), but most participants actively touched the orb. Fourth, more participants actively interacted with the N-DIDE than passively interacted with it. Fifth, most participants interacted with a caregiver, but not every caregiver stimulated or guided their children's reading or looking. Sixth, more participants skimmed the information than actively read it. Finally, participants showed curiosity by asking questions of their caregivers.

Table 17

Frequency table engagement behavior exhibition A (N-DIDE)

	Frequency	Percent
Participants		
Passes the exhibition		
No	39	97.5%
Yes	1	2.5%
Exploration behavior		
Exploration looking		
Actively looked at all the objects and images	21	52.5%
Skimmed the objects and images	16	40%
Does not look at the objects at all	2	5%
Passes the exhibition	1	2.5%
Exploration touching		
Actively touching various objects (orb not included)	6	15%
Passively touching various objects (orb not included)	4	10%
Does not touch various objects (orb not included)	29	72.5%
Passes the exhibition	1	2.5%
Exploration orb		
Actively touching orb	36	90%
Passively touching orb	2	5%
Does not touch orb	1	2.5%
Passes the exhibition	1	2.5%
Exploration wooden planks		
Actively interact with wooden planks	19	47.5%
Passively interact with wooden planks	11	27.5%
Does not interact with wooden planks	9	22.5%
Passes the exhibition	1	2.5%
Exploration wind		
Actively pressed down the paddle	6	15%
Passively pressed down the paddle	1	2.5%
Does not passively pressed down the paddle	32	80%
Passes the exhibition	1	2.5%

Social behavior**Social interaction caregiver**

Interacting with caregiver while engaging with exhibition	37	92.5%
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Does not interact with caregiver while engaging with exhibition	2	5%
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Passes the exhibition	1	2.5%
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Social interaction stimulates looking

Caregiver stimulates/guides child to look at the objects	27	67.5%
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Caregiver does not stimulates/guides child to look at the objects	12	30%
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Passes the exhibition	1	2.6%
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Social interaction stimulate reading

Caregiver stimulates/guides child to read the information	15	37.5%
---	----	-------

Caregiver does not stimulates/guides child to read the information	24	60%
--	----	-----

Passes the exhibition	1	2.5%
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Social interaction guidance

Child seeks for guidance from caregiver	26	65%
---	----	-----

Child does not seek for guidance from caregiver	13	32.5%
---	----	-------

Passes the exhibition	1	2.5%
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Social interaction peers

Interacting with peers while engaging with exhibition	25	62.5%
---	----	-------

Does not interact with peers while engaging with exhibition	14	35%
---	----	-----

Passes the exhibition	1	2.5%
-----------------------	---	------

Social interaction sharing

Shares experience with caregiver or peer	33	82.5%
--	----	-------

Does not share experience with caregiver or peer	6	15%
--	---	-----

Passes the exhibition	1	2.5%
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Reading behavior**Reading exhibits**

Actively reading labels, signs and information displayed in the exhibition	1	2.5%
--	---	------

Skimmed trough labels, signs or information displayed in the exhibition	14	35%
---	----	-----

Does not read the labels, signs or information displayed in the exhibition	19	47.5%
--	----	-------

Too young to read	5	12.5%
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Passes the exhibition	1	2.5%
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Questions**Question asking caregiver**

Expressing curiosity trough asking question to a caregiver	27	67.5%
--	----	-------

Does not express curiosity trough asking question to a caregiver	12	30%
--	----	-----

Passes the exhibition	1	2.5%
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Question asking peer

Expressing curiosity trough asking questions to a peer	3	7.5%
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Does not express curiosity through asking question to a peer	36	90%
Passes the exhibition	1	2.5%

Note. N = 40.

6.10.3. Comparative analysis: Independent t-test

Table 18 shows the values of the total time spent at the exhibition of the preliminary study and of study II.

Table 18

Exhibition time preliminary study and study II

	N	MIN	MAX	M	SD
Preliminary study Exhibition time	39	.00	7.22	2.40	1.62
Study II Exhibition time	40	.00	6.14	3.22	1.31

Note. Preliminary study N = 39. Study II N = 40

To investigate if the N-DIDE influenced the total time spent at the exhibition, an independent *t*-test is conducted. The following hypothesis is formulated: ‘‘Participants who attend exhibition A with N-DIDE will exhibit a significantly longer mean total time spent in the exhibition compared to those who attend the exhibition without infographics’’.

H₀: *There is no significant difference in the mean total time spent in exhibition A between participants who visited the exhibition with N-DIDE and those who visited the exhibition without N-DIDE.*

$$\mu(\text{With N-DIDE}) = \mu(\text{Without N-DIDE})$$

H_A: *Participants who visited exhibition A with N-DIDE spent a significantly longer mean total time in the exhibition than those who visited the exhibition without N-DIDE*

$$\mu(\text{With N-DIDE}) > \mu(\text{Without N-DIDE})$$

First, the assumption of equal variance was tested, and the results indicated that this assumption was met (Levene's = 1.29, $p = .260$). Second, an independent t -test was conducted. The results show that participants who visited the exhibition with N-DIDE do not spend a significantly longer mean total time in the exhibition than those who visited the exhibition without N-DIDE ($t(77) = -1.37, p = .175$). Therefore, the null hypothesis is not rejected.

In addition, the independent t -test was conducted to determine if there was a significant difference in the mean time spent 'touching the orb' and 'pressing down the wind machine' between study II and the preliminary study. First, equal variance was assumed for both variables. There were no significant differences in the mean time spent 'touching the orb' between study II ($M = 1.11, SD = .47$) and the preliminary study ($M = 1.21, SD = .57$) ($t(77) = .23, p = .366$), as well as in the mean time spent 'pressing down the wind machine' between study II ($M = .03, SD = .10$) and the preliminary study ($M = .04, SD = .08$) ($t(77) = .036, p = .419$).

6.10.4. Comparative analysis: frequency table and G-test

The frequency tables from the Preliminary Study and Study II are compared. Table 19 shows the categories with the main differences in engagement behavior. First, in Study II more participants actively looked at the objects than in the Preliminary Study. Second, slightly more participants in Study II actively touched the objects (orb, wind machine and N-DIDE not included). Third, more caregivers in Study II encouraged their children to look and read. Fourth, more participants in Study II shared their experiences with a caregiver or peer than in the preliminary study. Finally, more participants in Study II skimmed the information.

Table 19

Key differences preliminary study and study II (exhibition A)

	Preliminary study		Study II	
	Frequency	Per cent	Frequency	Per cent
Exploration behavior				
Exploration looking				
Actively looked at all the objects and images	14	35.9%	21	52.5%
Skimmed all the objects and images	15	38.5%	16	40%
Does not look at the objects at all	9	23.1%	2	5%
Passes the exhibition	1	2.6%	1	2.5%
Social interaction stimulates looking				
Caregiver stimulates/guides child to look at the objects	19	48.7%	27	67.5%
Caregiver does not stimulates/guides child to look at the objects	19	48.7%	12	30%
Passes the exhibition	1	2.6%	1	2.6%
Social interaction stimulate reading				
Caregiver stimulates/guides child to read the information	7	17.9%	15	37.5%
Caregiver does not stimulates/guides child to read the information	31	79.5%	24	60%
Passes the exhibition	1	2.6%	1	2.5%
Social interaction peers				
Interacting with peers while engaging with exhibition	19	48.7%	25	62.5%
Does not interact with peers while engaging with exhibition	19	48.7%	14	35%
Passes the exhibition	1	2.6%	1	2.5%
Social interaction sharing				
Shares experience with caregiver or peer	26	66.7%	33	82.5%
Does not share experience with caregiver or peer	12	30.8%	6	15%
Passes the exhibition	1	2.6%	1	2.5%
Reading behavior				
Reading exhibits				
Actively reading labels, signs and information displayed in the exhibition	2	5.1%	1	2.5%
Skimmed trough labels, signs or information displayed in the exhibition	4	10.3%	14	35%
Does not skim the labels, signs or information displayed in the exhibition	23	58.9%	19	47.5%

Too young to read	9	23.1%	5	12.5%
Passes the exhibition	1	2.6%	1	2.5%

Note. Preliminary study N = 40, Study II N = 40. Frequency and per cent highlighted in bold and italic are key differences between the preliminary study and study II.

Since the assumptions of the chi-square test were violated, the likelihood ratio chi-square test (*G*-test) was used to test whether these differences were significant. The following hypotheses were formulated: ‘‘there are significant differences in engagement behavior between participants in the preliminary study and participants in Study II.’’

H0: *There are no significant differences in the engagement behavior between participants who visited the exhibition without N-DIDE and those who visited the exhibition with N-DIDE*
 $\mu(\text{Without N-DIDE}) = \mu(\text{With N-DIDE})$

HA: *There are significant differences in the engagement behavior between participants who visited the exhibition without N-DIDE) and those who visited the exhibition with N-DIDE.*
 $\mu(\text{Without N-DIDE}) \neq \mu(\text{With N-DIDE})$

The *G*-test showed that there is a significant difference between the preliminary study and study II regarding the exploration behavior ‘‘reading exhibits skimmed’’ $G^2(3, N = 79) = 7.6, p = 0.05$. Four participants skimmed the information in the preliminary study, while in study 14 participants skimmed the information in study II. Therefore, the null hypothesis can be rejected, and it can be said that there is a significant difference in the engagement behavior between participants who visited the exhibition without N-DIDE and those who visited the exhibition with N-DIDE.

6.11. Results study II exhibition B

This section aims to investigate the impact of N-DIDE on the engagement behavior within exhibition B.

6.11.1. Descriptive statistics

Table 20 present the descriptive statistics of the participants within exhibition B.

Table 20*Descriptive statistics exhibition B study II*

	N	MIN	MAX	M	SD
Exhibition Time	40	.00	3.18	.54	.56
Globe Time	40	.00	3.18	.36	.57

*Note. N = 40***6.11.2. Frequency statistics**

The results of the observed engagement behavior after the implementation of N-DIDE are presented in Table 21. Several key findings were found. First, most participants visited the exhibition. Second, there were participants who interacted passively or actively with the N-DIDE. Fourth, participants interacted with a caregiver. However, not every caregiver stimulated or guided their children's reading. Finally, some participants skimmed the information, and no one actively read the information.

Table 21*Frequency table study II exhibition B*

	Frequency	Per cent
Participants		
Passes the exhibition		
No	31	77.5%
Yes	9	22.5%
Exploration behavior		
Exploration looking		
Actively looked at all the objects and images	7	17.5%
Skimmed the images and objects	17	42.5%
Does not look at the objects at all	7	17.5%
Passes the exhibition	9	22.5%
Exploration globe		
Actively interacting with globe	10	25%
Passively interacting with globe	7	17.5%
Does not passively interact with globe	14	35%
Passes the exhibition	9	22.5%
Social behavior		
Social interaction caregiver		
Interacting with caregiver while engaging with exhibition	22	55%
Does not interact with caregiver while engaging with exhibition	9	22.5%
Passes the exhibition	9	22.5%
Social interaction stimulates looking		

Caregiver stimulates/guides child to look at the objects	9	22.5%
Caregiver does not stimulates/guides child to look at the objects	22	55%
Passes the exhibition	9	22.5%
Social interaction stimulate reading		
Caregiver stimulates/guides child to read the information	5	12.5%
Caregiver does not stimulates/guides child to read the information	26	65%
Passes the exhibition	9	22.5%
Social interaction guidance		
Child seeks for guidance from caregiver	11	27.5%
Child does not seek for guidance from caregiver	20	50%
Passes the exhibition	9	22.5%
Social interaction peers		
Interacting with peers while engaging with exhibition	12	30%
Does not interact with peers while engaging with exhibition	19	47.5%
Passes the exhibition	9	22.5%
Social interaction sharing		
Shares experience with caregiver or peer	17	42.5%
Does not share experience with caregiver or peer	14	35%
Passes the exhibition	9	22.5%
Reading behavior		
Reading exhibits		
Skimmed trough labels, signs or information displayed in the exhibition	9	22.5%
Does not read the labels, signs or information displayed in the exhibition	17	42.5%
Too young to read	5	12.5%
Passes the exhibition	9	22.5%
Questions		
Question asking caregiver		
Expressing curiosity trough asking question to a caregiver	13	32.5%
Does not express curiosity trough asking question to a caregiver	18	45%
Passes the exhibition	1	2.5%
Question asking peer		
Expressing curiosity trough asking questions to a caregiver	1	2.5%
Does not express curiosity trough asking question to a peer	30	75%
Passes the exhibition	14	22.5%

Note. $N = 40$.

6.11.3. Pearson's correlation

To investigate the influence of the N-DIDE on the mean total time spent in the exhibition, Pearson's correlation analysis was performed ($\alpha = 0.10$). The analysis revealed a

strong significant positive correlation between the variables ‘‘globe time’’ and ‘‘exhibition time’’ $r(38) = .893, p < .001$.

6.11.4. Comparative analysis: Independent *t*-test

Table 22 shows the values of the total time spent at the exhibition of the preliminary study and of study II.

Table 22

Descriptive statistics preliminary study and study II

	N	MIN	MAX	M	SD
Preliminary study Exhibition Time	40	.00	1.50	.38	.49
Study II Exhibition Time	40	.00	3.18	1.16	.89

Note. Preliminary study N = 40, study II N = 40

To investigate if the N-DIDE influenced the total time spent at the exhibition, an independent *t*-test is conducted. The following hypothesis is formulated: ‘‘Participants who attend exhibition A with N-DIDE will exhibit a significantly longer mean total time spent in the exhibition compared to those who attend the exhibition without infographics’’.

H₀: *There is no significant difference in the mean total time spent in the Exhibition B between participants who visited the exhibition with N-DIDE and those who visited the exhibition without N-DIDE.*

$$\mu(\text{With N-DIDE}) = \mu(\text{Without N-DIDE})$$

H_A: *Participants who visited Exhibition B with N-DIDE spent a significantly longer mean total time in the exhibition than those who visited the exhibition without N-DIDE*

$$\mu(\text{With N-DIDE}) > \mu(\text{Without N-DIDE})$$

First, the assumption of equal variance was tested, and the results indicated that this assumption was met (Levene’s = 1.24, $p = .269$). Second, an independent *t*-test was performed. The results show that participants who visited the exhibition with N-DIDE do not

significantly spend longer in the exhibition than those who visited the exhibition without N-DIDE $t(78) = -1.5, p = .137$.

6.11.5. Comparative analysis: frequency table

The frequency tables from the Preliminary Study and Study II are compared. Table 23 shows the categories with the main differences in engagement behavior, highlighted in bold. First, more participants visited the exhibition in Study II. Second, in Study II more caregivers encouraged their children to read. Third, participants in Study II interacted with a peer, whereas none of the participants in the Preliminary Study interacted with a peer. Fourthly, more participants in Study II skimmed the information. Finally, more participants showed curiosity by asking questions than in the preliminary study.

Table 23

Key differences preliminary study and study II exhibition B

	Preliminary study		Study I	
	Frequency	Per cent	Frequency	Per cent
Participants				
Passes the exhibition				
No	26	65%	31	77.5%
Yes	14	35%	9	22.5%
Social behavior				
Caregiver stimulates/guides child to read the information				
Caregiver does not stimulates/guides child to read the information	25	62.5%	26	65%
Passes the exhibition	14	35%	9	22.5%
Social interaction peers				
Interacting with peers while engaging with exhibition	-	-	12	30%
Does not interact with peers while engaging with exhibition	26	65%	19	47.5%
Passes the exhibition	14	35%	9	22.5%
Social interaction sharing				
Shares experience with caregiver or peer	10	25%	17	42.5%
Does not share experience with caregiver or peer	16	40%	14	35%
Passes the exhibition	14	35%	9	22.5%
Reading behavior				
Reading exhibits				
Actively reading labels, signs and information displayed in the exhibition	1	2.5%	0%	0%

Skimmed through labels, signs or information displayed in the exhibition	<i>1</i>	<i>2.5%</i>	<i>9</i>	<i>22.5%</i>
Does not skim the labels, signs or information displayed in the exhibition	19	47.5%	17	42.5%
Too young to read	5	12.5%	5	12.5%
Passes the exhibition	14	35%	9	22.5%
<i>Questions</i>				
<i>Question asking caregiver</i>				
Expressing curiosity through asking question to a caregiver	<i>6</i>	<i>15%</i>	<i>13</i>	<i>32.5%</i>
Does not express curiosity through asking question to a caregiver	20	50%	18	45%
Passes the exhibition	14	35%	1	2.5%

Note. Preliminary study N = 39, Study I N = 40. Frequency and valid per cent highlighted in bold and italic are key differences between the preliminary study and study II.

Since the assumptions of the chi-square test were violated, the likelihood ratio chi-square test (G-test) was used to test whether these differences were significant. The following hypotheses were formulated: “there are significant differences in the engagement behavior between participants who visited the exhibition in the preliminary study and those who visited in study II.”

H0: *There are no significant differences in the engagement behavior between participants who visited the exhibition without N-DIDE and those who visited the exhibition with N-DIDE.*
 $\mu(\text{Without N-DIDE}) = \mu(\text{With N-DIDE})$

HA: *There are significant differences in the engagement behavior between participants who visited the exhibition without N-DIDE and those who visited the exhibition with N-DIDE.*
 $\mu(\text{Without N-DIE}) \neq \mu(\text{With N-DIDE})$

First, the G-test showed that there is a significant difference between the participants in the preliminary study and study II regarding the reading behavior “reading exhibits skimmed” $\chi^2(3, N = 80) = 8.5, p = .036$.

In the preliminary study one participant skimmed the information, and in study II nine participants skimmed the information. Second, there is a significant difference regarding social behavior “social interaction peers” $\chi^2(2, N = 80) = 18.5, p < .001$. In the preliminary study, none of the participants interacted with a peer, while in study II 12 participants

interacted with a peer. Lastly, there is a significant difference regarding social behavior “social interaction stimulate reading” $\chi^2 (2, N = 80) = 8.0, p = .018$. In the preliminary study none of the caregivers stimulated their children’s reading and in study II five participants were stimulated to read. Therefore, the null hypothesis can be rejected, and it can be said that there is a significant difference in the engagement behavior between participants who visited the exhibition without N-DIDE and those who visited the exhibition with N-DIDE.

7. Discussion

This study aimed to explore the impact of infographics (study I) and N-DIDE (study II) on the engagement behavior of primary school children within science exhibitions. Therefore, the results of the previous section will be discussed by putting them into perspective and providing a deeper understanding of their implications. Study I is discussed first, followed by Study II. In addition, the limitations and recommendations for further research are discussed.

7.1 Study I

According to Allen (2004), immediate apprehendability is an important factor of an exhibition. Incorporating information, labels or signs can add immediacy, resulting in more engaged visitors. The study of Dunlap and Lowenthal (2016) stated that infographics can provide clarity. Therefore, the impact of infographics on the behavioral engagement of primary school children was investigated within two science exhibitions.

First, Pearson's correlation showed that the time participants spent touching the orb and the wind machine in exhibition A was not significantly different from the preliminary study. These rules out the possibility that the orb and wind machine influenced the total time participants spent in the exhibition in study I. In addition, the results showed that participants who visited exhibition A with the infographics spent significantly more time in the exhibit than those who visited without them. This suggests that the infographics kept visitors in exhibition A for a longer time. However, in exhibition B, there was no effect on the amount of time participants spent in the exhibition. Second, in study I the number of caregivers who guided or stimulated their children to read was significantly higher in exhibition A than in the preliminary study. During the observations, it was noticeable that caregivers read the information on the infographics aloud to their children. This suggests that the infographics could stimulate child-parent interaction in an exhibition. It is interesting to note that Allen's (2004) study mentioned that the complexity within the exhibition could make it difficult for parents to guide their children. With the inclusion of the infographics, caregivers were more eager to stimulate or guide their children's reading. However, in exhibition B no significant difference was found in comparison with the preliminary study. In addition to these two significant points in exhibition A, there were also differences in exhibition A that were not significant but worth noting. Less participants skimmed the objects than in the preliminary study, but more participants actively looked at the objects. This may indicate that the

infographics influenced the way participants viewed the objects. Second, a higher number of caregivers guided or stimulated their children to look at the objects. Third, more participants skimmed the information in the exhibition than in the preliminary study. These (significant) differences observed in exhibition A are consistent with Allen's (2004) study, which suggests that a better understanding of the nature of the objects on display can increase visitor engagement. Furthermore, these findings resonate with Tan and Celebi's (2017) research, which argues that infographics are well suited to museums. However, in terms of visitors' active engagement in reading, Study I also challenged the claim of Tan and Celebi (2017). This is because in exhibition A, there was only an increase of two participants actively engaged in reading the information compared to the preliminary study. This observation suggests that while the infographics may have captured participants' attention (as evidenced by increased skimming), they may not have provided sufficient stimulus to encourage more in-depth reading. Furthermore, exhibition B shows no (significant) differences compared to the preliminary study. A possible explanation for the different results between exhibition A and B is the difference in appearance and content between the exhibitions. Where exhibition A has several interactive elements, sound effects and videos, exhibition B has none of these. This suggests that the specific exhibition context significantly influences the impact of infographics on engagement behavior, a factor not addressed in the studies by Allen (2004) and Tan and Celebi (2017).

The sub-question "what is the impact of infographics on the engagement behavior of primary school children within two science exhibitions?" can therefore be answered as follows: this research showed that infographics can indeed influence primary school children's engagement with science exhibitions. The inclusion of infographics in exhibition A increased the length of visit and encouraged parent-child interaction. However, it's important to note that despite these positive effects, the infographics did not have a significant impact on participants' active reading behavior. Therefore, more research is needed to decide whether infographics are still the right way to inform children about objects. In addition, no (significant) effects were found in exhibition B. Therefore, the effectiveness of the infographics seemed to depend on the overall design and content of the exhibition, highlighting the importance of tailoring exhibitions in similar research.

7.2 Study II

Besides immediate apprehendability, physical interactivity would also play an important role in visitors' engagement behavior (Allen 2004). In addition, the study by Hall

and Bannon (2005) emphasized the importance of interactivity in exhibits, highlighting that exhibits lacking interactivity are more likely to result in a loss of interest among children. Therefore, the impact of N-DIDE on the behavioral engagement of primary school children was investigated in two science exhibitions. Study II showed that the N-DIDE can improve engagement behavior in several areas.

Pearson's correlation showed that the time participants spent touching the orb and the wind machine in exhibition A was not significantly different from the preliminary study. These rules out the possibility that the orb and wind machine influenced the total time people spent in the exhibition in study II. Although not statistically significant, it is interesting to note that in exhibition A and exhibition B, participants spent more time in the exhibit with the inclusion of N-DIDE. This suggests that there is potential for the N-DIDE to have a significant impact on the length of time participants spend at the exhibition. This finding reinforces Hall and Bannon's (2005) point about the importance of including (non-digital) interactive elements to keep them interested for longer periods of time. Furthermore, with the inclusion of N-DIDE in exhibition A, there was a significant increase in the number of participants who skimmed the information compared to those who visited without N-DIDE. This significant difference was also observed in exhibition B. These results suggest that the N-DIDE can effectively promote reading behavior in primary school children. In addition, other significant findings were found in exhibition B. First, a significantly higher number of participants engaged with their peers. This suggests the potential of the N-DIDE to stimulate peer interaction, which can have a positive impact on engagement behavior, as noted by Rennie and Howitt (2022). Second, there was a significant increase in the number of participants who were guided or encouraged to read by their caregivers. This suggests that N-DIDE can involve caregivers in the exhibition experience. Although not statistically significant, similar findings were also observed in exhibition A. A possible explanation for why the results in exhibition B are significant and those in exhibition A are not, may be due to the different content of the two exhibitions, similar to what was found in Study I. Whereas in exhibition A they had a wide range of interactive elements to engage with, in exhibition B their interactions were primarily limited to the N-DIDE. Therefore, the N-DIDE may have had a greater impact on exhibition B than on exhibition A.

The findings in both exhibitions A and B, whether statistically significant or not, are consistent with previous research by Caulton (1998) and Allen (2004), who suggested that interactive elements do not need to be highly complex to have a significant impact on engagement behavior. Furthermore, the observed increases in engagement behavior in both

exhibitions A and B are consistent with the findings of Wood and Wolf (2008). Their study suggests that interactive elements provide opportunities for children to actively interact within exhibitions, potentially leading to increased engagement. In addition, as Witt and Kimple (2008) argued, interactive activities have the potential to help children sustain their attention for longer periods of time. Therefore, it is important to emphasize that the presence of N-DIDE did not lead to significant differences in participants' looking behavior. Thus, although the N-DIDE appears to prolong children's engagement with the exhibition, it may not necessarily affect the way they interact with other objects within the exhibition.

The sub-question “what is the impact of N-DIDE on the engagement behavior of primary school children within two science exhibitions?” can therefore be answered as follows: this research shows that even without high-tech gadgets, interactive elements can have a (significant) impact on how primary school children engage with science exhibitions. In particular, the N-DIDE led to an increase in the number of children skimming the objects, increased peer engagement, and more reading stimulation from caregivers to their children. This emphasizes that museums can opt for simpler, non-digital interactive design elements to enhance children's behavioral engagement in a museum setting. However, the N-DIDE does not guarantee that children will actively look at the exhibited objects.

7.3. Limitations and recommendations

The study has several limitations that need to be considered when interpreting the results. First, it is important to acknowledge that the sample sizes in the overall study are relatively small, which limits their ability to fully represent the entire population. In addition, these small sample sizes resulted in a violation of the assumptions of the Chi-square test, necessitating the use of the more appropriate *G*-test. In addition, the study revealed interesting differences in engagement behavior between the preliminary study and studies I and II, although these differences did not reach statistical significance. It is therefore recommended that these notable findings be investigated further with a larger sample size to better assess their potential significance. Second, the results of Study I indicated that although the infographics attracted the attention of primary school children, most did not actively engage with the content. It is therefore recommended to investigate whether infographics are still the right way to convey information to children or whether it was due to the design of the infographics. Third, it is important to note the differences in appearance and content between exhibition A and exhibition B. While exhibition A offered a variety of interactive elements, sound effects and videos, exhibition B did not have these features. As a result, the children

were naturally drawn to the more appealing exhibition A. Assessing the impact of the infographic in exhibition B on engagement behavior was complicated by the proximity of exhibition A, which may have distracted the children's attention. To truly measure the impact of the infographic and N-DIDE, it is recommended that follow-up research is carried out on two exhibitions with similar appearance and content. Fourth, the N-DIDE prototypes were not made from professional material. This sometimes led to inaccurate interpretations of their intended functions by the participants. It is therefore recommended that in future research the N-DIDE will be made by professionals.

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Figure A2: Exhibition B



B: Observation and coding scheme exhibition A

Table B1 Observation scheme

Observation scheme: <i>Child engagement behavior with science exhibitions</i>		
Date:		Name observer: Iris
Time and duration:		Type of exhibit: Thunder and lightning
Place:		
Observation item	Yes/ No	Note
Passes the exhibition		
Stand in front of the exhibit and inspect it by looking at objects and images. (<i>Skimming or actively</i>)	Time:	
Stand in front of the exhibit and inspect it by reading the information (<i>Skimming or actively</i>)		
Stand in front of the exhibit and touches the orb (<i>Passively or actively</i>)	Time:	
Engaging with the wind machine (<i>Passively or actively</i>)	Time:	
Interacts with the exhibit together with a caregiver.		
Interacts with the exhibit together with a peer.		
Shows signs of interest by asking questions to a caregiver.		
Shows signs of interest by asking questions to a peer.		
Shares experiences, and information about exhibit with caregiver or peer.		

Table B2 Coding scheme

Codes	Examples	Application
Category		
Participants		
<i>Description: Child does not visit the exhibition</i>		
1. Passes by the exhibition	A child walked past the exhibition and did not pay attention to the objects and information displayed in the exhibition	
Exploration behavior		
<i>Description: Observing, physically manipulating, or performing interactive activities with the exhibit</i>		
1. Looking at objects and images <i>Skimming or actively looking</i>	Skimming: a child is skimming the exhibitions by quickly looking at some of the objects and images	Active exploration enables children to engage with the exhibit through observation, hands-on learning, or interactive activities. It stimulates a deeper understanding of scientific concepts and fosters curiosity, experimentation, and discovery.
	Actively: a child is actively looking at all the objects and images	
2. Exploring by touching various objects (orb not included) <i>Passively or actively touching</i>	Passively: a child is using their hands to quickly feel various objects but is distracted or does not pay attention while touching the orb (orb not included)	
	Actively: a child is using their hands to investigate various objects and is paying attention while touching the objects (orb not included)	
3. Interacts with orb by touching it <i>Passively or actively touching</i>	Passively: a child is touching the orb but is distracted or does not pay attention.	
	Actively: a child is touching the orb and does pay attention when touching it	

4. Interacts with wind machine by pressing down the paddle
Passively or actively pressing down.

Passively: a child presses down on the pedal of the wind machine with their foot or hand but does not pay attention.

Actively: a child presses down on the pedal of the wind machine with their foot or hand and is paying attention

Social interaction between the child and caregivers or peers enables sharing of knowledge, ideas, or experiences. It promotes peer learning and shared exploration, which can enhance the child's engagement with the exhibit.

Social behavior

Description: Social interactions with caregivers or peers while observing, physical manipulating, or interacting with the exhibition

1. Interacting with caregiver while engaging with exhibition
A child interacts with a caregiver in the exhibit by talking about the exhibition or looking at objects together.
2. Caregiver stimulates/guide child to look at the objects
A caregiver leads the child through the exhibit, encouraging the child to look at the different objects and guiding the child by explaining information about the objects.
3. Caregiver stimulates/guide child to read the information
A caregiver stimulates the child to read the information that belongs to a specific object
4. Child seeks for guidance from caregiver
A child asks for help while looking/touching or reading in the exhibit.
5. Interacting with peers while engaging with exhibition
A child interacts with a peer in the exhibit by touching the orb together or talking about the exhibition.
6. Shares experiences with caregiver or peer
A child talks about their experience in the exhibition by mentioning what they see or feel. "Feel the orb, it gets warm when I touch it" or "look at that machine, it thinks it so big!"

Children can get additional information and explanations by reading the information in the exhibit. This will support their scientific knowledge

Reading behavior

Description: receives additional information about displayed objects through reading labels, signs or text

1. Reading labels, signs or information displayed in the exhibition
Skimming or actively reading.

Skimming: a child is skimming the information quickly next to the several objects displayed in the exhibition like the electrifying machine, the orb, or the wind machine

Actively: a child actively reads all the information next to the several objects displayed in the exhibition like the electrifying machine, the orb, or the wind machine

2. Too young to read the information

A child is too young to read the information that is displayed in the exhibition

Question asking

Description: receives additional information about displayed objects or text through asking questions.

1. Expressing curiosity through questioning

A child asks their caregiver or peer, “what happens when I touch this?” while pointing at an object

Asking questions shows children's curiosity and engagement with the exhibit. They build their understanding of scientific knowledge by seeking answers and information.

C: Observation and coding scheme exhibition B

Table C1 Observation scheme

Observation scheme: <i>Child engagement behavior with science exhibitions</i>		
Date:		Name observer: Iris
Time and duration:		Type of exhibit: Traveling
Place:		
Observation item	Yes/ No	Note
Passes the exhibition		
Stand in front of the exhibit and inspect it by looking at objects and images. (<i>Skimming or actively</i>)	Time:	
Stand in front of the exhibit and inspect it by reading the information. (<i>Skimming or actively</i>)		
Interacts with the exhibit together with a caregiver.		
Interacts with the exhibit together with a peer.		
Shows signs of interest by asking questions to a caregiver.		
Shows signs of interest by asking questions to a peer.		
Shares experiences, and information about exhibit with caregiver or peer.		

Table C2 Coding scheme

Codes	Examples	Application
Category		
Participants		
<i>Description: Child does not visit the exhibition</i>	A child walked past the exhibition and did not pay attention to the objects and information displayed in the exhibition	
Active exploration		
<i>Description: Observing, physically manipulating, or performing interactive activities with the exhibit</i>		Active exploration enables children to engage with the exhibit through observation, hands-on learning, or interactive activities. It stimulates a deeper understanding of scientific concepts and fosters curiosity, experimentation, and discovery.
1. Looking at objects and images <i>Skimming or actively looking</i>	Skimming: a child is skimming the exhibitions by quickly looking at some of the objects and images Actively: a child is actively looking at all the objects and images	
Social interaction		
<i>Description: Social interactions with caregivers or peers while observing, physical manipulating, or interacting with the exhibition</i>		Social interaction between the child and caregivers or peers enables sharing of knowledge, ideas, or experiences. It promotes peer learning and shared exploration, which can enhance the child's engagement with the exhibit.
1. Interacting with caregiver while engaging with exhibition	A child interacts with a caregiver in the exhibit by talking about the exhibition or watching together at objects.	
2. Caregiver stimulates/guide child to look at the objects	A caregiver leads the child through the exhibit, encouraging the child to look at the different objects and guiding the child by explaining information about the objects.	
3. Caregiver stimulates/guide child to read the information	A caregiver stimulates the child to read the information that belongs to a specific object	
4. Child seeks for guidance from caregiver	A child asks for help while looking or reading in the exhibit.	

- | | |
|--|--|
| 5. Interacting with peers while engaging with exhibition | A child interacts with a peer in the exhibit by talking about the exhibition or watching together at objects. |
| 6. Shares experiences with caregiver or peer | A child talks about their experience in the exhibition by mentioning what they see, "have you seen this animal? I think it's pretty" |

Children can get additional information and explanations by reading the information in the exhibit. This will support their scientific knowledge

Reading exhibits

Description: receives additional information about displayed objects through reading labels, signs or text

- | | |
|--|--|
| 3. Reading labels, signs or information displayed in the exhibition
<i>Skimming or actively reading</i> | Skimming: a child is skimming the information quickly next to the several objects displayed in the exhibition like the platypus or camera. |
|--|--|

Actively: a child actively reads all the information next to the several objects displayed in the exhibition like the platypus or camera.

- | | |
|--------------------------------------|--|
| 1. Too young to read the information | A child is too young to read the information that is displayed in the exhibition |
|--------------------------------------|--|









Question asking

Description: receives additional information about displayed objects or text through asking questions.

- | | |
|---|--|
| 1. Expressing curiosity through questioning | A child asks their caregiver, "what is this for animal?" |
|---|--|

Asking questions shows children's curiosity and engagement with the exhibit. They build their understanding of scientific knowledge by seeking answers and information.

D: Color scheme Museumfabriek

	CMYK
	0, 90, 50, 0
	0, 20, 5, 0
	0, 60, 0, 0
	0, 25, 75, 0
	100, 90, 10, 0
	50, 0, 0, 5
	85, 30, 60, 0
	12, 3, 7, 0

E: Brainstorming session mind maps

Mind maps exhibition A
Figure E1: Infographic

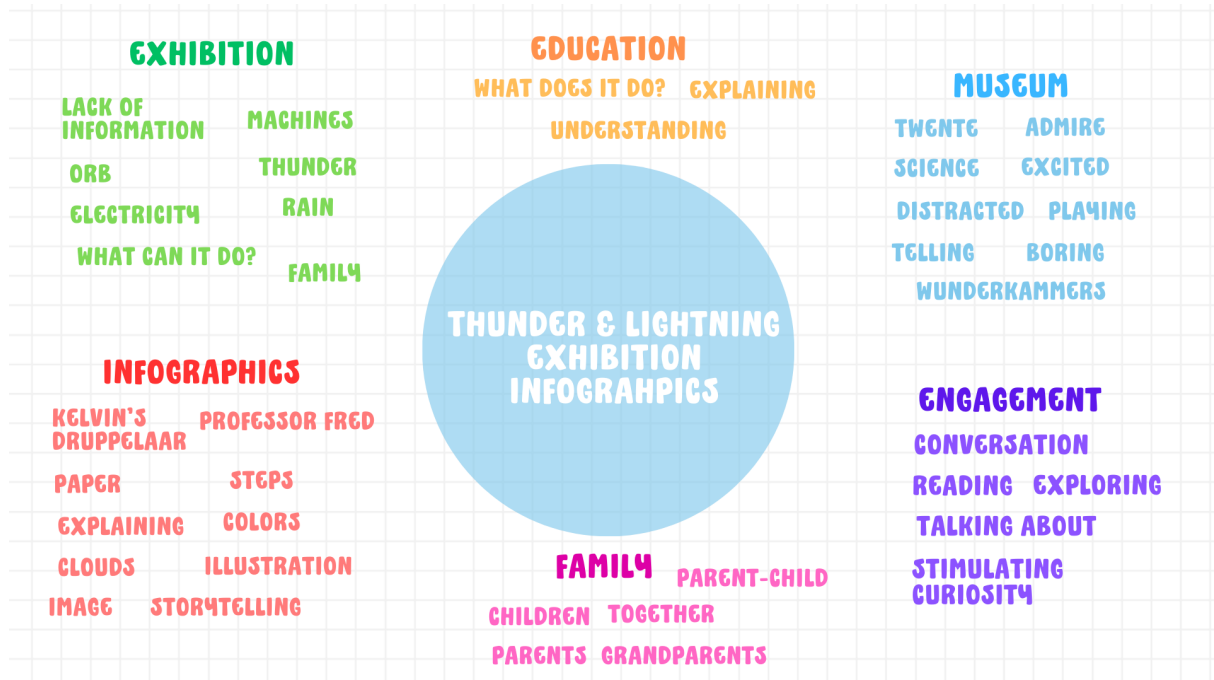
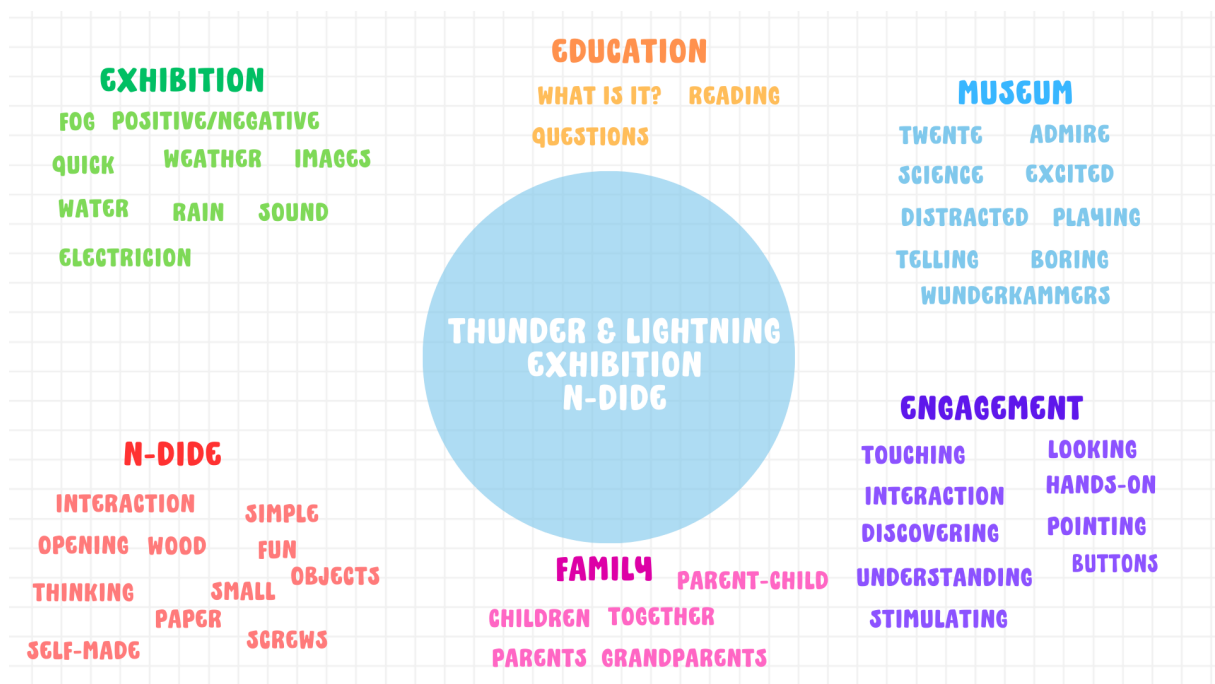


Figure E2: N-DIDE



Mind maps exhibition B

Figure E3: Infographic

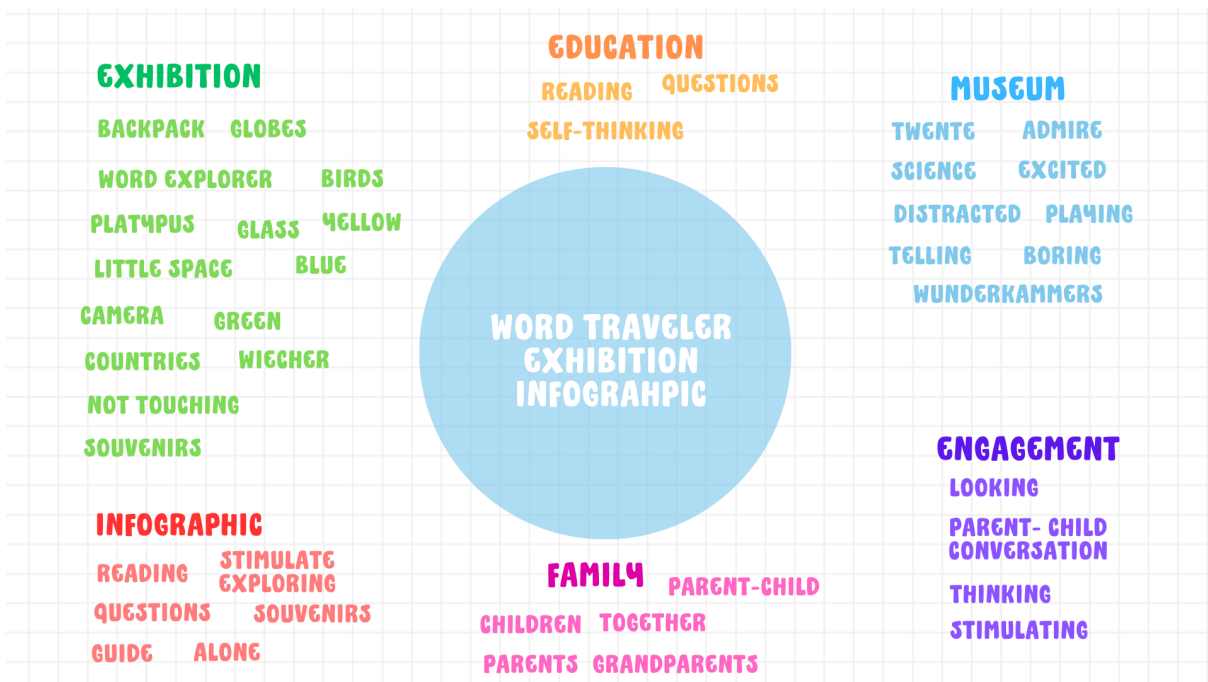


Figure E4: N-DIDE



F: First ideas

Thunder and lightning Design elements	Content	Supplies/ steps
1. Infographics displayed throughout the exhibition	<ul style="list-style-type: none"> • Providing children with step-by-step information about Kelvin's Druppelaar and the orb using images and text • Develop and include an illustration of Professor Fred in both infographics. • Promoting conversations between parents and children • Encouraging children to look and think about thunder, lightning, and the exhibited items. • Using colors of the color specifications from the Museumfabriek 	<ul style="list-style-type: none"> • Making sketches in Canva.com (A4) • Sending to Aafke for feedback • Finalize the infographics in Illustrator. • Send infographics to Aafke. • Print the infographics. • Size (A4)
2. Non-digital interactive design element	<ul style="list-style-type: none"> • Ask suggestive questions about the orb, Kelvin's Druppelaar and the Fog objects in the exhibit where children need to give the right answer by lifting a "yes" or "no" in a wooden plank. <p>The wooden planks bear the labels "yes" and "no," and they are designed to be lifted. Underneath the "yes" and "no" answers are provided.</p> <p>Example: <i>"When you touch the orb, the electrons in it are repelled." (Correct answer is no) →</i> If a child lifts the "no" plank, an explanation is given why they are wrong, and they are encouraged to try again to see how electrons are attracted in by their touch. Lifting the "yes" plank, on the other hand, confirms their correct answer and explains how electrons can be attracted through contact.</p> <ul style="list-style-type: none"> • Encouraging children to look and read about the objects. • Stimulating interaction between child and object • Stimulating interaction between caregiver and child • The interaction can be elaborated by giving the children a coloring page with several boxes. These boxes have assigned numbers. When children have the correct answer, they also see a number and a color. This number refers to the boxes that need to be filled with that color. When the 	<ul style="list-style-type: none"> • Making sketches of wooden planks in Canva • Sending to Aafke for feedback • Discuss plan with the technical department of the museum. • Develop the wooden planks with technical department of the museum.

child has completed all the questions, he or she has colored a lightning flash.

World traveler

1. Infographics displayed throughout the exhibition
 - Stimulating children to think about their travelling through asking questions: ‘What kind of souvenirs did you buy on your vacation?’’, ‘What do you think of when you see your souvenir?’
 - Promoting conversations between parents and children
 - Using colors of the color specifications from the Museumfabriek
 - Making sketches in Canva.com (A5)
 - Sending to Aafke for feedback
 - Finalize the infographics in Illustrator.
 - Send infographics to Aafke.
 - Print the infographics.
 - Size (A4)

2. Non-digital interactive design element: Globe
 - A globe will be placed in the exhibition. This globe comes with stickers of several exhibition objects. These stickers can be attached to the globe using Velcro. Children are instructed to investigate the origins of the objects. The objects can be placed on the countries from which they originated. Next to the globe, there will be flyers that encourage children to be "world travelers" in the exhibition. There will be fun facts and questions about the objects that they can answer on the flyers.
 - Globe
 - Velcro
 - Making stickers of the objects using lamination
 - Making a sketch of the flyers in Canva.com
 - Sending to Aafke for approval
 - Creating approved flyers in Illustrator
 - Send flyers to Aafke and designer Museumfabriek.
 - Print the flyers (Size A5)

G: Finalized ideas

Thunder and lightning	Content	Supplies/ steps
Design elements		
3. Infographics displayed throughout the exhibition	<ul style="list-style-type: none"> • Providing children with step-by-step information about Kelvin's Druppelaar and the orb using images and text • Develop and include an illustration of Professor Fred in both infographics. • Promoting conversations between parents and children • Encouraging children to look and think about thunder, lightning, and the exhibited items. • Using colors of the color specifications from the Museumfabriek 	<ul style="list-style-type: none"> • Making sketches in Canva.com (A4) • Sending to Aafke for feedback • Creating approved infographics in Illustrator • Send infographics to Aafke and designer Museumfabriek. • Pick up the printed infographics.
4. Non-digital interactive design element	<ul style="list-style-type: none"> • Ask suggestive questions about the orb, Kelvin's Druppelaar and the Fog objects in the exhibit where children need to give the right answer by lifting a "yes" or "no" in a wooden plank. <p>The wooden planks bear the labels "yes" and "no," and they are designed to be lifted. Underneath the "yes" and "no" answers are provided.</p> <p>Example: <i>"When you touch the orb, the electrons in it are repelled." (Correct answer is no) →</i> If a child lifts the "no" plank, an explanation is given why they are wrong, and they are encouraged to try again to see how electrons are attracted in by their touch. Lifting the "yes" plank, on the other hand, confirms their correct answer and explains how electrons can be attracted through contact.</p> <ul style="list-style-type: none"> • Encouraging children to look and read about the objects. • Stimulating interaction between child and object • Stimulating interaction between caregiver and child 	<ul style="list-style-type: none"> • Making sketches of wooden planks in Canva • Sending to Aafke for feedback • Discuss plan with the technical department of the museum. • Develop the wooden planks with technical department of the museum.
World traveler		
3. Infographics displayed throughout the exhibition	<ul style="list-style-type: none"> • Stimulating children to think about their travelling through asking questions: "What kind of souvenirs did you buy on your vacation?", "What do you think of when you see your souvenir?" • Promoting conversations between parents and children • Using colors of the color specifications from the Museumfabriek 	<ul style="list-style-type: none"> • Making sketches in Canva.com • Sending to Aafke for approval • Creating approved infographics in Illustrator • Size (A5) • Send infographics to Aafke and designer Museumfabriek. • Print the infographics.

4. Non-digital interactive design element:
Globe
5. A globe will be placed in the exhibition. This globe comes with stickers of several exhibition objects. These stickers can be attached to the globe using Velcro. Children are instructed to investigate the origins of the objects. The objects can be placed on the countries from which they originated. An infographic will be placed next to the globe that will give the assignment.
 - Find a globe on the internet and sent to Aafke.
 - Buying Velcro
 - Making stickers of the objects using lamination
 - Making a sketch of the infographic in Canva.com
 - Sending to Aafke for feedback
 - Creating infographics in Illustrator
 - Send infographics to Aafke and designer Museumfabriek.
 - Pick up the printed infographics.

H: Sketches infographic and N-DIDE

Sketches for exhibition A

Figure H1: Kelvin's Druppelaar

ONTDEK DONDER EN BLIKSEM MET PROFESSOR FRED

Mijn naam is **professor Fred** en ik ben dol op de wetenschap! Ik heb een machine gebouwd dat laat zien hoe onweer werkt. Kijk maar gauw mee, dan leg ik je alles uit!





1 Zie je het **water** in de bovenste bak? Via de tuitjes druppelt er water in de onderste bakken. Dit stellen **regendruppels** voor!

2 Dit water bevatten **positieve** en **negatieve** geladen deeltjes

+
+
+
-
-

3 Doordat de bakken via **elektrische ringen** met elkaar bevonden zijn, wordt het water gescheiden. In de **linker bak** zit water met **positieve geladen** deeltjes en in de **rechter bak** zit water met **negatieve geladen** deeltjes

4 De **rechter ring** is nu ook **positief geladen** en de **linker ring** is **negatief geladen**. Het verschil tussen deze bakken wordt zo groot dat er een vonk ontstaat





Figure H2: Orb

DE PLASMABOL DONDER & BLIKSEM

In de bol zitten **speciale gassen** zoals argon, neon en stikstof. Deze gassen zijn gevuld met kleine deeltjes genaamd **elektronen en ionen**. Als de bol aangaat, gebeurt er iets bijzonders: de elektronen en ionen beginnen heel snel heen en weer te bewegen. Ze rennen als een gek door de gassen en botsen tegen elkaar. Door al dat rennen en botsen krijgen de elektronen genoeg **energie** om **licht** te geven, alsof ze samen een spelletje spelen en elkaar laten **oplichten**.

ELEKTRONEN & IONEN

WIST JE DAT?
elektronen graag rondspringen en andere dingen laten oplichten? 😊



WIST JE DAT?
Ionen zowel positief als negatief geladen kunnen zijn?

+ -

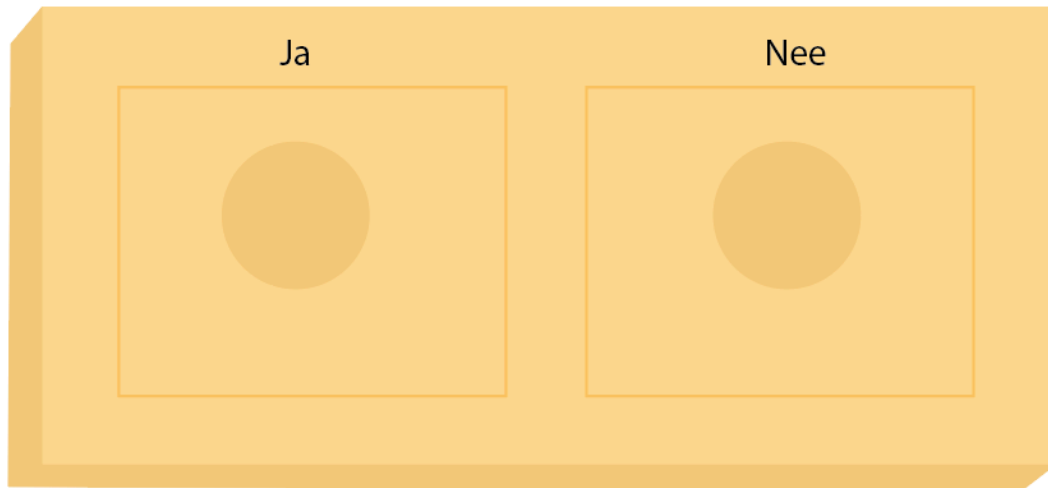
AANRAKING

. Als je de bol aanraakt, willen de elektronen graag naar je hand toe springen. Ze vinden het leuk om met je te spelen! Daarom voel je een kleine **stroom** door je lichaam gaan. Maar maak je geen zorgen, het is niet gevaarlijk!".



Figure H3: N-DIDE

"Als je de bol aanraakt, worden de elektronen in de bol afgestoten."



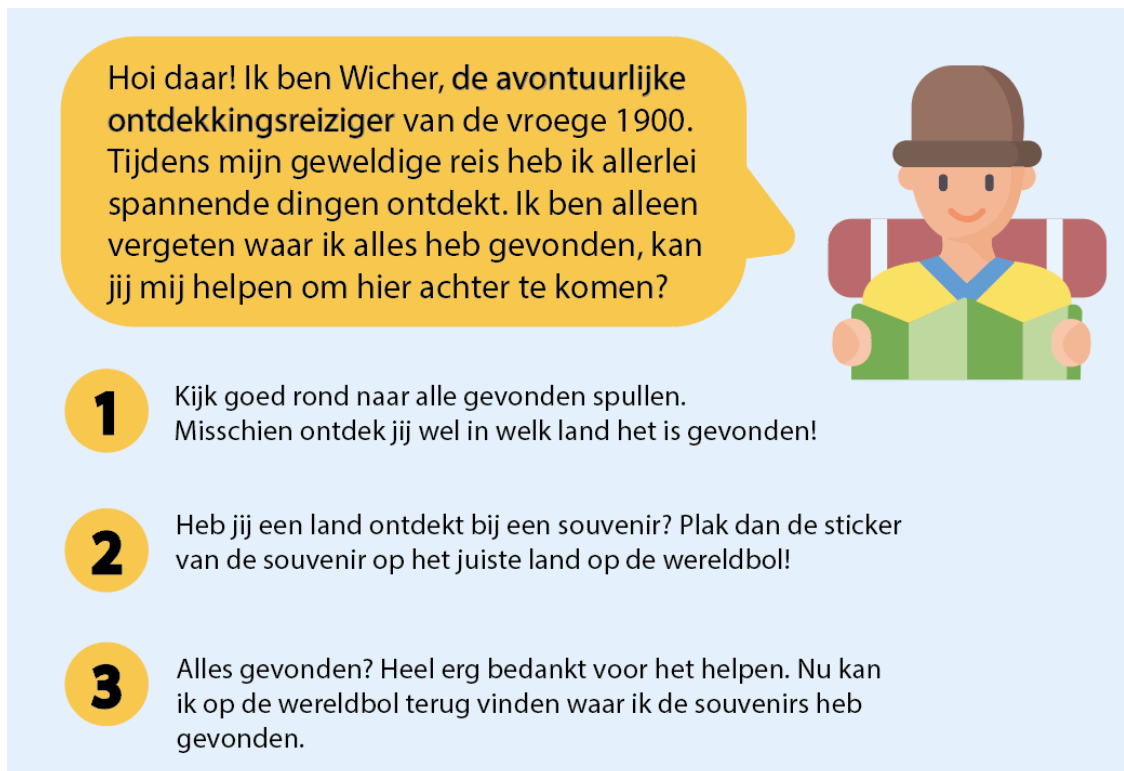
Sketches for exhibition B
Figure H4: Souvenirs



Hoi daar! Ik ben Wicher, de avontuurlijke ontdekkingsreiziger van de vroege 1900. Tijdens mijn geweldige reis heb ik allerlei spannende dingen ontdekt. En raad eens? Je kunt ze allemaal hier bewonderen! Maar eerst heb ik een aantal vragen voor jou.

- 1 **Welke souvenirs heb jij wel eens gekocht of gevonden?**
- 2 **Heb je ook een souvenir die erg bijzonder voor je is?**
- 3 **En waar denk je dan aan als je aan dit bijzondere souvenir terug denkt?**

Figure H5: Infographic for N-DIDE



Hoi daar! Ik ben Wicher, de avontuurlijke ontdekkingsreiziger van de vroege 1900. Tijdens mijn geweldige reis heb ik allerlei spannende dingen ontdekt. Ik ben alleen vergeten waar ik alles heb gevonden, kan jij mij helpen om hier achter te komen?

- 1 **Kijk goed rond naar alle gevonden spullen. Misschien ontdek jij wel in welk land het is gevonden!**
- 2 **Heb jij een land ontdekt bij een souvenir? Plak dan de sticker van de souvenir op het juiste land op de wereldbol!**
- 3 **Alles gevonden? Heel erg bedankt voor het helpen. Nu kan ik op de wereldbol terug vinden waar ik de souvenirs heb gevonden.**

I: Final elements infographics

Exhibition A

Figure 11: Infographic orb

Ontdek de **plasmabol** met professor Fred


Hallo, ik ben professor Fred en ik ben gek op wetenschap! Je hebt vast al deze mooie bol gezien. Dit heet een **plasmabol** en ik ga je er van alles over vertellen. Kijk maar gauw mee!

1
In de **plasmabol** zitten speciale gassen zoals argon, neon en stikstof. Deze gassen zijn als een huis voor kleine deeltjes genaamd **elektronen** en **ionen**. Wanneer de bol aangaat, gebeurt er iets bijzonders: de elektronen en ionen rennen als een gek door de gassen en **botsen tegen elkaar**. Door al dat rennen en botsen krijgen de elektronen genoeg energie om licht te geven. Het is net een magische show!

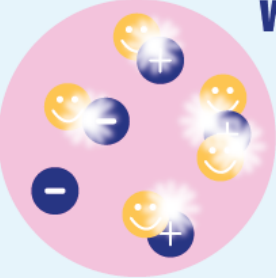
Kijk maar hier!

Elektronen

Wist je dat?
elektronen graag rondspringen en andere dingen laten oplichten?



&



Ionen

Wist je dat?
ionen zowel positief als negatief geladen kunnen zijn?



2
De elektronen in de **plasmabol** houden van avontuur en willen graag op ontdekking gaan. Wanneer je de **plasmabol** aanraakt, voelt je hand voor hen als een leuke bestemming. Dit komt doordat je hand een lichte positieve lading heeft. De elektronen vinden dat interessant en willen naar je hand toe springen om te zien wat daar te beleven valt. Als ze naar je hand stromen, voel je een kleine stroompje. Maar wees gerust, het is niet gevaarlijk en voelt eigenlijk een beetje kriebelig!

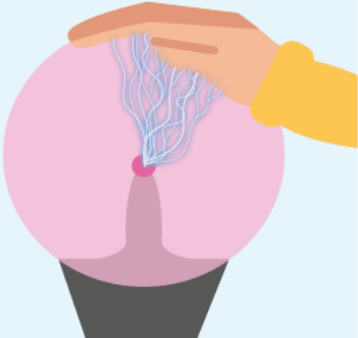


Figure I2: Infographic in exhibition A

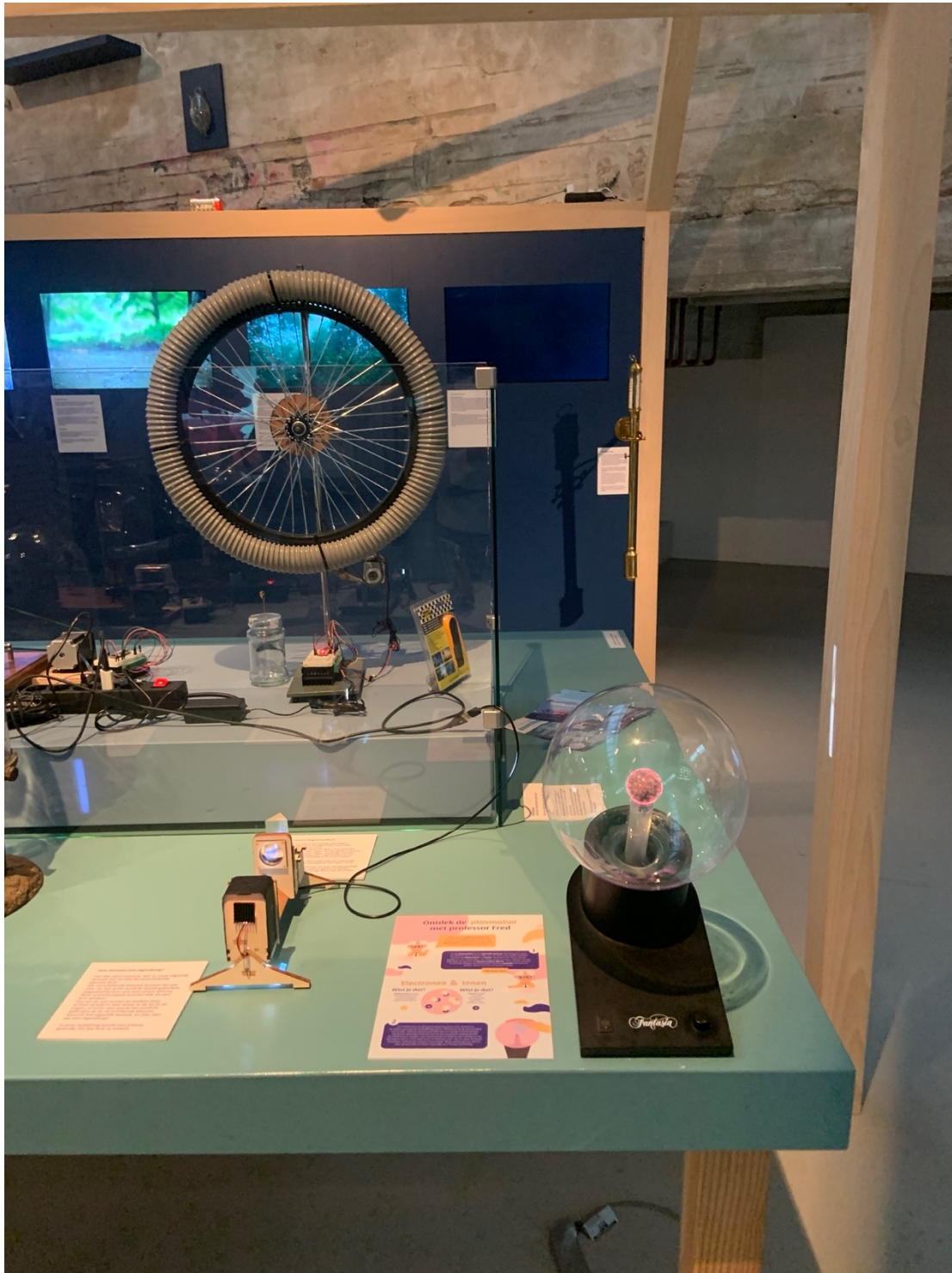


Figure I3: Infographic in exhibition A



Figure I4: Kelvin's Druppelaar

Ontdek Donder & Bliksem met professor Fred

Hallo, ik ben professor Fred en ik ben gek op wetenschap! Ik heb een machine gebouwd die laat zien hoe onweer ontstaat. Het heet Kelvin's Druppelaar! Kom snel kijken, dan leg ik je alles uit!"

1 Zie je de bak bovenop de machine staan? Het water uit deze bak druppelt langzaam in de onderste bakken. Net zoals regen uit een wolk!

2 Wist je dat water en regen positieve en negatieve geladen deeltjes hebben?

3 Zie je die twee ringen boven de onderste bakken? Hier loopt elektriciteit door heen. Door deze straling kan mijn machine de positieve en de negatieve deeltjes van elkaar scheiden.

4 De electriciteit in de ringen heeft positieve en negatieve deeltjes. Net zoals de waterdruppels.

5 Wist je dat, gelijksoortige ladingen elkaar wegduwen, terwijl verschillende soorten ladingen elkaar aantrekken?

6 De linker ring van de machine heeft een negatieve lading. Dit trekt dus het positief geladen water aan. Terwijl de rechter ring een positieve lading heeft. Dus raad je al welk water deze ring aantrekt? Juist! Het negatief geladen water.

Omdat de twee bollen onderaan nu zoveel verschil in ladingen hebben, trekken ze elkaar aan en ontstaat er een klein vonkje. Net als bliksem, maar veel kleiner!"

Figure 15: Kelvin's Druppelaar in exhibition A

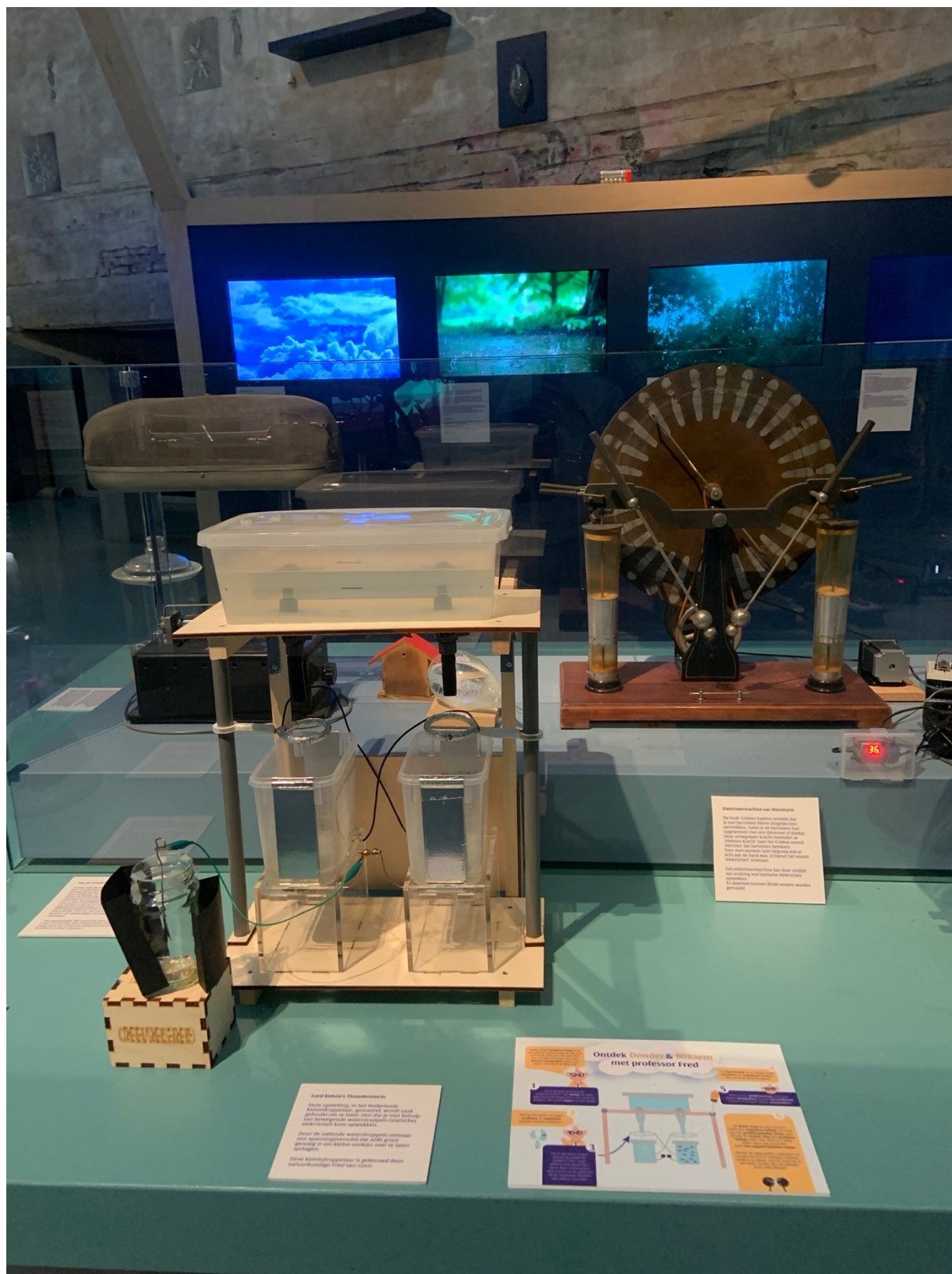


Figure I6: Kelvin's Druppelaar in exhibition A

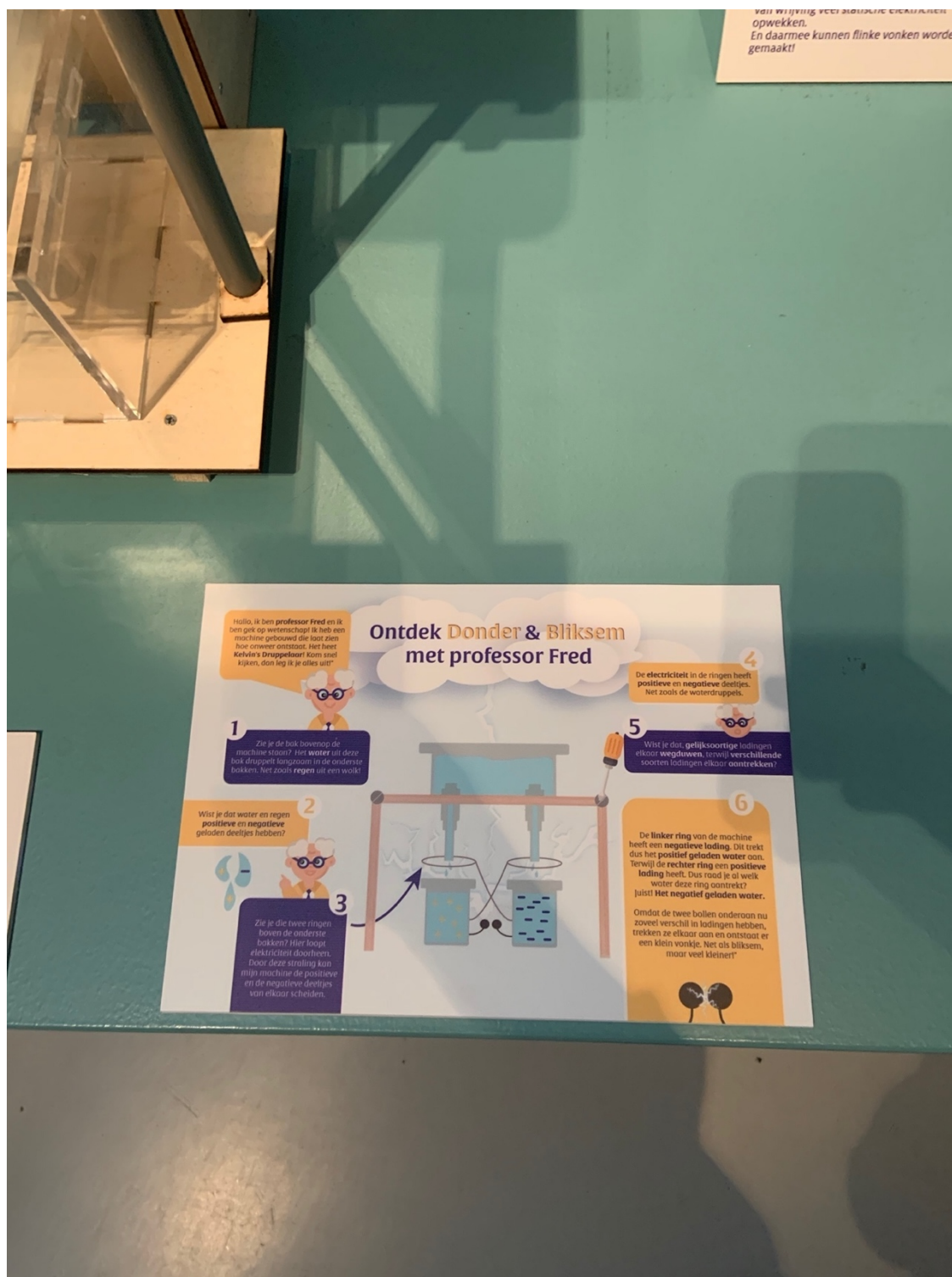



Figure I7: Infographic exhibition B



Hoi daar! **Ik ben Wicher, de avontuurlijke ontdekkingsreiziger** van ongeveer 100 jaar geleden. Tijdens mijn geweldige reis heb ik allerlei spannende dingen ontdekt. En raad eens? Je kunt ze allemaal hier bewonderen! Maar eerst heb ik een aantal vragen voor jou.

- 1 Welke souvenirs heb jij wel eens gekocht of gevonden?
- 2 Uit welk land of landen komen deze souvenirs?
- 3 Wat vind jij het mooiste souvenir die ik heb meegenomen van mijn wereldreis? Kijk maar gauw rond!

J: Final elements N-DIDE

Figure J1: N-DIDE exhibition A



Figure J2: N-DIDE exhibition A

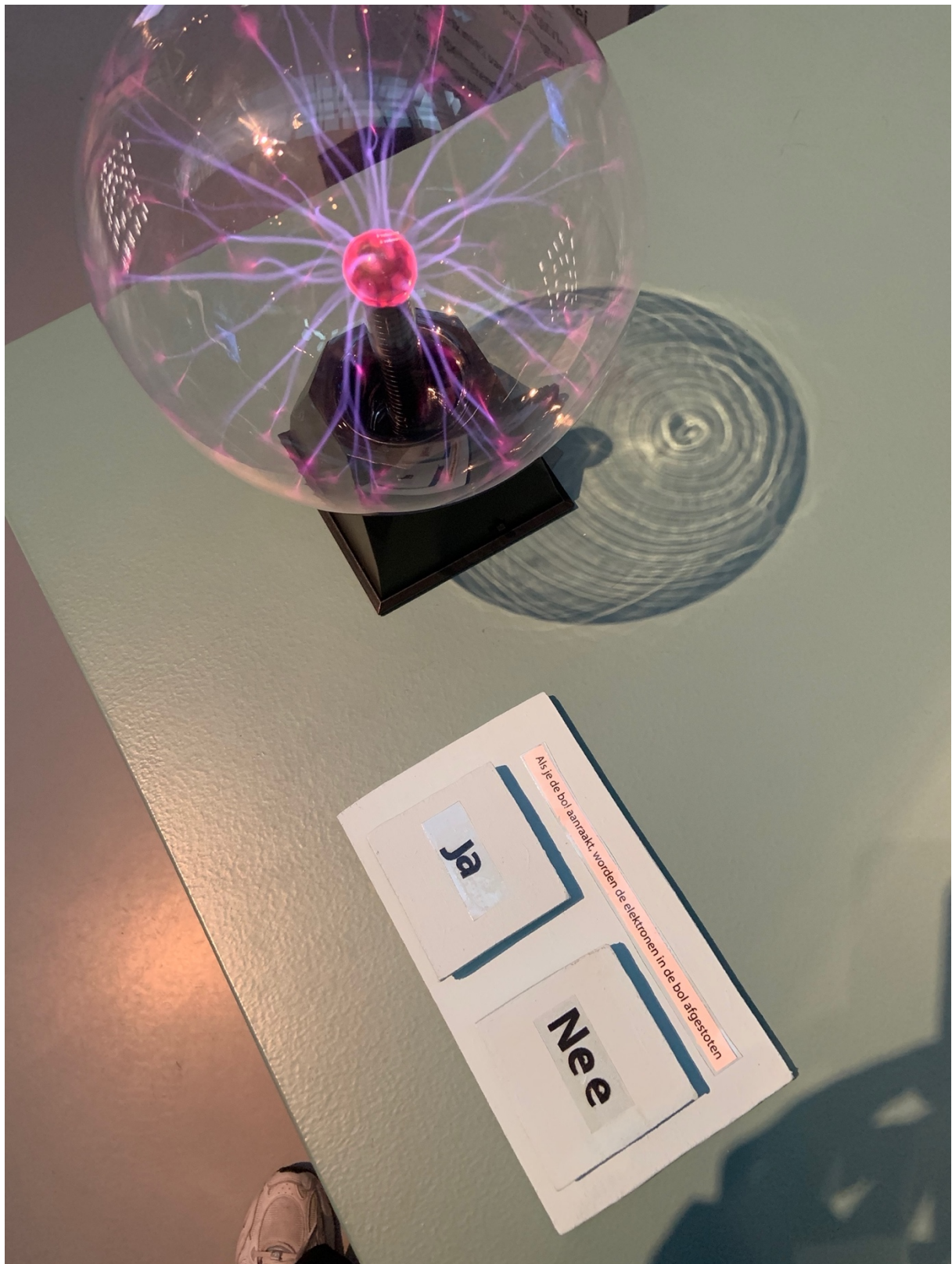


Figure J3: N-DIDE exhibition A

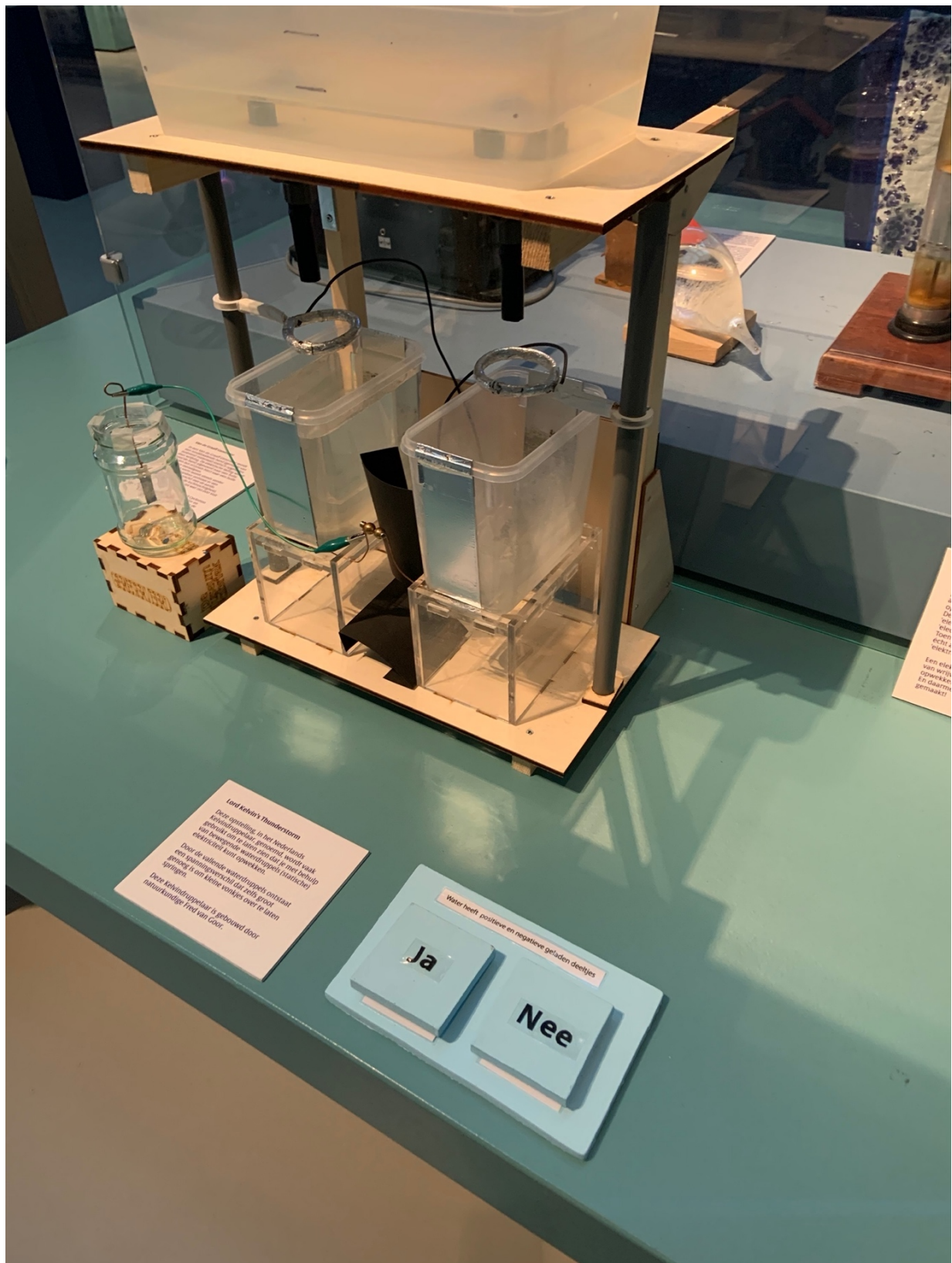
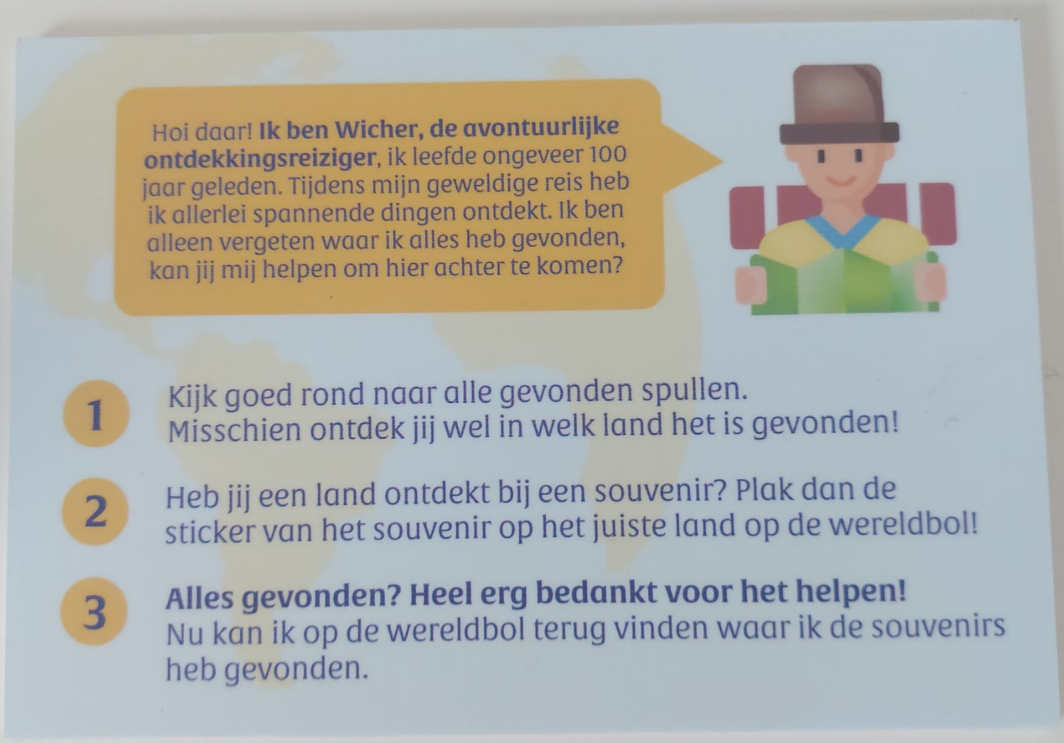


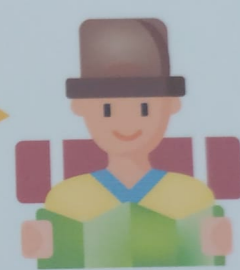
Figure J4: N-DIDE exhibition B



Figure J5: N-DIDE exhibition B



Hoi daar! **Ik ben Wicher, de avontuurlijke ontdekkingsreiziger**, ik leefde ongeveer 100 jaar geleden. Tijdens mijn geweldige reis heb ik allerlei spannende dingen ontdekt. Ik ben alleen vergeten waar ik alles heb gevonden, kan jij mij helpen om hier achter te komen?



- 1** Kijk goed rond naar alle gevonden spullen. Misschien ontdek jij wel in welk land het is gevonden!
- 2** Heb jij een land ontdekt bij een souvenir? Plak dan de sticker van het souvenir op het juiste land op de wereldbol!
- 3** **Alles gevonden? Heel erg bedankt voor het helpen!** Nu kan ik op de wereldbol terug vinden waar ik de souvenirs heb gevonden.

Figure J6: N-DIDE exhibition B



K: Added components observation and coding scheme study II

Exhibition A

Table K1: Observation scheme

Observation scheme: <i>Child engagement behavior with science exhibitions</i>		
Date:		Name observer: Iris
Time and duration:		Type of exhibit: Traveling
Place:		
Observation item	Yes/ No	Note
Interacts with wooden planks (<i>Passive or active</i>)		

Table K2: Coding scheme

Codes	Examples
Interacts with wooden planks <i>Passively or actively interacting</i>	<p>Passively: a child interacts passively with the wooden planks by touching them without reading the question and giving an answer</p> <p>Actively: a child interacts actively with the wooden planks by reading and answering the question.</p>

Exhibition B

Table K3: Observation scheme

Observation scheme: <i>Child engagement behavior with science exhibitions</i>		
Date: 14-08-2023		Name observer: Iris
Time and duration: 11:00 – 14:30		Type of exhibit: Traveling
Place: Museumfabriek		
Observation item	Yes/ No	Note
Interacts with the world globe	Yes Time: 01:25	Engaged

Table K4: Coding scheme

Codes	Examples
Interacts with globe <i>Passively or actively interacting</i>	<p>Passively: a child interacts passively with the globe, touching it only briefly and without completing the task.</p> <p>Actively: a child interacts actively with the globe by completing the task</p>