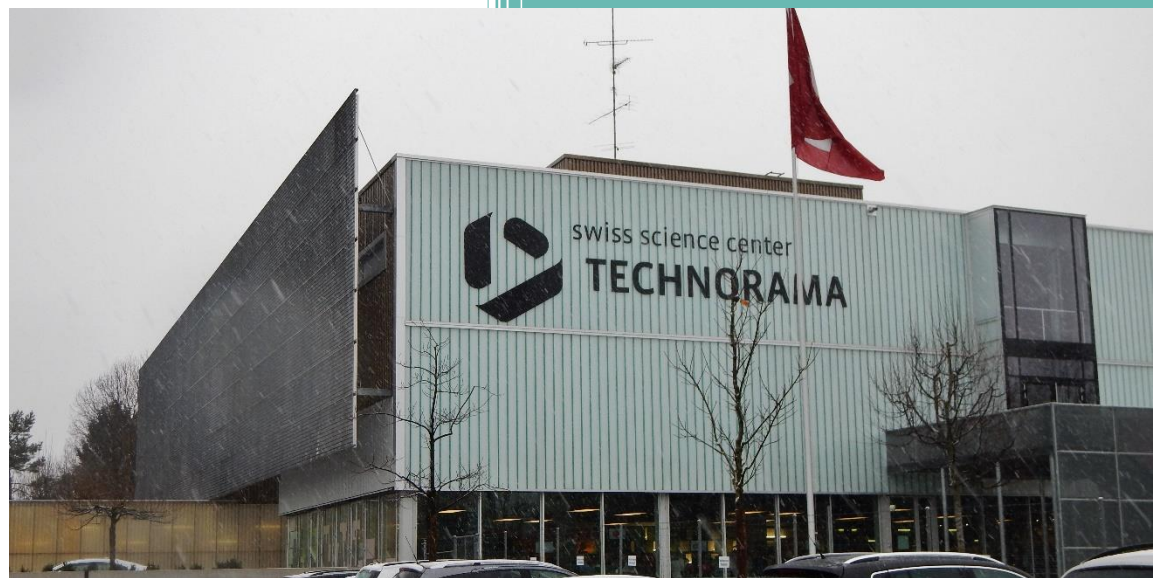


# Improving Student Learning at the Swiss Science Center Technorama



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# Improving Student Learning at the Swiss Science Center Technorama

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*<http://www.wpi.edu/Academics/Projects>.*

## **Abstract**

The problem Technorama faced was that it has so many exhibits that students often try to race through the whole museum, learning a minimal amount. To address this problem, we created a scavenger hunt so that students would focus on a few exhibits and better absorb the information presented. The hunt moves students through four exhibits with three questions to answer at each exhibit. We found that students using the scavenger hunt increased their learning more than other students.

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## **Executive Summary**

Visiting a science center can be a fun way to spend the day, but just because it is fun does not always mean it is educational. Sometimes, science centers have so many exhibits and activities that it can be difficult to absorb all the new information and effectively learn (Dr. Armin Duff & Stefan Tosch, personal communication, April 1, 2019). With so much to see and do, people tend to become overwhelmed and move from exhibit to exhibit in order to see everything without taking the time to understand what they are observing. This is a concern for many science centers because they are institutions designed to teach people about the sciences using experiments and demonstrations. Science centers want their exhibits to be fun in order to draw people in and keep them engaged, but they also want to teach the visitor. This can be a hard balance to strike and is a real problem for the Swiss Science Center Technorama (2019) in Winterthur, Switzerland. Technorama has approximately 70,000 students who visit each year, and the museum staff would like to ensure that the students' visits are worthwhile, as these students are the future of Switzerland's scientific and technological development. Students' trips to Technorama should be inspiring them to pursue careers in STEM (science, technology, engineering, and mathematics), and the best way to do that is through educational and engaging exhibits.

Technorama was searching for ways to improve the effectiveness of their exhibits through the implementation of a guide that would be both fun and educational for students. Our team's plan was to design a structured path through Technorama to increase students' understanding of the scientific concepts being taught by the exhibits. To accomplish this goal, our team had four measurable objectives. The first objective was to determine the effectiveness of the exhibits at Technorama as they currently stood. In order to accomplish this objective, our team contacted school groups visiting Technorama and provided them with a questionnaire after going through the exhibits. This questionnaire, along with observations of the students during their visit, allowed our team to set a baseline for how much time students spent at each exhibit and how much they think they learned during their visit. The second objective was to understand how students typically interact with exhibits and identify how to focus their learning, along with understanding what makes an exhibit both fun and educational. To accomplish this objective, our team conducted interviews with museum staff members from the Exhibition and Didactics Department and the Visitor Services Department to best understand what makes an exhibit both

educational and engaging, what makes exhibits attractive for visitors, and how students typically interact with those exhibits. The third objective was to identify the best ways to navigate the exhibits at Technorama to maximize learning. Our team went through the museum and determined paths based on the popularity of exhibits and the proximity to related exhibits, as well as staff input. The fourth and final objective was to determine the effectiveness of the proposed method using a survey. This survey contained questions based on the exhibits the students had visited using the proposed methods and was compared to a control group using just a map without the proposed method. The survey results were compared between students who used the proposed method and those who did not to determine the method's effectiveness.

### **Findings from Objective 1:**

- Overall, students very much enjoy visiting Technorama.
- Students generally do not attempt to learn more about phenomena.
- Students spend little time at each exhibit.
- Students prefer exhibits that were flashy with instantly noticeable phenomena.

Through our team's observations, we took note that most students spent very little time at each exhibit, staying just long enough to see the phenomena occur. In most cases, students did not attempt to learn more about the science behind the phenomena. Each exhibit contains an information card explaining the science, but students rarely even looked at it. However, this does not mean the students did not have fun at Technorama. Based on the surveys, most students very much enjoyed their time at Technorama. The students tended to state exhibits that were large and flashy, with the phenomena instantly noticeable, as their favorite in the survey.

### **Findings from Objective 2:**

- Not many people use the information cards at each exhibit, nor ask questions of staff.
- Younger visitors and students are much less likely to read the information cards.
- Effective exhibits should be heavily interactive.

Our team conducted interviews with nine members of the Technorama staff: six from Visitor Services and three from Didactics. All the staff members interviewed had similar views on exhibits and how visitors interact with them. Visitor Services stated that visitors rarely use the information cards, with younger visitors and students being much less likely to use them.

### **Findings from Objective 3:**

- A possible way to guide students is using a scavenger hunt .
- Initial tests of the scavenger hunt prototype yielded feedback regarding:
  - The placement of QR codes
  - Overcrowding of exhibits

Our team created a scavenger hunt web application that guided students through the Mechanics sector of Technorama. For this scavenger hunt, we picked four exhibits that related to the physics curriculum of students aged 14 to 16 in the Zurich canton. In the initial prototype tests, the most common feedback regarded the placement of the QR codes. To fix this for later testing of the prototype, our team hid the QR codes behind the information cards. Another vital piece of feedback we received as well as observed was the exhibits being overcrowded. This was due to the prototype consisting of a singular path so that all the students would be visiting the same exhibits in the same order. This was fixed by implementing a system to randomly choose a pathway between the four chosen exhibits, decreasing the traffic drastically at each one.

### **Findings from Objective 4:**

- On average, students aged 14 to 16 thought the questions were of a suitable level for their age.
- On average, students aged 14 to 16 enjoyed using the scavenger hunt and learned more than they expected to when using the scavenger hunt.
- The scavenger hunt increased the hold time of the exhibits.

Our scavenger hunt was tested to show increased learning outcomes of the students visiting Technorama. The students were given a survey after using the scavenger hunt. Through this survey, our team determined that the majority of students thought the questions were not too difficult or too easy and were suitable for their age. The majority of students enjoyed using the scavenger hunt and claimed to have learned more than they expected to when using it. Through observations, it was seen that the use of the scavenger hunt drastically increased the time that students spent at each exhibit. Due to this increased hold time, students were interacting and thinking through the phenomena at each exhibit significantly more than they had been before the scavenger hunt's implementation.

**Recommendations:**

- Recommendation 1: Expand the scavenger hunt throughout the museum.
- Recommendation 2: Optimize certain routes for specific school groups.
- Recommendation 3: Introduce mobile technology.
- Recommendation 4: Add multiple language options.

Our team recommends that the scavenger hunt be expanded to include different sectors of Technorama across all of its floors. This will allow those using the scavenger hunt to see more parts of the facility and learn about a wider range of topics. Going off that, since school groups could be of varying ages and learning about a variety of different topics, different scavenger hunts geared specifically towards topics the students are learning about would make the tool more versatile for all educators to use. The scavenger hunt can also be improved by making it into an app rather than a website and integrating a QR-code scanner into the application itself. A final recommendation is to increase the number of languages the scavenger hunt is available in, as information at Technorama is available in four languages.

## Chapter 1. Introduction

For many people, a museum is a place of discovery for new knowledge about topics they may be interested in. However, providing an educational environment in today's era can be quite difficult, struggling to be both educational and engaging for students (Allen, 2004). Addressing this issue is extremely important, as museums should not only excite visitors on the topics they present, but also engage them in a way that will be educational. Many science centers, museums that specialize in science and technology, address this issue by including hands-on activities and interactive exhibits (Ecotarium, 2019; Museum of Science, 2019a).

While enjoyable, trips to a science center are not always as educational as they should be, according to curators at Switzerland's Science Center Technorama (Dr. Armin Duff & Stefan Tosch; personal communication, April 1, 2019). Visitors can get overwhelmed by the number of exhibits available, trying to experience the museum by visiting every one of the exhibits. Yet, by rushing through the exhibits, visitors may not really gain or fully understand the knowledge that the museum's curators had in mind for them to obtain. The best scenario would be when visitors can both enjoy their time at each exhibit and also thoroughly learn about what they experienced. One of the many museums that struggles to strike this balance is the Swiss Science Center Technorama.

There has been significant research on the educational value of different types of learning and museum exhibits (Allen, 2004; Holstermann, Grube, & Bögeholz, 2010). Research has also been done on the effectiveness of museum worksheets for students on a school trip (Bowker, 2002; Griffin, 1994; Griffin & Symington, 1997). Many scientists agree that interactive based learning can be used to engage people and leave a lasting impression, and hands-on activities can increase a person's interest in a topic. Boston's Museum of Science (2019a) and the Ecotarium (2019) in Worcester, Massachusetts, engage their visitors through interactive learning exhibits. Other museums have incorporated technology into their exhibits, such as an app to guide visitors through the museum or implementing augmented reality and/or virtual reality into their exhibits (Detroit Institute of Arts, 2017; Franklin Institute, 2018).

There is insufficient research on how to guide visitors through a museum so that the visitors' learning is maximized. With over 500 exhibits, the Swiss Science Center Technorama is one of the many science museums that face this problem (Dr. Armin Duff & Stefan Tosch, personal communication, April 1, 2019). Staff at Technorama believe that if visitors would spend

more time at a limited number of related exhibits, they would most likely be able to better understand the concepts that are being presented.

The goal of this project was to develop a way to guide students through a limited number of Technorama exhibits so students would gain greater in-depth knowledge on a focused number of topics. It was predicted that being able to better engage students in a thorough and systematic exploration of certain science exhibits would lead to more complete education on these topics. To achieve this goal, our team identified four objectives to accomplish: determine the current effectiveness of the exhibits at Technorama, identify ways to focus students' learning on a few related scientific topics, determine the best ways to guide students through these related sets of exhibits, and determine the effectiveness of the proposed methods. To accomplish these objectives, our team used observations and student surveys with school groups from the greater Zurich area. Staff members from various departments at Technorama were also interviewed. A scavenger hunt to guide students was created, as our team determined it would be a good way to focus students' learning at Technorama. Various versions of this scavenger hunt were created and tested before a final version. The effectiveness of the final version was tested by comparing the results of a quiz that a school group took, with half the group using the scavenger hunt and the other half using a simple map to visit the same exhibits. After collecting and analyzing data, our team concluded that any sort of structured guide, like a map, will increase student learning, however, a scavenger hunt is more fun to use. Overall, this research provided a better understanding of how visitors, specifically students, learn and retain information from a museum, a vital component of ensuring a museum's success in the future.

## **Chapter 2. Background**

For visitors of all ages, museums fall into the intersection of recreation and education. (Semper, 1990). While museums all inform people about a wide variety of topics, science museums are challenged with introducing particularly complex ideas and principles. Museums around the world continuously strive to improve their educational model to create the most effective learning experience for visitors.

In this chapter, we will discuss the effectiveness of current methods being used for learning and how to measure that effectiveness. We will also review the research that has been done at museums about using exhibits to engage visitors. Finally, we present the current educational system in Switzerland and the methods the Swiss Science Center Technorama uses to present scientific concepts and their educational programs to students.

### **2.1 Effective Methods for Learning**

There has been significant research into what constitutes effective learning, both in and out of the classroom (Cornford, 2002). Generally, effective learning has been identified as consisting of three key features (Watkins, Lodge, Whalley, Wagner, & Carnell, 2002). The first feature is that learning is an active process in which learners create relationships between new information and their existing perceptions. The second feature is that learning does not occur at an isolated point in time and that there may be periods of lesser and greater understanding throughout the learning process. The third feature has been defined as the contextualizing of what has been learned so that new information may be used in later scenarios. When it comes to the typical classroom learning environment, the most effective strategies for student retention of information were found to be practice testing and distributed practice of the material. Moderately effective strategies were identified as elaborative interrogation, self-explanation, and interleaved practice (Dunlosky, Rawson, Marsh, Nathan, & Willingham, 2013). While these are undoubtedly crucial components to maximizing the effectiveness of teaching, the presence of alternative teaching methods has taken rise in recent years to become a staple of the innovative classroom.

Hands-on activities have been hailed as an essential component of a modern learning experience (Ateş & Eryilmaz, 2011). A key point that is made for hands-on experience is that it typically increases students' interest in the given topic. This happens because when a person



experiences a learning activity as enjoyable, pleasant, stimulating, and important their interest in increased. In particular, creating hands-on activities that incentivize the activity rather than just the conclusion is vital to developing effective learning environments (Holstermann, Grube, & Bögeholz, 2010). While it may seem like a daunting task to capture the interest of all students, designing intrinsically motivating activities is the basis by which lifelong learners are formed (Middleton, 1995). Therefore, we can conclude that hands-on teaching methods are beneficial for the student so long as they are able to interest the students and incentivize them to engage fully with the activities.

There is no doubt that the learning model has changed dramatically with the introduction of modern technology (Jonassen, 1995; Liu, Ritzhaupt, Dawson, & Barron, 2017). In higher education, integrating tablets and smartphones into the learning environment was also found to have a positive effect on the development of learning activities and general competence (Sevillano-García & Vázquez-Cano, 2015). This effect was most prominently observed in the category of analysis and synthesis of information. Additionally, with a growing generation of students who are increasingly comfortable with using technology, a benefit of integrating mobile technology into learning spaces is that it creates a seamless learning experience that transcends confinement to one particular space or style of education (Chen, Seow, So, Toh, & Looi, 2010).

Interestingly, the integration of classic games, like scavenger hunts, into modern technology has also been shown to improve learning for students (Chalmers, 2003). Games can be a very effective form of learning for children, especially as they are so caught up in the game's goals, they do not realize they are learning (Kwak, 2004). Scavenger hunts have been shown to be a powerful learning tool for students as they improve students' learning and research skills while retaining the aspects of a fun game. In addition, a scavenger hunt's ability to be facilitated through mobile devices makes them a great vehicle for linking learning environments and measuring students' learning.

## **2.2 Ways to Evaluate Learning**

In order to assess the success of an exhibit at a museum, it is necessary to evaluate the visitors' understanding of the concepts presented in these exhibits (Griffin, 1994). We can define a successful learning experience as an increase in understanding of the concepts presented. This experience should occur throughout the visitors' interaction with the exhibit; therefore,

measuring the knowledge level of a visitor before and information retention after interacting with the exhibit will indicate if the experience has been a success.

### **2.2.1 Ways to measure student knowledge retention**

Traditional classrooms usually measure how much students have learned using assessments (Cornell University, 2019). These assessments may be tests, quizzes, or any evaluation that gauges how much of the subject matter the student has learned and whether that information was retained from when the teacher introduced it to the time of the assessment.

While methods like this may work well for the classroom, using an assessment like that to measure student retention for a trip to a museum is not practical, or even feasible. If teachers give students a worksheet to fill out at or after visiting the museum, it may feel too much like a test, and the trip immediately becomes less enjoyable (Dr. Armin Duff & Stefan Tosch, personal communication, April 1, 2019).

### **2.2.2 Student worksheets for museum trips**

Museum worksheets allow teachers to see how much their students learned from their trip to the museum and how much they understood the concepts being presented in the exhibits (Griffin & Symington, 1997). The teacher can then look at the responses from the worksheet and determine what to expand upon when the students return to the classroom. However, there have been a few studies that found the worksheets can have unexpected outcomes (Griffin, 1994; Bowker, 2002). Students often look for the answers to their worksheet in the displayed text instead of thinking about the concepts being presented in the exhibit, which is what their teacher would prefer. Students also tend to only focus on the exhibits required for their worksheet and do not spend much time at those exhibits once they have found the answers for their worksheets. Students also may copy from each other to complete the worksheet instead of interacting with the exhibits.

### **2.2.3 Ways that museums evaluate visitor learning**

In order to assess the educational impact of an exhibit, museums often measure the attraction power of the exhibit, the holding power of the exhibit, and the visitor's engagement

level (Boisvert & Slez, 1995). Museums measure the attraction power by observing how many visitors stop at the exhibit. They measure holding power by observing how much time visitors spend at the exhibit. The visitor's engagement is measured by observing how well the visitor pays attention when at an exhibit. If a visitor just glances at an exhibit and does not spend a lot of time there, that exhibit has not successfully impacted the visitor's learning.

## **2.3 Science Museums**

Many museums across the world employ different methods to engage and teach their visitors about their exhibits. The core essence of these approaches has two important components: interactive based learning and the use of technology (Charitonos, Blake, Scanlon, & Jones, 2012). In this section, we will delve deeper into explaining these two components.

### **2.3.1 Interactive based learning at Museums**

There is an important difference when it comes to learning in a school or a museum environment; this is interaction (Semper, 1990). Unlike schools, museums that implement interactive based learning into their programs/exhibits allow people to explore and learn on their own accord. The basic idea is that an interactive based learning environment will leave a lasting impression and stimulate interest in the subject matter (Allen, 2004). A personal desire to learn and the freedom to obtain it is extremely important. There are many museums that produce exhibits that are centered on these ideas.

One of the many museums that provide an interactive based learning system is the Museum of Science (2019a) in Boston, MA. One of their exhibits, "Investigate!: A Do-It-Yourself Exhibition", focuses on the practice of the scientific method. Through this exhibit, visitors face a given problem and, through interaction, are able to test out their theory and identify the cause. Another interactive museum exhibit they offer focuses on four specific senses: sight, hearing, touch, and smell (Museum of Science, 2019b). The benefit of these exhibits is that visitors must personally engage with them, rather than simply reading or having the answer hand-delivered to them. For example, in the "Kitchen" section, visitors are tasked with finding the cup that best keeps liquids warm, and in the "Front Yard" section, visitors try to deduce the use for several mysterious tools.

The Ecotarium (2019) in Worcester, MA, is another museum that believes in this form of learning. Similar to the Museum of Science, the Ecotarium offers interactive based learning exhibits that focus primarily on the environment. One of these exhibits simulates “some of New England’s wildest weather patterns and the geology of the White Mountains” (para #1). Their other exhibits are of similar nature; their intentions are designed to provide visitors with real-life experience of the different kinds of environments in a safe and enclosed space. Some of the most interactive components include a phone-booth sized hurricane wind simulator and a bouldering wall highlighting the different rocks and minerals found on Mt. Washington.

A hands-on approach like these museums use is a crucial part of interactive based learning (Ateş & Eryilmaz, 2011). Through this method, visitors can effectively learn about what they are experiencing. Science can also be a rigorous topic to many; however, creating entertaining ways to deliver scientific topics can make it enjoyable and provide perhaps the best education (Chung, Park, Kim, Cho, & Chung, 2016).

### **2.3.2 Technology at museums**

Most modern-day museums usually incorporate some form of technology into their exhibits. The number of mobile device users across the globe is in the billions and will reach 4.78 billion by 2020 (eMarketer, 2016). What is clear is that many people have integrated technology into their lifestyles, so providing a means of bridging modern-day trends to museum exhibits is crucial to keeping people engaged and interested. New technologies are constantly being created, and museums across the world have already experimented on providing a different experience (Semper, 1990).

A growing technology that some museums have incorporated into their exhibits is AR (augmented reality). Detroit Institute of Arts (2017) was the first to implement AR technology into its museum. Lumin, a mobile application, generates a virtual 3D model of exhibits that is able to produce sounds, videos, photographs, or animations. This technology was incorporated into their public mobile tour to provide visitors with a better understanding of each exhibit.

VR (virtual reality) is another relatively new technology that some museums have decided to adopt (Cigainero, 2018). Like other technologies, VR presents itself with great cognitive benefits that produce better recollection than older methods, such as watching a video (Schöne, Wessels, & Gruber, 2017). The Franklin Institute (2018) has taken advantage of VR by

creating a “real world” experience for its visitors. With this technology, the museum is able to offer visitors a close-up experience of the human body, the solar system, the brain, etc. Rather than using a traditional 3D model, VR enables them to give visitors a seemingly realistic model of exhibits that would otherwise be difficult or impossible to provide. This is a different kind of realism and experience that older museums could not offer.

Some museums have incorporated their technology into their visitor’s smartphones (Pillsbury, Tarr, Gonzalez, Lyons, & Gutwill, 2019). Smartphones have the benefit of being extremely versatile, while retaining the fact that most visitors are already comfortable using them. A mobile application has the potential to provide features such as indoor navigation, assistive technology, multi-language compatibility, and scheduling of visitor programs. In return, museums are often able to gather valuable information about their visitors through their interactions with the application.

The American Museum of Natural History (2018) in New York has developed a means of bridging technology with its exhibits. Their recently released product has taken advantage of the vast number of mobile phone users across the US (Pew Research Center, 2018). The product they released was Explorer. One of the many features designed into this mobile application is the ability to guide and inform users about the exhibits throughout the museum (American Museum of Natural History, 2018). The application was developed to allow visitors to be both intentional, letting them say “point me to this,” as well as serendipitous, providing information as the visitors wander. For this particular museum, the curators decided to incorporate mobile technology to engage and educate their visitors, as well as increase visitors’ overall satisfaction with their experience at the museum.

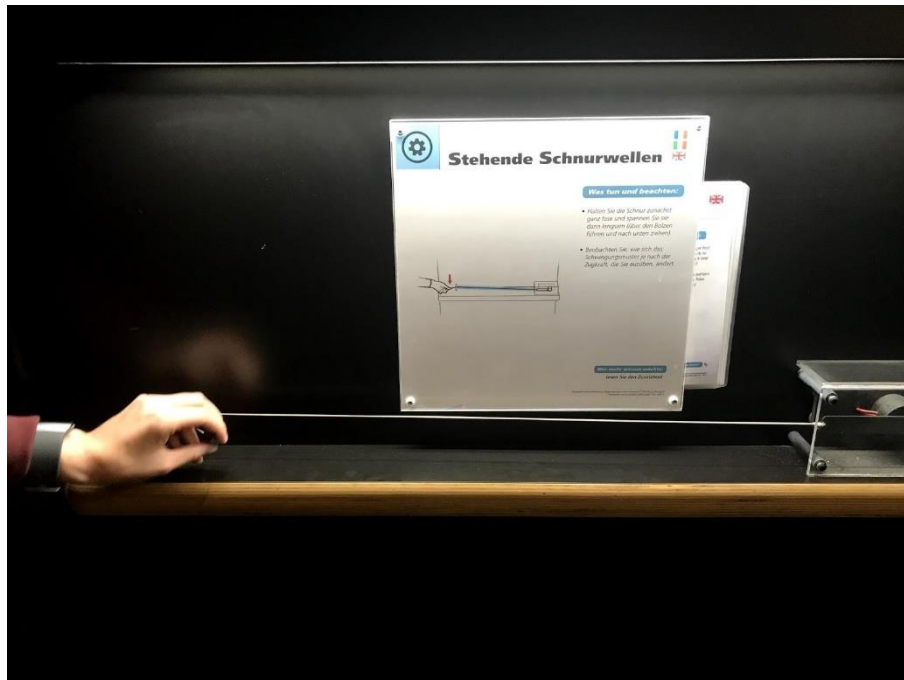
## **2.4 Education in Switzerland**

Students in the Zurich Canton (2017a) start learning basic physics in secondary school, before which they learned only broadly about the concepts of nature, people, and society. Their lessons have the purpose of letting students investigate mechanical and electrical phenomena (Canton of Zurich, 2017b). When studying forces, they learn about the magnitude and direction of forces, as well as being able to draw force diagrams to represent them. Their curriculum covers topics such as learning that the force of gravity is directly proportional to the mass of an

object, and that using ramps or other machines to reduce the amount of force required to move an object (this is called the golden rule of mechanics). When students learn about electricity, their curriculum includes the different effects of electrical currents as well as defining current, voltage, and resistance to understand Ohm's law. A typical physics class will introduce the students to series/parallel connection, nodes and mesh currents, and the functions of electrical motors and generators.

## 2.5 Learning at Technorama

Technorama uses a unique hands-on approach to engage visitors in learning about science (Swiss Science Center Technorama, 2019b). Technorama refers to this approach as “constructivist learning,” which is the concept of learners discovering information for themselves instead of having it simply told to them. All the exhibitions at Technorama use this approach to enable visitors to learn on their own terms, making it easier to take in all the new information. This results in a very hands-on approach where exhibits are designed with the intention of being touched and played with.



*Figure 2.1 Interaction with Vibrating Strings Exhibit*

The “constructivist learning” approach has many benefits when it comes to teaching visitors (Swiss Science Center Technorama, 2019b). With this method of learning, visitors will never just observe and watch science experiments unfold. Instead, they will be a part of the experiment, coming up with a hypothesis and ideas about what could happen themselves. Visitors will then test these ideas, which will grant them a better understanding of the science at work and further their learning. In order for this to be successful, Technorama must create exhibits that have reproducible phenomena so that all visitors have the same chance to learn. Technorama breaks down their “constructivist learning” approach into four different categories: experience of self-efficacy, experience of contemplation, experience of transfer effects, and experience of a research-oriented mindset.

The experience of self-efficacy means that the design of exhibits at Technorama is so that an individual visitor can complete the experiments on their own (Swiss Science Center Technorama, 2019b). The exhibits must not be too complex or the visitor will experience frustration, but not too simple so that learning can still occur. The exhibits strike a balance between these two levels of difficulty to give the visitors an experience where they feel like they have achieved something by being challenged. It is through this challenge that the visitors will learn and build self-confidence by trying to work through a problem.

The experience of self-efficacy means that the exhibits at Technorama must be able to grab visitors’ attention so that they are fully focused (Swiss Science Center Technorama, 2019b). Having the visitors’ attention fully on an experiment allows them to take in more information and be more open to the concept of learning something new. If the visitors’ attention goes away from the experience, say they are constantly checking their cell phone instead, they are not engaged in the experiment enough to learn anything. An exhibit that is engaging enough should cause the visitors to lose track of time, where they are lost in thought and contemplating the science behind the experiment

The experience of transfer effects is how Technorama strives for its exhibits to need creative problem solving by the visitors to be effective (Swiss Science Center Technorama, 2019b). The need for visitors to really think through problems and “go outside the box” to find solutions inspires learning because it forces the visitors to approach the problem from many different angles. This means visitors will not always succeed and will experience trial and error.

This is to teach them that mistakes are not something negative, but that they are great learning experiences.

The experience of self-efficacy means that while many people visiting Technorama do not have a background in science, the exhibits at Technorama aim to introduce the concepts of the scientific method to them (Swiss Science Center Technorama, 2019b). The exhibits aim to guide visitors through the scientific method by having them make a hypothesis and then test it. The exhibits also teach visitors that most of the time an experiment will not yield the expected or correct results, and that should not frustrate them because an experiment could take many tries before it gets conclusive results.

## **2.6 Education and STEM Learning at Technorama**

Technorama uses more than just standard exhibits to teach visitors about science (Swiss Science Center Technorama, 2019g). Technorama uses over 500 unique, interactive exhibits, all of which act as experiment stations. In addition to this, Technorama offers four live demonstrations to show visitors larger concepts than can be done in an exhibit. Labs and workshops allow visitors to go more in-depth with experiments and with more time to do them.

### **2.6.1 Workshops and OpenLabs for hands-on learning**

Technorama offers a wide range of labs and workshops geared towards introducing visitors to more in-depth concepts about biology, chemistry, and physics (Swiss Science Center Technorama, 2019a). These labs focus on a single experiment to ensure the visitor has a deeper understanding. These labs give visitors a hands-on experience using professional laboratory equipment to which they typically would not have access to. Learning in such a formal laboratory environment inspires confidence in visitors and makes it more exciting to learn.

Technorama has different types of labs based on the needs of the visitor (Swiss Science Center Technorama, 2019a). Public workshops are about 45 minutes long and are held at specific times. These can also be booked privately for groups and school trips. OpenLabs are more independent and are done without formal instruction, only requiring a brief introduction.



### 2.6.2 Live demonstrations

Technorama offers four live demonstrations that showcase scientific concepts in a larger and more theatrical way (Swiss Science Center Technorama, 2019d). These demonstrations are exciting and are meant to leave a lasting impression on the visitor's mind. While they are meant to be very exciting, they do also teach concepts of science. One example of this is the Lightning Arena demonstration where a large and loud electrical show is conducted. In this show, concepts about electricity are explained and then an experiment is done to prove or disprove concepts the audience just learned about.



*Figure 2.2. Live Demonstration: Natural History of a Lightning Flash*

### 2.6.3 Exhibition halls

Technorama's interactive exhibits are arranged across its space and floors into different sectors (Swiss Science Center Technorama, 2019c). Each sector contains exhibits that have a similar theme, such as mechanics or electricity. This allows for a natural flow between

experiment stations with each building off the knowledge of the previous one. Each of these experiment stations is designed to be interacted with.

A station that demonstrates these concepts is the “Gravity Model” (Swiss Science Center Technorama, 2019e). This is a simple exhibit demonstrating the effects of gravity. In this exhibit, a steel ball is released in a straight path before entering a large funnel. The steel ball then spirals towards the hole in the center of the funnel, accelerating as it approaches it. This exhibit is surrounded by others demonstrating similar concepts, and the interactive nature of the station allows visitors to place the steel balls into the funnel themselves. This allows visitors to play with the speeds and other factors that may change the outcome of the experiment from which they will learn more about gravity.

The problem with the current exhibits can also be demonstrated in the exhibit “Gravity Model” (Swiss Science Center Technorama, 2019e). Visitors may simply play with the exhibit, not absorbing the information that Technorama wants them to gain (Dr. Armin Duff & Stefan Tosch, personal communication, April 1, 2019). Visitors might have a fun time rolling the steel balls into the funnel, but not learn the significance of the science at work. There is currently no way to evaluate the educational value of the exhibits in a way that feels natural and enjoyable at Technorama. Mobile technology is a potential solution to this issue. In the next chapter, we explain how we carried out research to determine the best ways to evaluate and improve real learning in Technorama’s exhibits through the use of mobile technologies and other approaches.

## Chapter 3. Methodology

The goal of this project was to supply the Swiss Science Center Technorama with a way to guide visitors through their museum, resulting in a more in-depth understanding of the concepts in a limited number of the exhibits. We were able to achieve this goal by achieving the following measurable objectives:

- **Objective 1:** Determine the effectiveness of the current exhibits at Technorama in teaching scientific concepts.
- **Objective 2:** Identify ways to focus students' learning on a limited number of related exhibits so that they develop a more in-depth understanding of the concepts presented.
- **Objective 3:** Determine the best way to guide students through the exhibits to maximize learning.
- **Objective 4:** Determine the educational value of the method we proposed to guide students through Technorama.

This chapter describes the methods we used to accomplish these objectives.

### 3.1 Objective 1: Effectiveness of Current Technorama exhibits

The first step to carrying out this project was to determine the effectiveness of Technorama's current exhibits, especially how the exhibits present scientific concepts. Determining the effectiveness of the exhibits provided information on why visitors at Technorama may not be receiving the desired in-depth understanding of the scientific concepts being presented. Before our team performed any research with student visitors, we walked through Technorama to observe any problems that we could see with the exhibits. This gave us a sense of how students often flowed through the museum. Once our team identified specific problems within the exhibits, we began collecting data with observations and a student survey.

#### 3.1.1 Observations of school groups

Our on-site liaison, Stefan Tosch, reached out to three different schools that were sending students to visit Technorama during the time our team was present; the targeted age group was students aged 14 to 16. He informed these visiting school groups who we were and what our project was about and then asked them if they would like to participate in our study. Stefan

Tosch advised the teachers that their students would need to speak English in order to communicate with us. If the teachers were interested in assisting in our project, we briefly spoke to them about who we were and the purpose of our project once they had arrived at Technorama. We then presented the teacher with the permission slip (see Appendix B) and spoke to them about the liabilities and risks involved in the project. The teacher could then choose to sign the permission slip, granting our team consent to speak to the students in regard to the project.

During the time the visiting students walked around Technorama, our team used direct observation of student behavior. We chose to wait about 15 minutes for student groups to disperse naturally before we began observing in pairs, one of us to observe and the other to record our observations. The main focus of these observations was to see the engagement level of students and if they used both sides of the information card provided at each exhibit to improve their understanding of the concepts presented to them. While the student survey provided information on the students' own experiences, our observations allowed us to see how the exhibits and students interacted with one another. It also allowed us to compare some of the data from the student survey with what we observed. For example, we timed how long some students stayed at an exhibit, which we compared to the students' responses on the survey. When designing our guide, this was vital in helping us identify ways to interest the students. A total of 20 group observations were completed for this report. For observation guidelines, protocols and the student survey refer to Appendices F and C.

### **3.1.2 Student surveys**

After the students had gone through Technorama, provided that the permission slip (see Appendix B) was signed, our team distributed the survey questionnaires. Questionnaires were distributed on paper and on Samsung tablets using a Google Form. The paper questionnaires' responses were later manually entered into Google Forms. Some of the questions asked were: did you learn anything new at Technorama, how much time do you think you spent on most exhibits, and did you think that Technorama was well suited for your age? Their answers were used by our group to understand the effectiveness of the exhibits and how to improve understanding of the concepts that were presented. A total of 59 students completed the survey for this report. For the student survey and protocols refer to Appendix C.

### **3.2 Objective 2: Identify Ways to Focus Students' Learning**

To achieve our second objective, we focused on interviews with museum staff at Technorama. We conducted semi-structured interviews with nine staff members from the Visitor Services Department and the Exhibition and Didactics Department at Technorama. Staff members from Visitor Services work to answer visitors' questions and show them how to approach exhibits. Staff members from the Exhibition and Didactics Department create exhibits and are involved in the writing of the informational cards that are at each station. These informational cards describe what to do at the exhibit on one side and provide an explanation on the other side.

Since these departments only have a few members each, we interviewed individuals who were available during the time frame of our research. We located Technorama staff members and requested an interview if they were from the appropriate department; the interviews were done on the spot. However, some members, specifically from Exhibition and Didactics, asked us to meet them at a specific time. By targeting two different departments, this allowed us to ask a more diverse set of questions in order to obtain more information relevant to the project.

Most of the questions we asked members of the Exhibition and Didactics staff were about the cards that are written to explain what to do at an exhibit and the science behind each exhibit. From the staff members in the Exhibition and Didactics Department, we gathered information on the background of the information cards and what the thought process was for creating an exhibit. A total of three Exhibition and Didactics Department staff members were interviewed (see Appendix D). From the staff members in the Visitor Services Department, we gathered information on visitor feedback, which we used to determine which exhibits have been the most popular and most frequented. A total of six Visitor Services Department staff members were interviewed (see Appendix E).

We analyzed the data from the interviews for common themes and concerns. The results can be found in Appendices G and H.

### **3.3 Objective 3: Determine the Best Way to Guide Students**

After conducting student observations and surveys, as well as various interviews, we were able to think about the best way to guide visitors through Technorama. We decided to

create a scavenger hunt since such an activity was proven to be effective in providing a better learning experience for students (see Section 2.2). This scavenger hunt was intended to lead visitors through selected Technorama exhibits covering related scientific topics and promote a deeper understanding of the concepts presented. This would be achieved by asking each participant to answer a series of questions at each exhibit. By analyzing the data obtained for Objectives 1 and 2, we were able to better understand why students were not fully grasping the physics concepts being displayed and which limited number of exhibits to focus on. This allowed us to better formulate the questions for our prototype. However, before students could test out the prototype, teachers were given a permission slip, as described in Section 3.1.2. This allowed their students to participate in both the prototype and the feedback survey at the end (see Appendix O).

### **3.3.1 Identifying exhibits**

Our team identified exhibits for the scavenger hunt based on certain criteria. The first criterion for exhibits were that they must be focused on interactive learning. This is because our previous research (see Section 2.3.1) found that interactive learning effectively sparks interest and leaves a long-lasting impact (Allen, 2004). Another important criterion was based on the data we received from Objectives 1 and 2. Objective 1 provided information on which sectors students found difficult to learn from and could improve greatly addition of a guide. The staff interviews from Objective 2 allowed our team to better understand which exhibits, or sectors, visitors found the least interesting and which they found most enjoyable. These criteria helped our team to specifically target exhibits that could effectively work with our scavenger hunt. Refer to Appendix J for a map of the sector identifying the appropriate exhibits.

### **3.3.2 Formation of questions**

To come up with the questions presented for each exhibit along the path of the scavenger hunt, we started by looking at the current informational card for that exhibit. These cards gave us an idea of the concepts Technorama was looking to inform visitors about. The interviews we did with the three Exhibition and Didactics members were also important since they provided much needed background information on the cards. We then created the content for the scavenger hunt

that would educate the student about that specific exhibit. Working with Technorama Staff, we determined that a series of short questions for the student to answer about the exhibit would push the student to think more critically about the concepts presented, while still being reasonable to implement. Our team worked with WPI's Professor of Physics Blake Currier to determine how to formulate effective and accurate physics questions for students. We also worked with Technorama's Stefan Tosch to translate the English version of the questions to German.

### **3.3.3 Formation of a guide**

Our team consulted with Technorama staff to understand a possible format to present our guide to student visitors, deciding on a scavenger hunt. After the development of a prototype version of the scavenger hunt, our team asked if the students could try completing the scavenger hunt with their mobile devices or a Samsung tablet that we provided to them. Additionally, this allowed us to collect feedback electronically. This type of feedback drove iterative development and allowed us to continually improve our scavenger hunt as data was collected. After several iterations, we were able to create the most effective scavenger hunt for the student visitors of Technorama. A total of seven different school groups were tested for the prototype.

## **3.4 Objective 4: Determine the Effectiveness of the Proposed Methods**

Once we chose to guide students through the museum with a scavenger hunt and tested the implementation of it, we determined if it was effective or not. To do this, Stefan Tosch contacted three groups of students, as had been done to achieve Objective 1, as well as the permission slip process described in Section 3.3. We also used direct observation as students from these groups went through the museum. We then gave them a post-visit questionnaire at the end of the scavenger hunt. The data we collected from the post-visit questionnaires were compared with the students who did not use the scavenger hunt but had also gone through the museum visiting the same exhibits. Students of both groups usually worked in groups of three to four.

### **3.4.1 Testing the scavenger hunt with students**

After the students completed the scavenger hunt, the students were given a questionnaire on Google Forms using a Samsung tablet at the final exhibit in the scavenger hunt. The format of the questionnaire and the questions asked were similar to the student survey from Section 3.1.1. The answers to the questions on how long students felt they spent at each exhibit were compared to the answers from the same question on the original student survey. On the same questionnaire, students were given questions that tied in with the conceptual aspect of each of the four exhibits. The data from the conceptual questions were compared between the results from two different student groups: those who used the scavenger hunt and those who did not. The ones who did not use the scavenger hunt were given a simple map, which identified the appropriate exhibits to go to (see Appendix J). They were allowed to flow through those specific exhibits without being required to answer any questions, in contrast to the scavenger hunt model. They were required to take a paper version of the questionnaire after they finished, excluding the Student Survey questions (see Appendix N); a German version of the questionnaire was provided to the students.

### **3.4.2 Observations of the proposed method**

In order to assess the effectiveness of the proposed method, we observed students who used the scavenger hunt path and those who used the simple map. The observations that our team made were based on the usage of the information cards, and how long the user used the app/simple map at each exhibit. The observation criteria are the same as the ones from Objective 1 (see Appendix K and L).

## **3.5 Summary of Methodology**

In order to improve student learning at Technorama, we created four objectives to do this. To achieve Objective 1, we focused on using student surveys and observations to understand the relationship between students and exhibits. For Objective 2, we used interviews to understand Technorama from the perspective of the employers and teacher surveys to identify the state of student education for the student visitors. To achieve Objective 3, we focused on the development of the scavenger hunt through iterative prototype testing with visitors. For Objective 4, we tested the final version of our scavenger hunt to see if our method proved



successful in educating student visitors. In the next chapter, we will present the results of our research, which were the basis for the conclusions that we reached after analyzing these results.

## **Chapter 4. Results and Analysis**

The purpose of our research was to develop a method to guide visitors, specifically students, through Technorama. This guide focused on a few exhibits with unified scientific principles being demonstrated to help them have a better in-depth understanding of these principles. In this chapter, we will present the results of our research for each of our objectives and analyze how these results relate to our goal.

### **4.1 Objective 1: Interaction Between Technorama and Students**

The information we obtained to achieve Objective 1 offered insights on the student-Technorama dynamic: for example, the student engagement level and the effectiveness of information cards. In this section, we discuss our discoveries about the ways that students interact with exhibits at Technorama.

Our team discovered that Technorama has a range of exhibits: some exhibits instantly attract the attention of students, other exhibits lack that attraction. For example, Figure 4.1 shows an exhibit that would be very attractive to student visitors because it shows something that most people do not see every day, making it more appealing to its audience. Meanwhile, Figure 4.2 shows an exhibit that does not possess that same attraction power because it looks too plain. In addition, it requires much more work from the user to observe the phenomenon, which deters students from spending time there. The concept presented in this exhibit is not uninteresting in principle, but its presentation prevents it from garnering the attention of its audience the way the very visible phenomenon shown in exhibit in Figure 4.1 does.



*Figure 4.1. Tornado Exhibit*

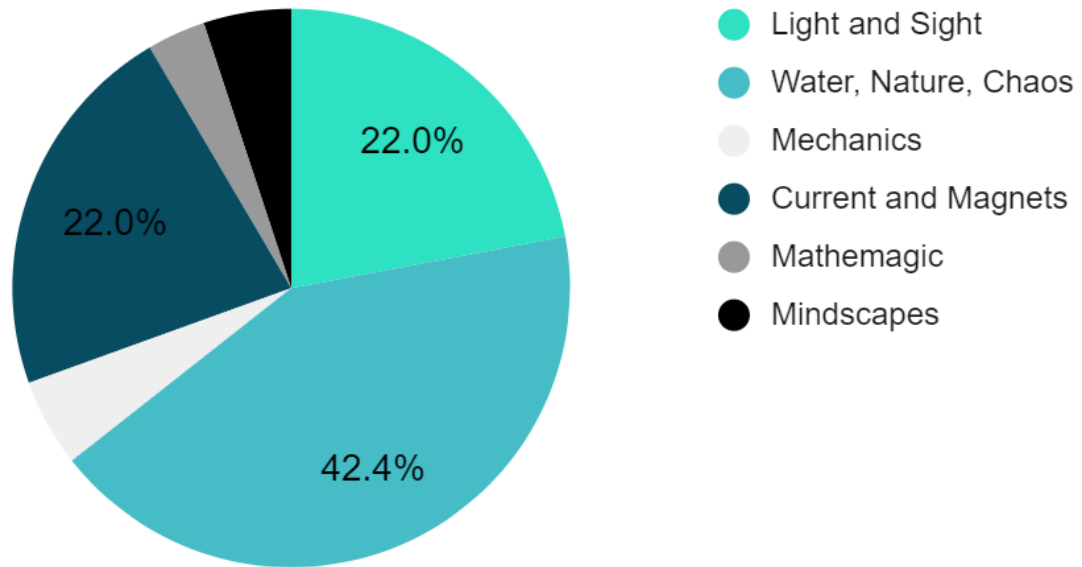


*Figure 4.2. Magnetische Kopplung*

We found that having different kinds of exhibits resulted in a large popularity difference between not only the exhibits themselves, but the entire sector they are in. The Water, Nature, Chaos sector at Technorama, contains many visually appealing exhibits similar to Figure 4.1. 42.4% of students who took our survey (see Figure 4.3) identified that sector to be the most fun, the highest percentage for any sector of Technorama.

## Which sector did you find most fun?

59 Responses

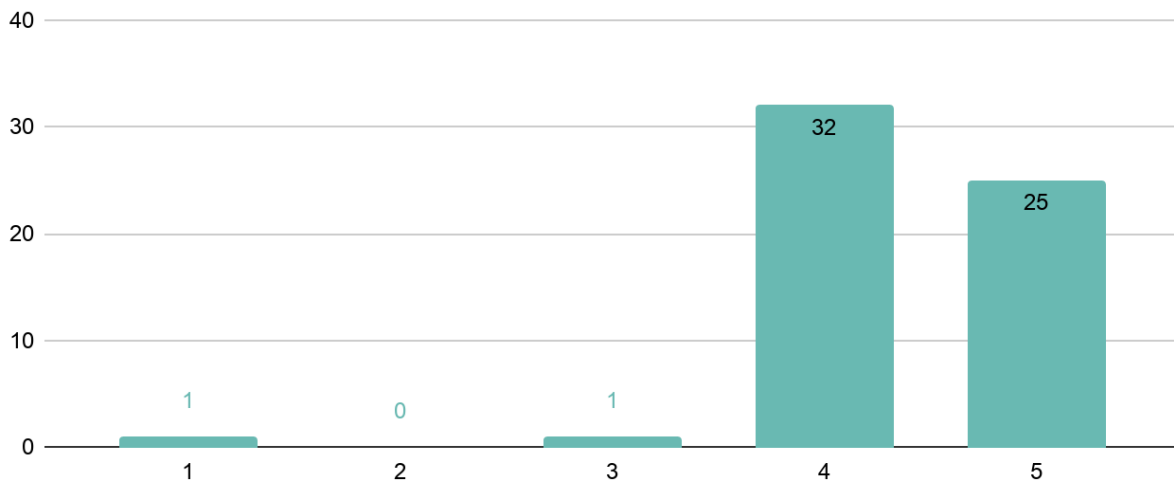


*Figure 4.3. Percent of students who found a specific sector the most fun*

However, some of the other sectors, like the Current and Magnets sector (Figure 4.2 is an exhibit from that sector), contain exhibits that are less flamboyant and seemingly less enjoyable than the sector students found most fun. Nonetheless, Technorama was considered to be quite enjoyable to students overall (see Figure 4.4). Data from the student survey found that most students had fun.

## Please rate your experience at Technorama so far:

59 Responses (1 - Terrible, 5 - Amazing)



*Figure 4.4. Number of Students with a Positive Experience*

While we managed to assess the engagement levels at Technorama's exhibits, the main issue that we needed to identify was the gap between student engagement and the amount that the student learned. For a learning opportunity to be fully successful, it is important that it must be fun to experience (see Section 2.1), which Technorama's exhibits do achieve, but it must also be capable of educating visitors. As a learning resource, each of these exhibits at Technorama possesses an information card that provides the conceptual knowledge of a phenomenon being displayed. We found that Technorama's exhibits attract the attention of its student visitors, but the data we collected suggested that students were not obtaining the full educational experience, as 57.6% of students reported they infrequently or never used the informational cards provided.

This is supported by our observations of students' interactions with the exhibits, of which 70% of interactions were of groups of students who did not look at the informational card at all (see Figure 4.6).

## Did you use the information located on the back of the cards to further your understanding?

59 Responses (1 - Never, 5 - Frequently)

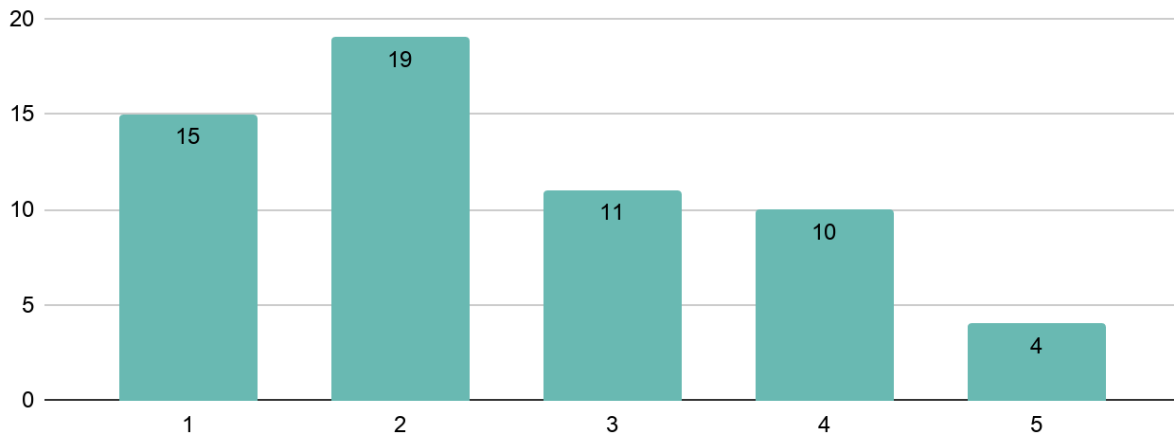


Figure 4.5. The Number of Students Who Used Both Sides of the Information Card

## Did the student look at the information card?

20 Responses (1 - Student did not look at card, 5 - Student is fully engaged with card and exhibit)

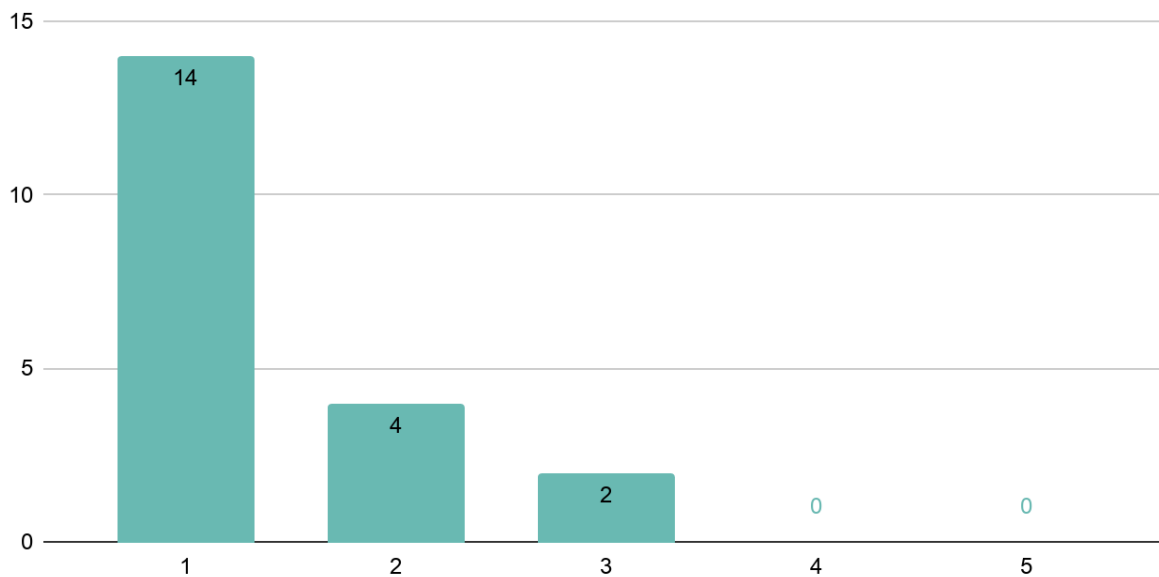




Figure 4.6. Observed Student Interaction with Information Cards

When we observed the students, there were a few who looked at the information cards. However, the few who did quickly lost interest and returned them to their holding place.

Similarly to the range of appeal of the exhibits at Technorama, we found that there is a range in the quality of the information cards. Some information cards provide a simple text (see Figure 4.7), while others are lengthier and more difficult to grasp (see Figure 4.8); we had a difficult time understanding some of the information cards as well. The fact that the information cards are an unpredictable source of educational material can contribute to the fact that students do not look to the cards for further explanations, decreasing their learning experience at Technorama.

 **Resonant Rods** 

Rods can wiggle in crazy ways...

**Want to know more?**


At certain frequencies the movement of the table is at the same natural frequency of a rod and it moves with the table. We say it is **in resonance** with the table.

This shaking occurs when even small movements occur at the right time, the continuous input of energy builds up standing waves in the rod.

In other words; due to resonance, the amplitude or size of waves in an object (the rod) can be much greater than the actual energy input given by the exciter, (the table).

Examples of forced resonance vibrations:

- The vibration of a car at certain speeds (motor rpm).
- The high swinging of a child on a swing.
- The way a glass breaks at a certain tone.
- Buildings damaged by earthquakes.

**To do and notice:** 

Concept and Realisation: Exploratorium San Francisco („Resonator“)  
\*Stäbe in Resonanz\_DEFI.indd“, Nr. 10407

*Figure 4.7. Simple Information Card: Resonant Rods*





# Efron's Dice

Second always wins!

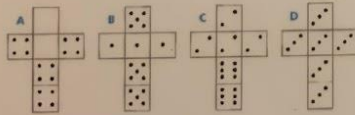


### Want to know more?

This set of four dice (A,B,C,D) has the property that for any one of them, there is another one which is likely to beat it on any throw, with a probability of 2/3. Provided the player who chooses second knows which one to choose, they will probably win (with probability 2:1). It is unusual to have a set of things with a "non-transitive" property. Normally we expect a transitive relationship like "if Peter is better than John, and John is better than Mark, then Paul is better than Mark" to be valid. This isn't the case with these dice!

There is another non-transitive relation between the objects in the well known "rock-paper-scissors" game, in which every symbol wins against another and loses against another.

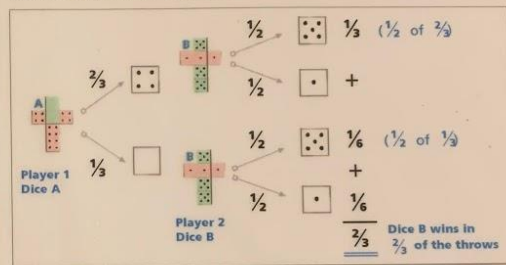
The example here (Efron's dice) shows that the relationship "has a greater probability of being greater" for random variables need not be transitive.



To illustrate the way in which the increased probability in the Efron Dice game arises, it is worth working through the "probability tree" for a pair of dice.

Suppose the first player chooses dice A (two sides with 0, four sides with a 4), then the second player should choose dice B (three sides with 1, three with 5).

The tree diagram looks like this:



In the probability tree, the outcome of any throw is at the end of a branch (arrow), the probability of that outcome is shown alongside the branch.

Dice A has a 2/3 chance of throwing a 4, and a 1/3 chance of throwing a zero (player A thinks he is on a winner!). Player B has an equal probability (1/2) of throwing a 1 or a 5.

On the right of the diagram you can see the probabilities that B will have the winning throw in each of the cases of A's throw. Notice that following a branch to the end, the probabilities of that outcome are multiplied (shown in brackets).

You then add up the probabilities of each of the outcomes where B wins, and you get 2/3, which is a 2:1 likelihood that B will win, provided that the number of throws is quite large (Jacob Bernoulli's Law of Large Numbers).

Efron's Dice have the property: B beats A, C beats B, D beats C and A beats D, so the player who chooses second should always win.

**To do and notice:** ↗

Idea and Concept: Mathematikum Giessen / Realisation: Technorama "Efronsche Würfel\_DEFI.indd", Nr. 10098

Figure 4.8. Complex Information Card: Efron's Dice

Upon inspection, most people can tell that the lengthier information cards belong to exhibits that try to explain a complicated phenomenon. For students, however, reading a long and confusing text that they cannot understand deters them from learning about an exhibit.

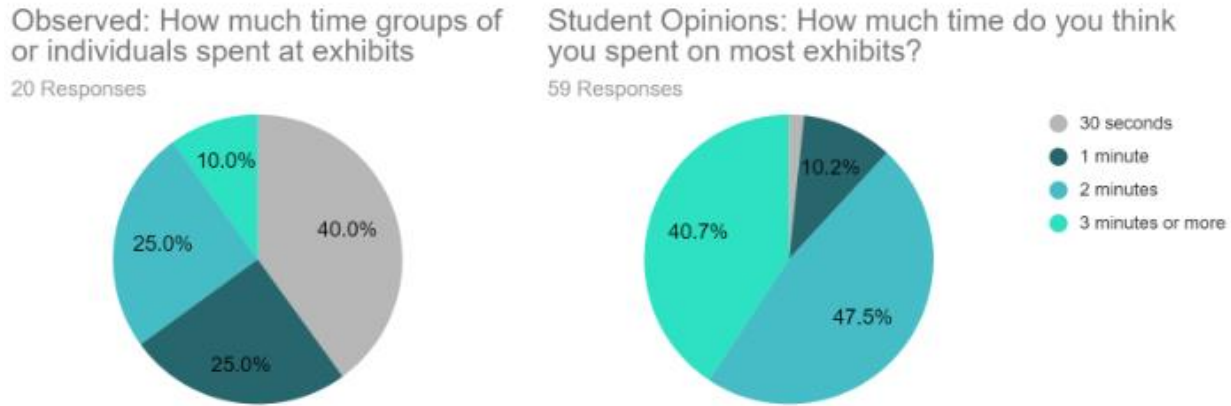


Figure 4.9. Time Spent at Exhibits: Student Opinions vs Observed Time

We also observed that students did not spend much time at an exhibit. Most students were quick to jump from one exhibit to the next, as Technorama staff had observed previously. It seemed like most of the students were not eager to explore the concepts presented beyond simply observing the phenomenon. When analyzing the time it took for students to move on from one exhibit to the next, we found that most students spent little time at each exhibit, as opposed to the data collected from the students themselves on the survey. When we timed the students, we found that most students spend about 30 seconds at each exhibit, however, they believed that they had spent two or more minutes instead.

**Key Finding:** Technorama possesses a vast number of exhibits. While there are distinctions between all of them (e.g. appearance, quality, and concept), they all possess the same purpose, to educate students on a particular physics concept. However, students are not very interested in learning these concepts when going through Technorama. Even though students have an enjoyable time, Technorama also believes it is important that they receive an educational experience as well.

## **4.2 Objective 2: Focusing Students' Learning**

From our team's interviews with the Exhibition and Didactics Department, we found that the information cards at the exhibits have been used at Technorama for a long time, but they are always being updated for a better learning experience. The newer cards have less text, but explanations are presented in the same way: the phenomenon is mentioned first, then the science behind the exhibit, and finally a connection to everyday life. Members of the Exhibition and Didactics Department are aware that these cards do not work for everyone, and although an increase in the conceptual understanding of exhibits because of the cards has never been tested, staff members still see the cards as very helpful for some of the exhibits. Refer to Appendix G for the answers to each question we asked the Exhibition and Didactics Department and Appendix H for the answers to each question we asked the Visitor Services Department.

Staff members from the Visitor Services Department work on the museum floor and saw things differently. Visitor Service staff noted that it is unlikely visitors deeply understand the topics being presented to them because most do not read the informational cards, or if they do, they do not read the back, which explains the scientific concept of that exhibit. This is especially true with younger visitors, while adults are more likely to look at the informational cards, children rarely do. Furthering this, Visitor Services staff noted it is very rare that visitors ask for assistance in understanding the exhibits and rarely ask questions about the science of the phenomena.

*Table 4.1. The exhibits most people frequent according to Visitor Services*

Name of Exhibit	Number of Votes
Rocking drawing board	1
Cloud rings	1
Tornado	1
Colored shadow	1
Frozen shadow	1
Plasma exhibits	1
Turntable	2
Rotating tunnel	2
Giant pin screen	2

Both departments had similar opinions on what makes a popular exhibit. The Exhibition and Didactics Department stated that exhibits that are very flashy attract the most attention and that they should be heavily interactive, allowing visitors to use their hands and think about the phenomenon immediately after arriving at each exhibit. If the phenomenon takes too long to appear, the visitor may get bored and move on to the next one. This lines up with the response from Visitor Services, which stated that the most frequented exhibits are large enough so that visitors can see them from far away, and they also allow multiple visitors to experience the phenomena at the same time. The examples of the most frequented exhibits they chose represent this (see Table 4.1). The most common answers for which exhibits members of the Visitor Services Department see visitors frequent were the table with rotating objects in the Mechanics sector, the rotating turntable in Mindscapes, and the giant pin screen in the Light and Sight sector. In addition to this, staff members reported many students stated their favorite exhibit was

the rotating tunnel. The answers to this question are shown above in Table 4.1. To support the idea of flashy and interactive exhibits being the most popular or frequented, an example is that visitors can compete against each other on the turntable by knocking others' rotating objects off or seeing whose object will rotate the longest.



*Figure 4.10. Giant Pin Screen Exhibit*

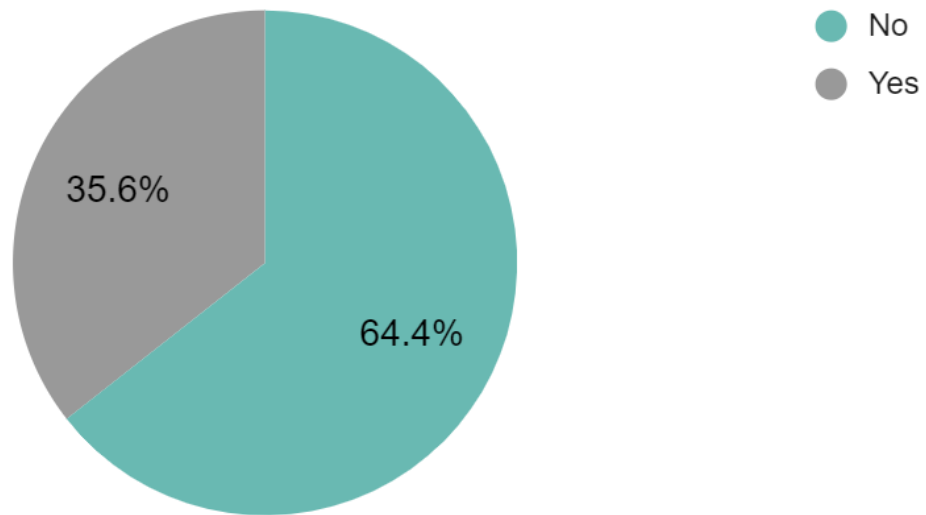
The key finding from this question was that the exhibits visitors tend to frequent the most are large and easy to see, as well as fun, and they do not have to read a lot of text before knowing what to do. Further supporting the answer given by the Exhibition and Didactics department, Visitor Services noted the exhibits that are often neglected are small ones that might be overlooked, especially if they are in a corner. Exhibits where visitors do not see an immediate effect usually do not hold their attention. Visitors Services staff members see that if visitors do not know what to do, they will usually move onto the next exhibit instead of trying to figure it out.

Additionally, when we asked the staff how they saw most visitors flowing through the museum, it was clear that visitors move quickly between the sectors so that they can see all of the museum, not spending enough time at any of the exhibits to think about the phenomena

behind them. This supports data collected from the student surveys. Our student surveys indicated 64.4% of students did not have enough time to see all the exhibits they wanted, so it is likely that students move quickly through the Technorama because they want to see as many of the exhibits as possible (see Figure 4.11).

## Did you have enough time to see all the exhibits you wanted?

59 Responses



*Figure 4.11. Percentage of Students on Whether or Not They Saw Everything They Wanted*

The staff also gave insight into the typical structure of a school trip to Technorama. Some student groups may have a workshop, exhibits, or events their teachers want them to see, but other than that, most students are free to wander around the museum, exploring all the sectors.

When conducting staff interviews, we were discussing possible methods to guide students, with a scavenger hunt being our prevailing idea. We received many good responses when we asked what the staff members thought we should include in the scavenger hunt. One interviewee suggested that the scavenger hunt should include many sectors so that students do not feel like they did not get to explore the entire museum. Another interviewee recommended that it would be useful to students if they could choose a specific path based on how much they want to read, topics that interest them, and the difficulty of the concepts in the scavenger hunt. Another interviewee advised us to ask questions that are more specific to why something

happened, as opposed to what happens if you do this, to get the students to think more. We took this feedback into account when creating the scavenger hunt but could not implement all of it in the time we had. Additionally, our team opted to keep the scavenger hunt in a single sector for the ease of testing and prototyping.

**Key finding:** Visitors are not learning as much from the exhibits as they could. It is very important for visitors to be able to connect an exhibit to their everyday life. If a visitor can relate to what they are seeing, they will be more interested in learning about the science behind the exhibit, which will lead to a more educational experience. We also learned that an educational exhibit should allow visitors to use their hands and think about the phenomenon immediately after arriving at each exhibit. Based on the interview responses from the staff, we also found that the best way to focus visitors' learning is to guide them through the museum by having them only go to a limited number of exhibits so that the students have time to thoroughly explore the phenomenon at each instead of rushing through.

### **4.3 Objective 3: Development of the Scavenger Hunt**

After analyzing the results from Objectives 1 and 2, we decided that the scavenger hunt would be a potentially effective way to guide students through the museum by only focusing on a few exhibits and introducing them to the scientific concepts behind each exhibit. Our team decided that the hunt should not last longer than 30 minutes because the student groups were at Technorama for about three hours and their teachers wanted them to spend more time exploring the museum. We also chose to cover only one sector so that it could be tested easily. Refer to Appendix S for scavenger hunt guidelines and protocol.

#### **4.3.1 Choosing the exhibits and creating the questions**

From our interviews with members from the Exhibition and Didactics Department, we learned that students should be able to relate to exhibits for them to be educational (see Appendix G). After finding this out, we decided to focus on the Mechanics sector, as the exhibits there cover the basic physics principles they learn in school (see Section 2.4). This would allow them to visualize what they learn about in school, creating a more educational visit. We chose four

exhibits for the scavenger hunt with the intention of students spending around five minutes at each exhibit for a total of 20 minutes. All of those chosen exhibits are from the Mechanics sector, as staff interviews indicated that this would be a useful section to focus on and students of the 14 to 16 age range are first introduced to mechanics principles in school at that age. In addition, mechanics principles are often easily related to events in the physical world that the students observe each day. The exhibits we chose are shown in Table 4.2.

*Table 4.2. Identified Exhibits and the Reasoning*

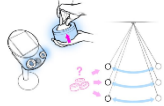
<b>Exhibits</b>	<b>Reasoning</b>
Pendulum's Cradle	The phenomenon behind this exhibit are momentum and conservation of energy, physics principles that many students study in secondary school.
Vibrating Strings	This exhibit is an example of standing waves; students can easily see nodes and antinodes.
Bike Wheel Gyroscope	This exhibit is a great example of magnitude and direction of forces, which is one of the first things students in the canton of Zurich learn about in their physics class.
Triple Pendulum	This exhibit can help students visualize that the force of gravity is directly proportional to the mass of an object.

Each exhibit was accompanied by three questions crafted in a specific sequence. The specific questions and rationales we developed for the Triple Pendulum exhibit are shown in Table 4.3, with the correct answer for each question highlighted. See Appendix R for the full listing of the questions asked at each exhibit in our scavenger hunt. The first question at each exhibit simply asked the student to look closely and observe the phenomenon showcased at the specific exhibit. The second question then asked the student to change the way they interact with the exhibit and observe the following change in what they observe. This question prompts the student to think more deeply about the reasoning behind what they observe, rather than just superficially watching. Lastly, we asked the student a question that related the phenomenon



observed to everyday life. The goal of this question was to solidify the link between the concepts seen isolated at Technorama and the world the student interacts with each day.

*Table 4.3. Scavenger Hunt Content Sample*

Exhibit	Triple Pendulum (Drei-Zeiten-Pendel) - Mechanics
Question 1	The three pendulums all have the same mass. What happens when you swing all three pendulums?
Answers	<ol style="list-style-type: none"> <li>1. They swing at the same speed</li> <li>2. The shorter pendulums take less time to swing</li> <li>3. The longer pendulums take less time to swing</li> </ol>
Reasoning	That's right! Since the pendulums are all different lengths, it takes different amounts of time for them to swing. The shorter the length of the pendulum, the shorter time it takes to swing!
Question 2	What happens when you add mass to the pendulums? 
Answers	<ol style="list-style-type: none"> <li>1. The oscillation period does not change</li> <li>2. The oscillation period of the swing is faster</li> <li>3. The oscillation period of the swing is slower</li> <li>4. The pendulum swings further</li> </ol>
Reasoning	That's right! Mass does not affect the time it takes for a pendulum to swing. The only thing that changes the time of the swing is the pendulum length and the effect of gravity. On Earth gravity is always the same! To observe how gravity changes the oscillation period, check out <a href="#">Jupiter Pendulum</a> in the Mechanics Sector.
Question 3	Who can swing faster on a swing, an adult or a kid?
Answers	<ol style="list-style-type: none"> <li>1. They swing at the same speed</li> <li>2. The adult swings faster</li> <li>3. The kid swings faster</li> </ol>
Reasoning	That's right! When you are riding a swing on a playground, you are actually riding a pendulum! An adult and a kid would swing at the same speed on a swing because mass does not affect the time it takes to swing just like the three pendulums in the exhibit.

### 4.3.2 Creating the scavenger hunt prototypes

Technorama conveyed to our team that they were looking for a guide that would utilize mobile technology, as previous pen-and-paper approaches had proved cumbersome and inefficient. Therefore, we decided to develop the guide in the form of a website. At each exhibit on the path of the scavenger hunt, there was a QR code that let the student access the related questions and encouraged extended interaction with the exhibit. We chose to use a QR code method because it was the simplest way to correlate a physical location, in this case, the exhibits we chose, with a specific web page. After scanning a code and completing a set of three questions, students then moved onto the next exhibit, and therefore the next set of questions. Figure 4.13 illustrates the general format of each question of the scavenger hunt as seen on a smartphone screen: a helpful graphic followed by an explanation to the previous question, as well as a new challenge/question for the student to answer. The answer choices are all multiple choice and listed below the question.

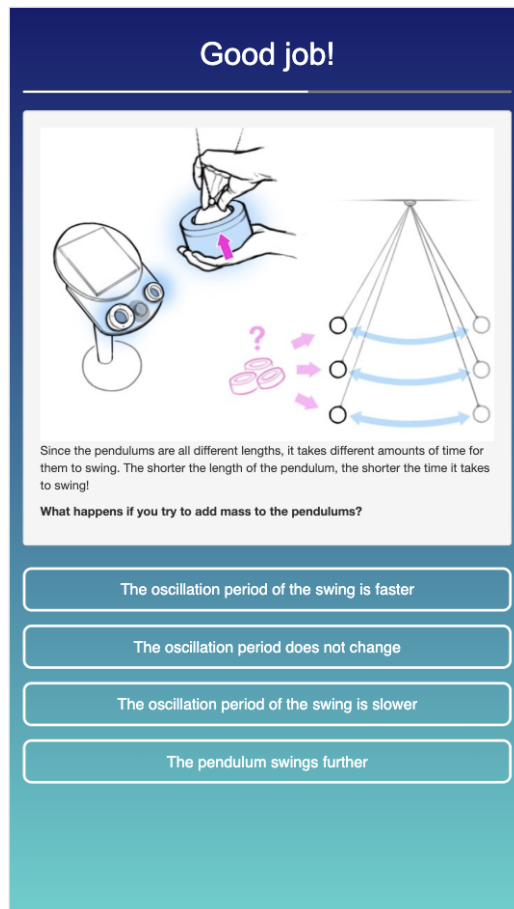


Figure 4.12. Scavenger Hunt Screenshot

The Technorama staff we worked with suggested that most student visitors would not be familiar with the English terminology for many physics concepts, so we decided to create a German version of the scavenger hunt as well. On the “Begin” page of the scavenger hunt, students have the option to choose whether to proceed in English or German.

Our team tested multiple prototypes of the scavenger hunt before testing the final version. The most common feedback that we received on our prototypes were that the QR codes were too visible and that the questions were too simple for students who were older than our target age group (see Figure 4.13 and Table 4.4).

### Were the concepts presented to you suitable for your age group?

18 Responses

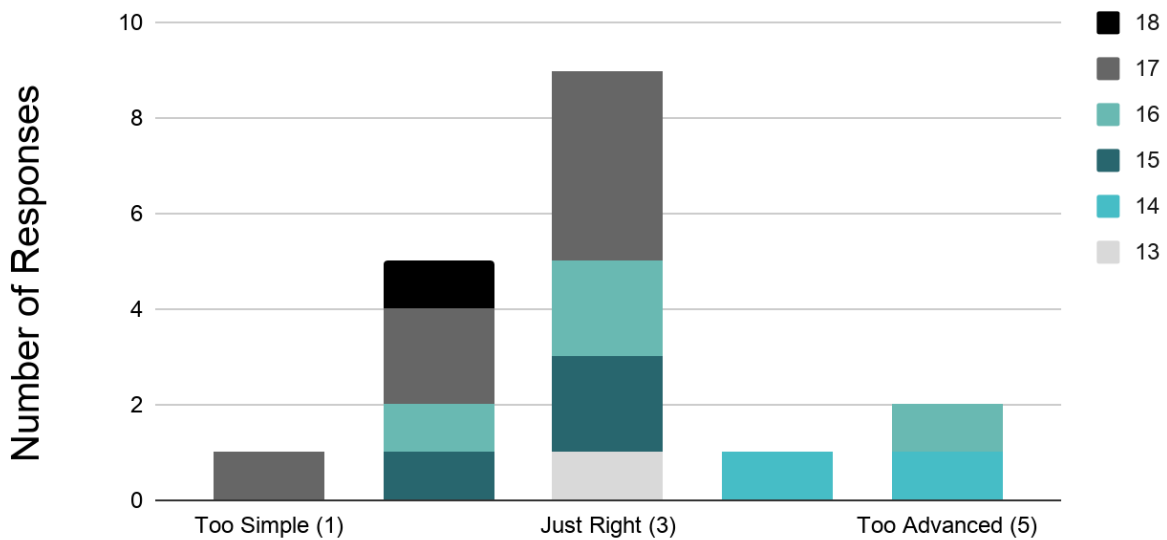


Figure 4.13. Prototype Feedback: Difficulty of Questions

The QR codes being visible was a problem in the first prototype that we fixed for the second prototype by shrinking their size and placing them on the back of the information cards instead of on the exhibits themselves. For each prototype, we tried to adjust the difficulty of the questions so that a larger range of ages could be challenged enough by the questions in the scavenger hunt.

*Table 4.4. Prototype Feedback: Problems and Recommended Improvements*

<b>How can this guide be improved for the future?</b>
Hide more difficult questions and QR code better and more distributed
Several stations, larger and distributed on an age-appropriate difficulty level
Assign the stations to the groups in different order.
Better German translations. Extended with more areas. Integrate Website/QR scanner into an app.

Data gathered through testing the prototype of the scavenger hunt indicated that another major issue was the bottlenecking that occurred (see Table 4.4). As there was only one pre-set pathway for students to complete during the scavenger hunt, exhibits along the path became crowded, making it difficult for the students to interact with the exhibit properly. In order to address this issue, we adjusted the prototype to randomly choose one of four possible routes through the exhibits. This allowed the students to still visit all the exhibits included in the scavenger hunt without causing crowding at any one exhibit. In addition, the multiple pathways enhanced the “hunting” aspect of the scavenger hunt, as the students did not move in one mass from one exhibit to the next.

**Key finding:** By testing three versions of the prototype, we found that our scavenger hunt must contain specific features to make it more appealing and usable to users: variation in exhibit order to avoid bottlenecking and hiding the QR codes to make it less noticeable. While we did receive feedback on our questions, we decided to keep them about the same as our data suggested that they were generally reasonable for the targeted age group.

#### **4.4 Objective 4: The Effectiveness of the Final Product**

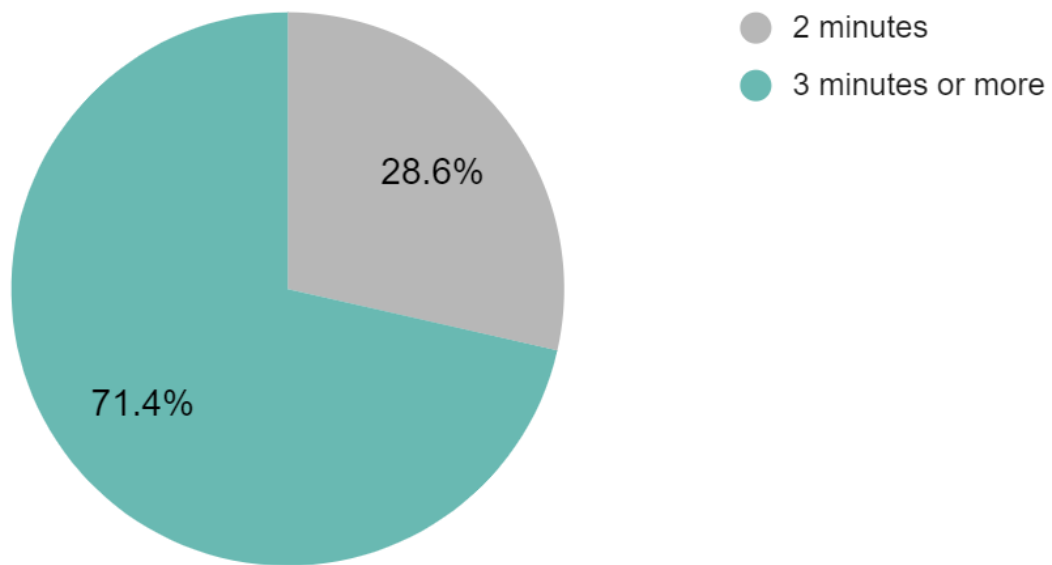
After we created and tested multiple versions of our scavenger hunt prototype, we tested the final product to determine its effectiveness in educating student visitors.

#### 4.4.1 Observing students using the scavenger hunt

We observed students using the final version of the scavenger hunt and identified that our scavenger hunt increased the time students spent at each exhibit. Prior to implementation, 73% of students spent one minute or less at each exhibit (see Figure 4.9). When using the scavenger hunt, however, 71% of students spent three minutes or more (see Figure 4.14). This increase in hold time spent shows that students spent more time interacting with exhibits when they were using the scavenger hunt, which allowed them more time to engage with the concepts demonstrated in a more in-depth way.

### Observed: Time spent using scavenger hunt

7 Responses

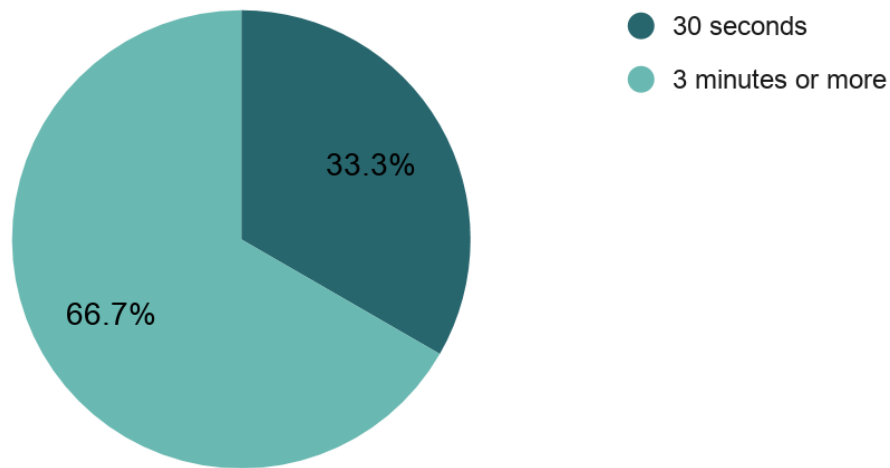


*Figure 4.14. Observed Time at each Exhibit using Scavenger Hunt*

An interesting result that we found was that this increase in time spent was applicable for students who just used the simple map to visit the selected exhibits as well (see Figure 4.15). This indicates that a significant factor in increasing a student's time at each exhibit was just having some sort of structure or guidance in their visit, whether it was the scavenger hunt or the simple map.

## Observed: Time spent using map

3 Responses



*Figure 4.15. Observed Time at each Exhibit using Simple Map*

Another interesting finding we observed was that students tended to naturally take on different collaborative roles as they completed the scavenger hunt. For example, there was usually one person holding the mobile device who directed the students to do the listed challenge. The other students worked together, some interacting with the exhibit, others observing the phenomenon and discussing what was happening with the group. While this was not something we predicted when creating the scavenger hunt, it seemed to be a positive effect of having students complete the scavenger hunt in groups rather than individually.

### **4.4.2 Gathering data from the scavenger hunt webpage**

Using Google Analytics, we were able to track the traffic on each separate webpage of the scavenger hunt. One statistic we were able to gather was the amount of traffic each page specifically got. Since a question and the correlating incorrect screen were separate web pages, we were able to calculate the ratio of views to a question and views to the incorrect screen for that question (see Table 4.5). The number of incorrect answers for Question five is 75%, much higher than the other questions. This outlier is because of a technical error on our part, which caused the correct answer to be listed as incorrect. One limiting factor of this data is that we were not able to discern these results along individual sessions. Therefore, one user going through the

scavenger hunt completely guessing at each question multiple times would add greatly to the number of incorrect page views overall.

*Table 4.5. Ratio of Incorrect Page Views to Question Page Views*

Exhibit	Pendulum's Cradle			Vibrating Strings			Triple Pendulum			Bike Wheel Gyro		
	1	2	3	4	5	6	7	8	9	10	11	12
Incorrect Page Views	25%	16%	42%	37.5%	75%	35%	20%	12.5%	44%	20%	12.5%	33%

We were also able to gather data about the way students used the scavenger hunt through Google Analytics. The average time each page was viewed is indicated in Table 4.6. Students tended to spend the most time at the second question of each exhibit, averaging 40.25 seconds. They spent the least time, only 23 seconds on average, at the last question of each exhibit, which makes sense as this question did not ask them to physically complete a task. These times are notably lower than the time we observed students spending at each exhibit, even factoring in the added two or three seconds that come each time the student answers a question incorrectly. A possible explanation for this is that if a student were to click an incorrect answer quickly, then return to try another answer, this would be recorded as two separate, shorter interactions with the page, rather than showing that the same person tried a question multiple times, significantly lowering the average time spent for that question.

*Table 4.6. Average Minutes Spent per Page in Scavenger Hunt*

Exhibit	Pendulum's Cradle			Vibrating Strings			Triple Pendulum			Bike Wheel Gyro		
	1	2	3	4	5	6	7	8	9	10	11	12
Avg. Time	0:23	0:42	0:44	0:32	0:35	0:25	0:23	0:32	0:10	0:53	0:52	0:13
Total Avg. Time for exhibit	1:49			1:32			1:05			1:58		

### 4.4.3 Analyzing data from post-guide questionnaire

At the end of the scavenger hunt, we linked students to a short questionnaire that asked them to evaluate their experience with this guide. We discovered that 80% of student groups enjoyed using the final version of our scavenger hunt (see Figure 4.16). As the amount of fun a student has while learning is a factor in how effective their learning experience is (see Section 2.1), we can conclude that our scavenger hunt maintained the fun aspect of students' Technorama visits (see Figure 4.4). Technorama was already successful in creating an enjoyable experience for students, so it is a positive result that our scavenger hunt was enjoyable for the students as well.

#### Did you like the use of the learning course?

10 Responses (1 - Not really, 5 - Very much)

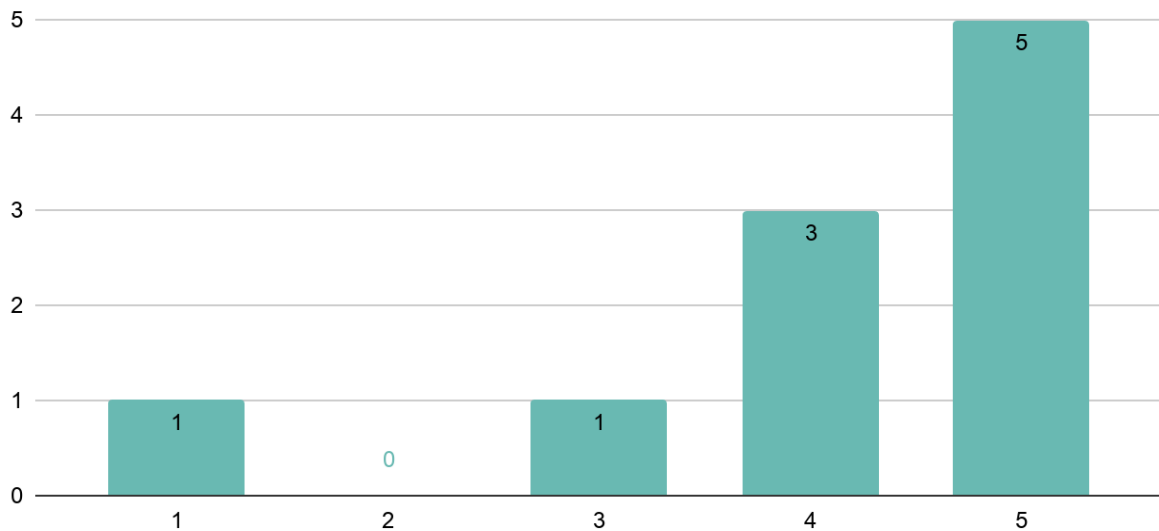


Figure 4.16. Reported Student Enjoyment of Scavenger Hunt

### 4.4.4 Analyzing data from post-guide quiz

At the end of both the scavenger hunt and the use of the simple map, the students were prompted to take a four-question quiz. This quiz was given on paper for users of the simple map and on Google Forms with the post-guide questionnaire for users of the scavenger hunt. The students were all asked the same four questions.

While each question individually differed in correct responses across both guides, overall, they yielded a very close percentage of average correct responses (see Table 4.7).



Questions one and four for both guides yielded similar percentages of correct answers, but the results from questions two and three were drastically different between the guides. In general, students showed a greater understanding of the concepts of standing waves and momentum, relating to the first question about the Vibrating Strings exhibit and the fourth question about the Click-Clack exhibit. Students lacked an understanding about gyroscopic forces, which had the lowest average scores across both guides. Students were divided on the concept of pendulums, with the simple map scoring well and the scavenger hunt scoring poorly.

This may have been the case for a number of reasons. One is the background of the students. Due to the flexibility of the educational curriculum in Switzerland, some students may have lacked the background knowledge that could have assisted them on certain questions. Another factor could have been the complexity of the guides. The map contained few words, just pointing students to certain exhibits to focus on. The scavenger hunt contained large quantities of text that our team had to translate to German from English, leaving a large quantity of room for translation errors. Translation errors could account for lower scores on certain questions for the scavenger hunt because ways of explaining the science in English may not be the same in German.

The outlier from this data is question three for students using the simple map. Out of six groups of students answering this question, no students got the correct answer. After observing students using the exhibit related to this question, the Bike Wheel Gyroscope, our team determined that the most probable reason for this is the lack of understanding of how to set up the exhibit. The scavenger hunt provided supplementary information in the form of text, but the simple map did not. Through our observations, our team noticed that students would look at the information card and attempt to set up the exhibit, but still do so incorrectly. This seemingly led to a misunderstanding of the scientific concept and ultimately the incorrect answer to the question.

Although students only averaged 58.33% correct when using the simple map and 55.56% when using the scavenger hunt, our post-guide questionnaire found that students on average did learn more than they expected to and found the scavenger hunt enjoyable to use. Additionally, with our observations indicating a significantly longer hold time and better engagement with the exhibits, the scavenger hunt did increase the learning experience of the students at Technorama. The similarity of the retention of information between the two guides demonstrates that any

guide, not just a digital one, that focuses visitor attention to fewer, more related exhibits will increase their learning and interaction with the exhibits.

*Table 4.7. Comparing the Results of the Simple Map and Scavenger Hunt*

<b>Guide</b>	<b>Question 1</b>	<b>Question 2</b>	<b>Question 3</b>	<b>Question 4</b>	<b>Average Correct per Question</b>
Simple Map Percentage Correct (6 responses)	83.33%	83.33%	0.00%	66.67%	58.33%
Scavenger Hunt Percentage Correct (10 responses)	77.78%	33.33%	55.56%	55.56%	55.56%

#### **4.5 Limitations of our data collection**

As our collection of data from student groups progressed, we noticed that results tended to be grouped similarly based on the student group that was visiting. Speaking further with Technorama Staff who were familiar with the Swiss School System, we discovered that teachers in Switzerland have much more freedom in the content they teach their students than we had expected. This means that students coming from the same age group may have significantly different backgrounds when it comes to their familiarity with the physics concepts we focused on. In addition, Technorama attracts school groups from neighboring areas such as Germany and Austria, whose background also differs from the Swiss curriculum. The fact that the scavenger hunt we created matched well with the curriculum of some school groups was the largest limitation of our data collection. It is difficult to judge the effectiveness of it against all the data as the tested students have different backgrounds when it comes to physics concepts.

## **Chapter 5. Conclusions and Recommendations**

In this chapter, we present the conclusions we have reached and the recommendations we have for the Swiss Science Center Technorama. Our conclusions are based on the key findings we found from our research. The list of recommendations presented in this chapter is for Technorama staff to continue to improve the guide we have created, as well as general improvements to the exhibits that can be made. After presenting our findings to Technorama, Technorama has decided to use our scavenger hunt in the future. We have provided them with a short guide for making their own edits and expansions to the scavenger hunt (see Appendix T).

### **5.1 Conclusions Based on Key Findings**

- Students want to visit all the exhibits they can in Technorama and/or are not interested in learning scientific concepts. Therefore, the students do not spend enough time at each exhibit to learn as much as they can.

With Technorama containing over 500 different exhibits, our team found through both observations and student surveys that students are overwhelmed by the number of exhibits. While students do enjoy their visit to Technorama, most students feel they do not have the time to see everything. It can be concluded that one of the primary reasons the exhibits do not have a long hold time is because of the pressure of feeling the need to see everything Technorama has to offer.

In addition to this, the students are not as interested in the science behind the exhibits, making their visits less educational than they could be. Staff members from the Visitor Services Department at Technorama rarely see students using the information cards at each exhibit, which was something we also noticed during our student observations. In our interviews with Visitor Services staff members, they explained that if students do not see a phenomenon right away, they will usually move onto the next exhibit. This aligns with our observations that most students spent a minimal amount of time at each exhibit.

- Due to the students rushing through the museum, the students need to focus on a fewer number of hands-on exhibits to allow them to learn the most amount of information possible.

Another finding from both our team's observations and staff interviews was that if the students are presented with fewer exhibits, they will spend more time at each exhibit. As previously stated, the students tended to rush through the museum. Through these findings, our team concluded that the most effective way to focus the student's learning was to have the scavenger hunt guide them through only a select few (four) exhibits centered around a theme. In the case of the scavenger hunt, this theme was the mechanics concepts being taught in school to 14 to 16-year-old students. The results from the scavenger hunt support this, with students spending significantly more time at each of the four exhibits and thoroughly engaging with them in ways they did not before the scavenger hunt's implementation.

We tested the effectiveness of the final scavenger hunt's ability for students to learn by administering a simple quiz to both students who used the prototype as well as other students who were just given a map and told to go to the same four exhibits. Students from both groups scored well on the test, so we concluded that any form of structured guidance, being a map or a scavenger hunt with the intention of sending students to fewer, more closely related exhibits, can improve the conceptual understanding for students on a school trip to Technorama. However, it is clear that a scavenger hunt is more fun and engaging tool based on the positive feedback we received from staff and students alike.

- Since many of the concepts presented at Technorama are outside of what the students may be able to understand, it is important to relate the concepts to their everyday life.

The idea of the students gaining better understanding through being able to relate phenomena to their everyday life was stressed to our team from the very beginning. Through our staff interviews it was found that if students can make the connection between the exhibits and what they experience every day, they will better be able to wrap their heads around the scientific concepts. Our team concluded that our three-question model was to act as a lens that focused on the real-world applications over the course of the three questions. With the first question acting as a simple question about observation, it gives the students the quick satisfaction of having answered a question. The second question expands upon this, asking them to figure out why this phenomenon they had observed occurred. The third question demonstrates to the students where

in their everyday life the phenomena occurs, working to help the students make the connection and gain a better understanding.

- Due to an increased hold time and higher levels of student engagement, any guide that focusses students' attention to fewer, more closely related exhibits will increase the educational value of their visit to Technorama.

The use of both the scavenger hunt and the simple map drastically increased the time that students spend at exhibits and the amount that they interacted with the exhibits. Additionally, both types of guides scored similarly on the post-guide questionnaire. Our team has concluded from this data that the implementation of a structured guide in which students visit fewer exhibits is an effective way to increase student learning at Technorama. These fewer exhibits work best when they are related to what the students are learning in school, as it will help them grasp a greater understanding of those scientific concepts. Due to the similar results from the use of the scavenger hunt and the simple map, this guide does not have to be related to the use of mobile devices. However, the scavenger hunt is an effective option as students did find it enjoyable to use.

## **5.2 Recommendations for the Continued Use of the Scavenger Hunt**

We present the following recommendations for the Swiss Science Center Technorama to incorporate into or change about the deliverable, the scavenger hunt, that we created for them. These suggestions are:

- Recommendation 1: Expand the scavenger hunt throughout the museum.
- Recommendation 2: Optimize certain routes for specific school groups.
- Recommendation 3: Introduce mobile technology.
- Recommendation 4: Add multiple language options.

This chapter will provide an explanation and justification for each recommendation.

### **5.2.1 Expanding the current product**

Our current model for the scavenger hunt has proved to be effective in providing an enjoyable and educational experience for students. However, there are plenty of ways to improve the scavenger hunt.

As mentioned in Section 4.3.1, our scavenger hunt was designed to cover basic physics principles, so it remained in the Mechanics sector. Covering other topics would expand the scavenger hunts over more sectors of the museum. For our first recommendation, we suggest that Technorama should expand our scavenger hunt or create new scavenger hunts with exhibits from multiple sectors of the museum. Having the scavenger hunt cover different sectors of the museum was suggested to us by members of the Visitor Services Department, however, we did not feel like this would be possible for us to implement as we wanted to observe the students using our guide. A scavenger hunt covering multiple floors would be much more time consuming, so the audience would most likely be visitors who wanted to use the scavenger hunt during the majority of their time at the Technorama. The advantage of this would be that those using the scavenger hunt would be able to see more of the museum, which is a common goal of people who come to Technorama according to our student survey. Our first recommendation is intended to not only improve the current model, but to achieve the maximum benefit from it. If our scavenger hunt can become integrated alongside all of Technorama's exhibits, its full potential can be realized, providing a structured and in-depth guide for every visitor.

The scavenger hunt we have created was designed specifically for students aged 14 to 16 studying basic physics. When we tested our prototypes with this age group, they usually enjoyed it, and they found the questions to be suitable for their age. However, students older than 16 often felt the questions were too easy for them. To solve this problem, more pathways with a wider array of questions can be added in the future so that visitors and students of all ages could use and learn from the scavenger hunt. Another option would be to use the same pathway but with questions at each exhibit that are written for certain age groups. In addition, the routes the scavenger hunt covers can be expanded to different topics besides basic mechanical physics principles. The Swiss secondary school curriculum covers a variety of introductory physics concepts ranging from mechanics to electricity and magnetism, as well as covering topics about the natural world. From our discussions with staff members from Visitor Services and Exhibition and Didactics, we determined it might be helpful to align different sets of exhibits and questions with the visiting school group's curriculum. For our second recommendation, we suggest that Technorama should work with schools to create specific scavenger hunts that align with their curriculum. For example, a school group learning about landslides might see a selection of exhibits from the "Water, Nature, and Chaos" sector of Technorama. This would help connect

the phenomenon the students observe to what they learn about in school, further improving the educational value of their trip.

### **5.2.2 Benefits of mobile technology**

Technorama currently possess no programs that use mobile technology, or a strong presence of it, to improve visitor learning. It is our recommendation to Technorama that they should take advantage of our scavenger hunt by creating a mobile application that utilizes it.

At this moment, we recommend that the mobile application focus on two particular features: incorporating the scavenger hunt and a QR code scanner. Our scavenger hunt would perform the best as a mobile application, as it was originally intended. As a mobile application, it would make it easily accessible for all visitors of Technorama. A mobile platform would also make it more appealing to teenagers (the target age group), therefore making education at the museum more interesting for them. A QR code scanner should also be incorporated into the application because we discovered that some mobile devices required a 3rd party application to read QR codes. By incorporating these two features, the base model for an effective scavenger hunt application can be created.

Based on our research (see Section 2.3.2), the number of mobile device users today are in the billions. To take advantage of this, creating an application would greatly benefit not just Technorama, but for visitors as well. Once the app is downloaded onto a user's device, cellular data would no longer be required. This is important as we found that some students did not want to use their own devices because of their data plan. Furthermore, since Wi-Fi is blocked throughout the floors, except the lobby, Technorama would not need to worry about integrating Wi-Fi onto the different floors and visitors using Wi-Fi to go onto social media while they are at the museum. During our time at Technorama, we learned that a big part of how the museum functions was the absence of connection to the Internet. Visitors of all age groups come to Technorama to see the many phenomena being displayed but allowing easy access to the Internet could definitely affect the flow of the museum. Without access to Wi-Fi, most visitors would be deterred from using their mobile devices when exploring the museum since they cannot access, say, their social media accounts. However, with Wi-Fi, visitors would be more compelled to use their phones instead of focusing on the exhibits.

Another benefit of converting the scavenger hunt to a mobile application would be the increased detail Technorama would be able to collect about users and their behavior. Being able to understand the patterns of the way students interact with the scavenger hunt will help Technorama understand the thought process of students who visit their exhibits, as well as allow insights for teachers into topics their students struggle with.

Our third recommendation provides a new way for Technorama to incorporate mobile technology programs and the educational benefit it could provide to future visitors.

### **5.2.3 More language options**

Technorama attract visitors that speak a variety of languages and because of this, Technorama translates their exhibit cards into German, English, French, and Italian. For our fourth and final recommendation, we suggest that Technorama translate the scavenger hunt so that all four of these languages are covered. While some of the German-speaking students we worked with were comfortable speaking English, we found that it was difficult for them to answer scientific questions in English. Giving all visitors the option to choose to use the scavenger hunt in their native language would solve this problem.

## **5.3 General Recommendations**

The following recommendations were created by our team to the Swiss Science Center Technorama to improve its educational impact on visitors. These recommendations are not directly related to improving the scavenger hunt we have designed; however, we believe they should still be taken into consideration. The recommendations are:

- Updating the conceptually difficult information cards.
- Rotating out certain exhibits.
- Creating a different type of guide that utilizes our question-answer model.

We will explain each suggestion in the following sections.



### **5.3.1 Improving learning at Technorama**

After conducting research at Technorama, it was clear to our team that some of the information cards at each exhibit are problematic due to their lengthiness and complexity. For our first general recommendation we suggest that Technorama update these cards. One way to do this would be to reduce the amount of text on the cards. This would make the cards more appealing to read. Another way to update the cards would be to have multiple explanations for different reading levels.

The number of hands-on exhibits Technorama has is incredible, however, many visitors often feel overwhelmed by the number of exhibits. While creating a scavenger hunt to focus visitors to only visit a few exhibits helped them to not feel overwhelmed, having fewer exhibits in each sector would help all visitors, including those who do not want to use the scavenger hunt. For our second general recommendation, we suggest that Technorama rotate their exhibits so that not all of the exhibits are on the floor at the same time. We also found that there are some exhibits that are very similar; for example, there are a few gyroscope exhibits in the Mechanics sector that show the same phenomenon (e.g. Gyroscope in a Suitcase, Bike Wheel Gyroscope, Rodeo Gyroscope). As these exhibits are right next to each other, some visitors might become uninterested in an exhibit if they saw the same phenomenon in an exhibit they were just at. This is why rotating out certain exhibits would make visitors more interested and they would feel less overwhelmed as the sectors would not be as crowded.

### **5.3.2 Testing other types of guides**

The guide we created was a scavenger hunt. However, there are other ways of structuring school visits so that students learn more. The scavenger hunt was an idea presented to us by our sponsor, and it was the one we decided to test. This does not mean all other possibilities were eliminated, there could be a more effective way to focus students' learning. We found our scavenger hunt to be more effective in increasing student learning than letting the students run around Technorama without any structure. However, we also found that the use of a map increased student learning, so we recommend that Technorama test the effectiveness and enjoyment of different types of guides, besides a map and a scavenger hunt. Finding the most effective and enjoyable guide would allow students to get the most out of their visit to Technorama.

We believe education is extremely important, so we hope this project will lead to improvements in how the Technorama approaches achieving its educational goals. We believe the scavenger hunt concept can improve the educational experience for students and visitors in the future.

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## Appendices

### Appendix A: Sponsor Description

The mission of the Swiss Science Center Technorama is to encourage learning and understanding of the natural sciences by everyone (Swiss Science Center Technorama, 2019c). Technorama uses over 500 unique, interactive exhibits to give visitors a science experience that is not only enjoyable but also educational. Technorama is a public, non-profit organization aimed at teaching its visitors, specifically the youth, about science and technology. Admission is charged at Technorama, being 29.00 CHF for adults and 18.00 CHF for children (Swiss Science Center Technorama, 2019b). Technorama first began as an organization with the intention of founding a museum of technology in 1947 when it began accumulating a collection of Swiss historical objects (Swiss Science Center Technorama, 2019a). The organization became Technorama of Switzerland on June 22nd, 1969 and later became a public technology museum with the opening of its first exhibition in 1982. At that time, Technorama was very much a conventional science museum with nothing that made it stand above the rest. This changed in 1990, when Technorama adopted the idea of interactive exhibits based on the structures of the San Francisco Exploratorium and the Exploratory in England. Technorama is still growing, reaching a new record for annual visitors in 2016 at just over 280,000 people, 70,000 of which are students on school trips. Technorama currently has 127 employees, 73 of which are full-time (Ehlers, Le, Charles, & Bago, 2018).

Technorama is structured with a senior management team and eight departments, led by director Thorsten-D. Künemann (Swiss Science Center Technorama, 2019b). One of the departments is the department of Exhibition and Didactics led by Dr. Armin Duff. Since our team's project is in designing mobile technology to aid in the retention of information in the exhibits, the department that our team will be interacting with the most is the Department of Exhibition and Didactics. Another department is marketing and reception led by Roy Schedler, which specializes in promoting Technorama and making sure the visitors are pleased. The department of administration makes sure everything runs smoothly behind the scenes. Visitor services are always present and ready to help visitors with any questions and concerns they may have. The department of laboratories is led by Martin Engel and is in charge of organizing and running the workshops. Workshop and facility management makes sure day-to-day operations

are successful. Technorama also has a foundation board. Not only is the management carefully structured, but so are Technorama's exhibits. Technorama spans four floors, referred to as sectors, with each sector containing groupings of exhibits that address similar topics (Dr. Armin Duff & Stefan Tosch, personal communication, April 1, 2019).

While Technorama is a non-profit organization, it does have many sponsors that provide funding so Technorama can continue to improve and develop. Technorama's three largest sponsors are the Biogen Foundation, Kistler, and Merck (Swiss Science Center Technorama, 2019f). The Biogen Foundation (2019) is a neuroscience company working on the development of innovative therapies for neurological and neurodegenerative diseases. The Kistler Group (2019) is a company that uses advanced technologies for the measurement of pressure, force, torque, and acceleration. Merck KGaA (2019) is a science and technology company that works with other companies across the globe.

## **Appendix B: Consent Form for Student Survey**

**Investigators:** Isabella Feeney, Tae Hyun Je, Nathaniel Shimkus, Trisha Worthington

**Contact Information:** gr-sciencecenteriqp@wpi.edu

**Title of Research Study:** Mobile Science Activities at the Swiss Science Center Technorama

**Sponsors:** Swiss Science Center Technorama and Worcester Polytechnic Institute

**Introduction:** Your students are being asked to participate in a research study. Before you agree, however, you and your students must be fully informed about the purpose of the study, the procedures to be followed, and any benefits, risks or discomfort that you may experience as a result of your participation. This form presents information about the study so that you may make a fully informed decision regarding your student's participation.

**Purpose of the study:** This study is being conducted to gain data that can be used to improve the educational value of the Swiss Science Center Technorama. By collecting results for the following questions within the survey, we will gain important insight into what works best about the education at the Swiss Science Center Technorama, and what could be improved to enhance the educational value for student groups and visitors in the future.

**Procedures to be followed:** A questionnaire will be provided for your students to answer multiple-choice and short answer questions about their trip to Technorama and their interactions with the exhibits there. This questionnaire will be administered in the format of a paper form to be filled out by hand or a Google Form to be filled out electronically, depending on electronic availability. The questions should take about 3-5 minutes to complete.

**Risks to study participants:** No greater risks to participants than experienced in everyday life.

**Benefits to research participants and others:** The benefits that can be expected from this research are information about the effectiveness of science museum visits for children and adolescents, as well as possible ways to improve on these trips.

**Recordkeeping and confidentiality:** All results collected will be anonymous. Records of your students' participation in this study will be held confidential so far as permitted by law. However, the study investigators, the sponsor or its designee and, under certain circumstances, the Worcester Polytechnic Institute Institutional Review Board (WPI IRB) will be able to inspect and have access to confidential data that identify you by name. Any publication or presentation of the data will not identify you.

**Compensation or treatment in the event of injury:** There is minimal risk of injury or harm. You do not give up any of you or your students' legal rights by signing this statement.



**For more information about this research or about the rights of research participants, or in case of research-related injury, contact:**

- Mobile Science Activities Research Group - gr-sciencecenteriqp@wpi.edu
- IRB Chair - Professor Kent Rissmiller, +1 508- 831-5019, kjr@wpi.edu
- Human Protection Administrator - Gabriel Johnson, +1 508-831-4989, gjohnson@wpi.edu

**Your students' participation in this research is voluntary.** Their refusal to participate will not result in any penalty to them or any loss of benefits to which they may otherwise be entitled. You or your students may decide to stop participating in the research at any time without penalty or loss of other benefits. The project investigators retain the right to cancel or postpone the experimental procedures at any time they see fit.

**By signing below,** you acknowledge that you and your students have been informed about and consent to participate in the study described above. Make sure that your questions are answered to your satisfaction before signing. You are entitled to retain a copy of this consent agreement.

\_\_\_\_\_  
Teacher Signature

\_\_\_\_\_  
Date

\_\_\_\_\_  
Teacher Name (please print)

\_\_\_\_\_  
Signature of Person who explained this study

\_\_\_\_\_  
Date

# Appendix C: Pre-Implementation Student Survey

Please circle your answer for each question or write in the space provided

Your age \_\_\_\_\_ Your gender: male | female | prefer not to say

How has your experience been so far? (5 - Amazing, 1 - Terrible)

1 2 3 4 5

Is this your first time at the Technorama?

Yes No

Did you learn anything new at Technorama? (5 - more than expected, 1 - nothing)

1 2 3 4 5

Did you use the information located on the back of the cards to improve your understanding? (5 - frequently, 1 - never)

1 2 3 4 5

If so, how understandable did you find the explanations? (5 - very difficult, 1 - very easy)

1 2 3 4 5

About how much time do you think you spent at most exhibits (Exponate)?

30 seconds 1 min 2 min 5 min

Did you have enough time to see all the exhibits (Exponate) you wanted?

Yes No

How did you find the number of exhibits (Exponate) in the Technorama?

(5 - too many, 1 - too few)

1 2 3 4 5

Did you think that Technorama was well suited for your age?

(5 - too advanced, 1 - too simple)

1 2 3 4 5

Which sector did you find most fun? (circle one of the six choices)

Mechanics Water, Nature, Chaos Light and Sight  
Current and Magnets Mathemagic Mindscapes

In which sector did you learn the most? (circle one of the six choices)

Mechanics Water, Nature, Chaos Light and Sight  
Current and Magnets Mathemagic Mindscapes

Was there an exhibit (Exponat) where you had an "Aha-moment!?" Which one?

Did you find the most fun sectors were also the most educational? Why/Why not?

Which exhibit (Exponat) did you find most memorable today?

Would you want to visit Technorama again?

Yes No

## **Appendix D: Questions for Interviews with Museum Staff (Exhibition and Didactics)**

We are students from Worcester Polytechnic Institute in Worcester, Massachusetts, in the United States. We are currently working on a project with the Swiss Science Center Technorama to design a better learning experience for visitors. This interview was designed to obtain an understanding of your knowledge of the museum as a member of the Exhibition and Didactics Department, and any opinions you might have that could help our project. This information will remain anonymous and will only be used for summary purposes. If at any time, after this interview, you wish to not have your answers published, you may let us know by emailing [gr-sciencecenteriqp@wpi.edu](mailto:gr-sciencecenteriqp@wpi.edu)

1. What is your position here at Technorama?
2. How long have you worked here?
3. Questions regarding information cards
  - a. What information do you look to provide on the back of the cards?
  - b. How long have the cards been used here?
  - c. Do you think the conceptual understanding of the exhibits has increased since the introduction of the cards?
  - d. For what level of understanding do you write the cards? Are they tailored for certain age groups?
4. What do you look for when creating an educational exhibit?
5. Do you try to create exhibits for every age group or are there exhibits specifically for younger visitors or older visitors?

## **Appendix E: Questions for Interviews with Museum Staff (Visitor Services)**

We are students from Worcester Polytechnic Institute in Worcester, Massachusetts, in the United States. We are currently working on a project with the Swiss Science Center Technorama to design a better learning experience for visitors. This interview was designed to obtain an understanding of your knowledge of the museum as a member of the Visitor Services Department, and any opinions you might have that could help our project. This information will remain anonymous and will only be used for summary purposes. If at any time, after this interview, you wish to not have your answers published, you may let us know by emailing [sciencecenteriqp@wpi.edu](mailto:sciencecenteriqp@wpi.edu)

1. What is your position here at Technorama?
2. How long have you worked here?
3. What questions do visitors most frequently ask you in relation to exhibits?
4. What is the typical structure of a planned school trip to Technorama? Are there certain exhibits and guides or is there an allotted time to roam the museum freely?
5. Which exhibits do most people frequent and why?
6. How often do you observe visitors using the information on the backs of the cards?
7. What is the normal flow of students, and visitors in general, through the Technorama?
8. Which theme (physics, water, etc.) is the most and least popular? Do you have any thoughts on why this could be?
9. What factors do you think contribute to exhibits being ignored or causing disinterest?
10. What is the most common feedback you receive regarding the exhibits at Technorama?
11. If any, what is the most common feedback from students?
12. If any exhibits have been changed or altered in the past, what is the general feedback received about it? What changes were made that yielded positive or negative feedback?
13. Have you ever received feedback on improvements that can be made to the exhibits? If so, what might these be?
14. Do you have any ideas for our guide to help focus visitors?

# Appendix F: Protocol for Observation of Students with Google Forms

## Student Observations

Observing students pre-implementation

Observer Name

Isabella

Ted

Nate

Trish

**NEXT**

Never submit passwords through Google Forms.

## Student Observations

### Observations

Exhibit Name?

Your answer \_\_\_\_\_

Number of Students

Your answer \_\_\_\_\_

Time spent

30 seconds

1 minute

2 minute

3 minute or more

Did the student look at the information card

1 2 3 4 5

Student did not look at card      Student is fully engaged with card and exhibit

Any comments:

Your answer \_\_\_\_\_

## **Appendix G: Interviews with Museum Staff (Exhibition and Didactics)**

We interviewed three members from the Exhibition and Didactics team. Their answers for each question are summarized below to keep the identity of the staff members anonymous. The summarized answers are categorized as typical answer, average answer (used for numbers), or answers if there was a wide varied of answers and listing all of the responses wouldn't identify any of the interviewees. The key finding for each question is also listed where applicable.

1. What is your position here at Technorama?
  - a. Typical answer - part of the didactics team
  - b. Key findings - N/A
6. How long have you worked here?
  - a. Average answer - 2.67 years
  - b. Key findings - N/A
7. What information do you look to provide on the back of the cards?
  - a. Typical answer - The cards are there for people who are more interested in the phenomena behind an exhibit. It is difficult to write cards that will work for all visitors. The new cards are structured so that they first talk about the phenomena and then explain the science behind it, and finally connect it to their everyday life.
  - b. Key findings - It is important for the cards to link concepts to everyday life so that visitors can relate to what they are seeing, however, many of the cards are old and Technorama is working on improving them for the visitors who would like to learn more about the phenomena at each exhibit.
8. How long have the cards been used here?
  - a. Typical answer - I don't know how long the cards have been used here, they were here before I got here.
  - b. Key findings - These cards have been around for a long time but have been improved since then.
9. Do you think the conceptual understanding of the exhibits has increased since the introduction of the cards?

- a. Typical answer - The cards can be very helpful for some exhibits but they are of varying quality and difficulty level so it would be hard to test the effectiveness of the cards on the conceptual understanding of the exhibits.
  - b. Key findings - The value of the cards in terms of the conceptual understanding of the exhibits has never been tested, but some staff members believe they are very helpful depending on the exhibit and how interested the visitor is and how well they understand science.
10. For what level of understanding do you write the cards? Are they tailored for certain age groups?
- a. Typical answer - The cards are usually written for everyone aged 12 years and up.
  - b. Key findings - The level of understanding the cards provide vary but are usually written so that visitors above the age of 12 can understand them.
11. What do you look for when creating an educational exhibit?
- a. It needs to be catchy. A good exhibit is one where you don't need to read anything, you can use your hands and are instantly fascinating. It is not a good exhibit where you have to spend a lot of time before you realize it is fascinating. We want it to grab their attention immediately.
  - b. Being able to change a variable and see what happens. You should be intrigued so that you wonder about the phenomenon.
  - c. It's all about the phenomenon. There's always two principles that have to come together to make a good exhibit: the science behind it has to be acceptable and strongly scientifically sound, it also has to be perceivable and hands-on and they have to be able to connect to it emotionally, to connect it to everyday life and how they live. It is a long process: start with phenomenon, then build rough prototype, then refine more and more until the final version of the exhibit.
  - d. Typical answer - An educational exhibit needs to be catchy. If you don't need to read what to do and you can just use your hands to be instantly fascinated, that's a good exhibit. It should make you think about the phenomenon and the science behind it should be strong.

- e. Key findings - An educational exhibit has to make visitors think about the phenomenon immediately, they should be able to use their hands and they should be able to connect it to their everyday life.
12. Do you try to create exhibits for every age group or are there exhibits specifically for younger visitors or older visitors?
- a. Typical answer - A certain age group is not targeted when an exhibit is created. However, children are always in mind for all of the exhibits if it is something up high, we will add a block for them to stand on so they can use it just like an adult would.
  - b. Key findings - Adults are usually the ones in mind when exhibits are being created, but no exhibits are designed specifically for children, although, certain exhibits attract certain age groups.



## **Appendix H: Interviews with Museum Staff (Visitor Services)**

We interviewed six staff members from Visitor Services. Their answers for each question are summarized below to keep the identity of the staff members anonymous. The summarized answers are categorized as typical answer or answers if there was a wide variety of answers and listing all of the responses would not identify any of the interviewees. The key finding for each question is also listed where applicable.

1. What is your position here at Technorama?
  - a. Typical answer - a member of Visitor Services, answer visitors' questions and show them how to approach exhibits
  - b. Key finding - N/A
2. How long have you worked here?
  - a. Typical answer - only a few months
  - b. Key finding - N/A
3. What questions do visitors most frequently ask you in relation to exhibits?
  - a. Typical answer - Visitors usually only ask where an exhibit is or if they can see an exhibit that requires a staff person to demonstrate it.
  - b. Key finding - Visitors don't usually ask about the science behind an exhibit or why they are seeing what they are seeing.
4. What is the typical structure of a planned school trip to Technorama? Are there certain exhibits and guides or is there an allotted time to roam the museum freely?
  - a. Typical answer - Sometimes their trip is scheduled around labs and shows, sometimes the kids have all free time during their trip. Some teachers prefer to have all the students stay in one section of the museum, while other teachers let

them roam around all of the floors. Students usually have a worksheet they need to fill out as they go to the different exhibits.

- b. Key finding - There is no set structure of a school trip to Technorama. It depends on what the teacher wants the students to see and how far they are comfortable with the students exploring without a chaperone, which probably most likely a factor for younger kids.
5. Which exhibits do most people frequent and why?
- a. Answers –
    - i. Atrium: Air fountain
    - ii. Mechanics: table with rotating objects (2) and rocking drawing board
    - iii. Mindscapes: rotating tunnel (2)
    - iv. Water, Nature, Chaos: cloud rings and tornado exhibits
    - v. Light and Sight: pin screen (2), colored shadow, and frozen shadow
    - vi. Plasma exhibits
  - b. Key finding - The exhibits people tend to frequent the most are fun exhibits that are very big and easy to see. With these exhibits, you can instantly start playing with them, you don't need to read any long texts to understand what to do.
6. How often do you observe visitors using the information on the backs of the cards?
- a. Typical answer - visitors don't tend to look at the cards, children tend to run from one exhibit to the next, while parents will stay behind and read the cards at each exhibit. If a kid is at an exhibit and they don't see anything happening, they usually move on to the next without reading the card to try and figure out how to

use the exhibit. On the other hand, adults feel a bit timid and would rather read what to do instead of figuring out what to do using their hands.

- b. Key finding - Visitors tend to only read the back of the cards (when the explanations are) if they are really interested in the phenomena behind an exhibit, they tend to put the card back when they see how much text they have to read for an explanation.
7. Do you ever receive any feedback about the cards?
- a. Typical answer, not very often or rarely
  - b. Key finding – no
8. What is the normal flow of students, and visitors in general, through the Technorama?
- a. Typical answer - most people start on the ground floor in the mechanics section and then move on to the first floor and the second floor. Visitors who have been here before or if it is really crowded sometimes start on the second floor. For school groups, it depends where the teacher wants them to start, sometimes they are split into groups and spread out over the different floors.
  - b. Key finding - Visitors usually explore Technorama by starting from the bottom and then go to the top. Visitors tend to move quickly between the exhibits, once they see the phenomenon, they tend to move on and not think about it because they want to see the other exhibits.
9. Which theme (physics, water, etc.) is the most and least popular? Do you have any thoughts on why this could be?

- a. Typical answer - Popular ones are the lightning show, plasma, and the first floor in general. The least popular sectors are the holograms and the inventor laboratories on the ground floor.
  - b. Key finding - Each sector has something unique about it but the sectors that are a big eye catcher are usually the most popular
10. What factors do you think contribute to exhibits being ignored or causing disinterest?
- a. Typical answers - Exhibits that are ignored are usually ones that take more effort to approach since you don't know what to do, you can't just jump right in, instead you might have to read what to do. Visitors like an immediate response so if they have to wait to see something happen, they usually move on to the next exhibit. Exhibits that are not very bright and are in the corner are usually ignored too.
  - b. Key finding - If visitors can't see an effect or comprehend it within a few minutes, they usually move on to the next exhibit.
11. What is the most common feedback you receive regarding the exhibits at Technorama?
- a. Typical answer - Positive feedback about the adventure rooms, exposure to scientific concepts, and the shows.
  - b. Key finding - People generally like Technorama, they find it fascinating and exciting.
12. If any, what is the most common feedback from students?
- a. Typical answer - They usually don't give feedback, but they do sometimes mention exhibits they liked like the rotating tunnel or ones where they can compete with each other.

- b. Key finding - Students don't really give a lot of feedback to Visitor Services.  
However, it seems like they do enjoy their time at the museum.
- 13. If any exhibits have been changed or altered in the past, what is the general feedback received about it? What changes were made that yielded positive or negative feedback?
  - a. Typical answer - Usually when an exhibit is removed, they usually receive questions asking where it is. For example, the inventory laboratory used to be more complicated and was very interesting if you had a scientific background in the topics and some people really liked it and ask where it is.
  - b. Key finding - Exhibits are rarely changed, when they are, they are usually changed to improve them which doesn't generate feedback unless a well-liked exhibit is removed.
- 14. Have you ever received feedback on improvements that can be made to the exhibits? If so, what might these be?
  - a. Typical answer - Feedback isn't received often, sometimes the text has a spelling mistake that they tell us about, sometimes they want a few more exhibits on topics like climate change and astronomy.
  - b. Key finding - Feedback on improvements that can be made to the exhibits is rare but usually is about the cards, not the actual exhibits.
- 15. Do you have any ideas for our guide to help focus visitors?
  - a. Answers –
    - i. The guide should extend over many sectors, if it just covers one area of the museum kids might feel like they are missing out on the rest of the exhibits

- ii. The cards don't do a very good job of answering my questions that I have about the exhibit or they are too advanced for my understanding
- iii. It would be good if there were multiple guides where students could choose based on topics they are interested in, how much they want to read, and the difficulty of the concepts being presented to them
- iv. The questions shouldn't all be do this and now do this, they should ask them more specific questions like why is this happening to try to get them to think more

## **Appendix I: Consent Form for Scavenger Hunt**

**Investigators:** Isabella Feeney, Tae Hyun Je, Nathaniel Shimkus, Trisha Worthington

**Contact Information:** gr-sciencecenteriqp@wpi.edu

**Title of Research Study:** Mobile Science Activities at the Swiss Science Center Technorama

**Sponsors:** Swiss Science Center Technorama and Worcester Polytechnic Institute

**Introduction:** Your students are being asked to participate in a research study. Before you agree, however, you and your students must be fully informed about the purpose of the study, the procedures to be followed, and any benefits, risks or discomfort that you may experience as a result of your participation. This form presents information about the study so that you may make a fully informed decision regarding your student's participation.

**Purpose of the study:** This study is being conducted to gain data that can be used to improve the educational value of the Swiss Science Center Technorama. By collecting results for the following questions within the survey, we will gain important insight into what works best about the education at the Swiss Science Center Technorama, and what could be improved to enhance the educational value for student groups and visitors in the future.

**Procedures to be followed:** A scavenger hunt will be provided for your students to answer multiple-choice regarding specific exhibits at Technorama and their interactions with the exhibits there. This scavenger hunt will be administered in the format of an online form to be filled out by to be filled out electronically. The scavenger hunt should take about 5-10 minutes to complete. An optional questionnaire will also be provided at the end of the scavenger hunt, on a Google Forms. The questionnaire will contain multiple-choice and free response questions. It should take about 4-8 minutes to complete.

**Risks to study participants:** No greater risks to participants than experienced in everyday life.

**Benefits to research participants and others:** The benefits that can be expected from this research are information about the effectiveness of science museum visits for children and adolescents, as well as possible ways to improve on these trips.

**Recordkeeping and confidentiality:** All results collected will be anonymous. Records of your students' participation in this study will be held confidential so far as permitted by law. However, the study investigators, the sponsor or its designee and, under certain circumstances, the Worcester Polytechnic Institute Institutional Review Board (WPI IRB) will be able to inspect and have access to confidential data that identify you by name. Any publication or presentation of the data will not identify you.

**Compensation or treatment in the event of injury:** There is minimal risk of injury or harm. You do not give up any of you or your students' legal rights by signing this statement.

**For more information about this research or about the rights of research participants, or in case of research-related injury, contact:**

- Mobile Science Activities Research Group - gr-sciencecenteriqp@wpi.edu
- IRB Chair - Professor Kent Rissmiller, +1 508- 831-5019, kjr@wpi.edu
- Human Protection Administrator - Gabriel Johnson, +1 508-831-4989, gjohnson@wpi.edu

**Your students' participation in this research is voluntary.** Their refusal to participate will not result in any penalty to them or any loss of benefits to which they may otherwise be entitled. You or your students may decide to stop participating in the research at any time without penalty or loss of other benefits. The project investigators retain the right to cancel or postpone the experimental procedures at any time they see fit.

**By signing below,** you acknowledge that you and your students have been informed about and consent to participate in the study described above. Make sure that your questions are answered to your satisfaction before signing. You are entitled to retain a copy of this consent agreement.

\_\_\_\_\_  
Teacher Signature

\_\_\_\_\_  
Date

\_\_\_\_\_  
Teacher Name (please print)

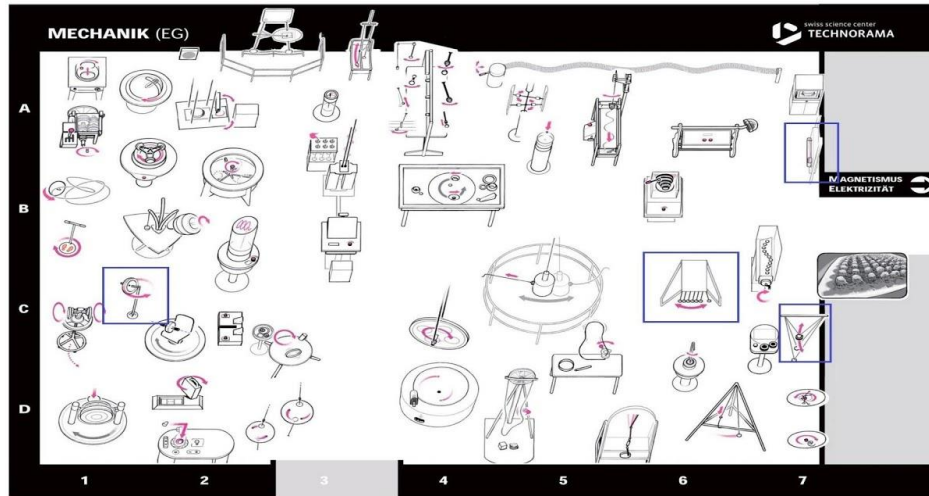
\_\_\_\_\_  
Signature of Person who explained this study

\_\_\_\_\_  
Date



## Appendix J: Simple Map

Front side:



### ENGLISH

Hello, thank you for participating in our research. If you look closely at the map above, you can see that there are 4 exhibits that are boxed. Your goal today is to visit those exhibits and interact with them as you would normally do! After you are done, please return to 3 and take the quiz! Good luck!

### GERMAN

Hallo, vielen Dank für Ihre Teilnahme an unserer Forschung. Wenn Sie sich die Karte oben genauer ansehen, sehen Sie, dass es 4 Exponate gibt, die verpackt sind. Ihr Ziel ist es heute, diese Exponate zu besuchen und mit ihnen zu interagieren, wie Sie es normalerweise tun würden! Nachdem Sie fertig sind, kehren Sie bitte zu 3 zurück und nehmen am Quiz teil! Viel Glück!

Backside:

Exhibits (Exponate):

1. Stehende Schnurwellen
2. Drei-Zeiten-Pendel
3. Velokreisel
4. Pendelreihe

## Appendix K: Post Implementation Scavenger Hunt Student Survey

# Post Implementation Student Observation Scavenger Hunt

Form description

Exhibit Name

Short answer text

Number of Students

Short answer text

Time spent

- 30 seconds
- 1 minute
- 2 minutes
- 3 minutes or more

Did the student look at the information card?

	1	2	3	4	5	
student did not look at card	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Student is fully engaged with card and exhibit

## Appendix L: Post Implementation Simple Map Student Observation

### Post Implementation Student Observation Simple Map

---

Form description

---

Exhibit Name

Short answer text

---

Number of Students

Short answer text

---

Time Spent

- 30 Seconds
- 1 minutes
- 2 minutes
- 3 minutes or more

Did the student look at the information card?

1 2 3 4 5

student did not look at the  
card

Student is fully engaged  
with card and exhibit

## Appendix M: Post Implementation Questionnaire [ENGLISH]

1. Vibrating Strings
  - a. To increase the number of nodes on a vibrating string, you should...
    - i. Make the string vibrate faster
    - ii. Make the string less taut
    - iii. Make the string vibrate slower
2. Triple Pendulum
  - a. If you wanted to make the oscillation time of a pendulum faster, you should...
    - i. Increase the mass of the pendulum
    - ii. Decrease the length of the string
    - iii. Pull the pendulum further back before you swing it
3. Bicycle wheel gyroscope
  - a. If you increase the size of the wheel so that it becomes much heavier, the wheel would...
    - i. Spin against the pole since it would be too heavy
    - ii. Still spin in the air (not touching the pole) as before
    - iii. Not be able to rotate at all
4. Click-Clack
  - a. If you wanted to increase the amount of momentum the balls have, you should...
    - i. Swing the balls faster
    - ii. Decrease the mass of the balls
    - iii. Swing only one ball at a time

## Appendix N: Post Implementation Questionnaire [GERMAN]

1. Stehende Schnurwellen
  - Um die Anzahl der Knoten auf einer vibrierenden Saite zu erhöhen, solltest du...
    1. Die Schnur schneller vibrieren lassen.
    2. Die Schnur weniger straffen.
    3. Die Schnur langsamer vibrieren lassen.
2. Drei-Zeiten-Pendel
  - Um die Schwingungsdauer eines Pendels schneller zu machen, musst du...
    1. Die Masse des Pendels erhöhen.
    2. Die Seillänge verkürzen.
    3. Das Pendel vor dem Schwingen weiter auslenken.
3. Velokreisel
  - Wenn du die Größe des Rades erhöhen würdest, so dass es viel schwerer würde, würde das Rad...
    1. Das Rad würde die Stange berühren, da es zu schwer wäre.
    2. In der Luft drehen (ohne die Stange zu berühren) wie bisher.
    3. Würde sich gar nicht drehen.
2. Pendelreihe
  - Wenn du den Impuls der Kugeln erhöhen willst, solltest du...
    1. Die Kugeln schneller schwingen.
    2. Die Masse der Kugeln verringern.
    3. Nur eine Kugel auf einmal schwingen lassen.

## Appendix O: Prototype Feedback for Scavenger Hunt

**QUESTIONS**    RESPONSES

### Prototype Feedback

How did you like our guide?

Your Age \*

Short answer text

---

⋮

**Gender** Multiple choice ▾

Female ×

Male ×

Prefer not to say ×

Add option or [ADD "OTHER"](#)

---

📄 🗑️ | Required  ⋮

Please rate your experience at the Technorama so far:

1      2      3      4      5

Terrible                    Amazing

Did you learn anything new at the Technorama?

1      2      3      4      5

Nothing                    More than expected

Did you enjoy using this guide? \*

	1	2	3	4	5	
It was awful	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	I loved it!

Did you learn anything new while using this guide? \*

	1	2	3	4	5	
nothing	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	more than expected

About how much time do you think you spent at most of these exhibits? \*

- 30 seconds
- 1 minute
- 2 minutes
- 5 minutes

Were the concepts presented suitable for your age level? \*

	1	2	3	4	5	
Too simple	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Too advanced

Has this guide improved or hindered your experience at the Technorama? \*  
Please explain.

Long answer text

---

How can this guide be improved for the future? \*

Long answer text

---

## Appendix P: Scavenger Hunt Questionnaire [ENGLISH]

How did you like our guide?

---

Your Age \*

Short answer text

---

Gender \*

- Female
- Male
- Prefer not to say

Vibrating Strings: To increase the number of nodes on a vibrating string, you should... \*

- Make the string less taut
- Make the string vibrate faster
- Make the string vibrate slower

Triple Pendulum: If you wanted to make the oscillation time of a pendulum faster, you should... \*

- Increase the mass of the pendulum
- Decrease the length of the string
- Pull the pendulum further back before you swing it



Bicycle Wheel Gyroscope: If you increase the size of the wheel so that it becomes much heavier, the wheel would...

\*

- Rotate against the pole since it would be too heavy
- Rotate in the air (not touching the pole) as before
- Not be able to rotate at all

Click-Clack: If you wanted to increase the amount of momentum the balls have, you should...

\*

- Swing the balls faster
- Decrease the mass of the balls
- Swing only one ball at a time

Please rate your experience at the Technorama so far:

	1	2	3	4	5	
Terrible	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Amazing

Did you learn anything new at the Technorama?

	1	2	3	4	5	
Nothing	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	More than expected

Did you enjoy using this guide? \*

1      2      3      4      5

It was awful                                    I loved it!

Did you learn anything new while using this guide? \*

1      2      3      4      5

nothing                                    more than expected

About how much time do you think you spent at most of these exhibits? \*

- 30 seconds
- 1 minute
- 2 minutes
- 5 minutes

Were the concepts presented suitable for your age level? \*

1      2      3      4      5

Too simple                                    Too advanced

Has this guide improved or hindered your experience at the Technorama? \*  
Please explain.

Long answer text

---

How can this guide be improved for the future? \*

Long answer text

---

## Appendix Q: Scavenger Hunt Questionnaire [GERMAN]

### Post- Implementation Questions [SCAVENGER HUNT]- German

---

Wie hat dir unser Lernparcours gefallen?

---

Dein Alter \*

Short answer text  
.....

Geschlecht \*

- männlich
- weiblich
- divers

Stehende Schnurwellen: Um die Anzahl der Knoten auf einer vibrierenden Saite zu erhöhen, solltest du..... \*

- Die Schnur schneller vibrieren lassen.
- Die Schnur weniger straffen.
- Die Schnur langsamer vibrieren lassen.

Drei-Zeiten-Pendel: Um die Schwingungsdauer eines Pendels schneller zu machen, musst du..... \*

- Die Masse des Pendels erhöhen.
- Die Seillänge verkürzen.
- Das Pendel vor dem Schwingen weiter auslenken.

Velokreisel: Wenn du die Größe des Rades erhöhen würdest, so dass es viel schwerer würde, würde das Rad..... \*

- Das Rad würde die Stange berühren, da es zu schwer wäre.
- In der Luft drehen (ohne die Stange zu berühren) wie bisher.
- Würde sich gar nicht drehen.

Pendelreihe: Wenn du den Impuls der Kugeln erhöhen willst, solltest du..... \*

- Die Kugeln schneller schwingen.
- Die Masse der Kugeln verringern.
- Nur eine Kugel auf einmal schwingen lassen.

Bitte bewerte deine bisherigen Erfahrungen im Technorama: \*

	1	2	3	4	5	
Schrecklich	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Erstaunlich

Hast du im Technorama etwas Neues gelernt? \*

	1	2	3	4	5	
nichts	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	mehr als erwartet

Hat dir die Benutzung dieses Lernparcours gefallen? \*

	1	2	3	4	5	
Es war schrecklich.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Ich habe es geliebt!

Hast du bei der Verwendung des Lernparcours etwas Neues gelernt? \*

	1	2	3	4	5	
nichts	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	mehr als erwartet

Wie viel Zeit hast du deiner Meinung nach bei den meisten dieser Exponate verbracht? \*

- 30 sekunden
- 1 min
- 2 min
- 5 min

Waren die vorgestellten Konzepte für deine Altersgruppe geeignet? \*

	1	2	3	4	5	
Zu einfach	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Zu fortgeschritten

⋮

Hat der Lernparcours deine Erfahrung in Technorama bereichert oder hat er dich eher negativ beeinflusst. Bitte erkläre deine Arbeit kurz. \*

Long answer text

---


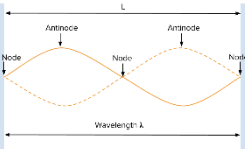
Wie könnte der Lernparcours für die Zukunft verbessert werden? \*

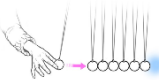
Long answer text

---

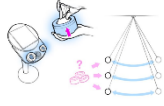
## Appendix R: Scavenger Hunt Questions


\*Correct answers are highlighted

Exhibit	Vibrating Strings (Stehende Schnurwellen) - Mechanics
Hint	Near where the two pendulums are connected, look for the white string on the wall!
Question 1 	A wave in water ripples outwards. When there are many waves in water at once, the movement becomes completely chaotic! The waves in this string are similar to waves in the ocean. However, when the wave reaches the end of the string, it is forced to bounce back. Slowly pull the end of the string, so that the string becomes taut. What do you notice about the waves in the string? Do you notice anything interesting?
Answers	<ol style="list-style-type: none"> <li>The string has no waves</li> <li>The string moves in chaotic waves</li> <li>Multiple waves go through the string</li> <li><b>The wave in the string is stationary</b></li> </ol>
Reasoning	That's right! If the wave reaches the end of the string at the right time, it will reflect back in the same shape. This can make the string look like it is staying still, which is called a standing wave.  When you look closer, it almost seems as if there are a series of loops in the string, side by side. In between each loop is a point where the string appears to be stationary, which is called a node.
Question 2	Now, slowly pull the string tighter. What happens to the nodes on the string?
Answers	<ol style="list-style-type: none"> <li>There are more nodes on the string</li> <li>The amount of nodes remains the same</li> <li><b>There are fewer nodes on the string</b></li> <li>There are no nodes visible</li> </ol>
Reasoning	That's right! The tighter the string is pulled, the fewer nodes there are! This is because the wave moves faster through the string.
Question 3	This phenomenon can also be seen when tuning a guitar, what happens to the pitch of a guitar string when it is tightened?
Answers	<ol style="list-style-type: none"> <li><b>It creates a higher pitch</b></li> <li>It creates a lower pitch</li> <li>The pitch stays the same</li> </ol>

Reasoning	That's right! If you want to learn more about this topic, check out an exhibit called <b>Oszynderscope</b> on the first floor in mindscapes after this scavenger hunt is over.
<b>Exhibit</b>	Pendulum's Cradle (Pendelreihe) - Mechanics
Hint	Search for the silver balls suspended in a line
Question 1 	What happens when you swing one ball into the others? Now, try swinging two balls at once. Even try pulling back three or four balls at once. What do you observe about the balls that swing up from the other side?
Answers	<ol style="list-style-type: none"> <li>1. All the balls stop moving</li> <li>2. <b>The same amount of balls from the other side swing up</b></li> <li>3. All of the balls start moving at once</li> <li>4. One ball from the other side swings</li> </ol>
Reasoning	That's right! No matter how many balls you pull back and release into the center, the same amount of balls will swing up from the other side. This is because the momentum of the balls always needs to go somewhere! When an object is in motion, it has momentum. The more mass or more speed the object has, the more momentum it has.
Question 2	If you swing a ball at the same time into both ends, what happens?
Answers	<ol style="list-style-type: none"> <li>1. Both balls stop</li> <li>2. One side stops and the other bounces back</li> <li>3. <b>Both balls keep bouncing back</b></li> <li>4. All of the balls start swinging</li> </ol>
Reasoning	That's right! The same principle applies here! Since one ball is hitting on either side, one ball from both sides will swing up. The momentum is still conserved in the collision.
Question 3	If a football and a table tennis ball are both moving with the same velocity, which ball has more momentum?
Answers	<ol style="list-style-type: none"> <li>1. Both balls have the same momentum</li> <li>2. <b>The football has more momentum</b></li> <li>3. The table tennis ball has more momentum</li> <li>4. Neither has momentum</li> </ol>
Reasoning	That's right! If you've ever played with a football before, then you'd know it has much more mass than a table tennis ball. Because it has more mass and the velocity is the same, the football would have a higher momentum!



<b>Exhibit</b>	Triple Pendulum (Drei-Zeiten-Pendel) - Mechanics
Hint	These three pendulums hang above each other
Question 1	The three pendulums all have the same mass. What happens when you swing all three pendulums?
Answers	<ol style="list-style-type: none"> <li>1. They swing at the same speed</li> <li>2. <b>The shorter pendulums take less time to swing</b></li> <li>3. The longer pendulums take less time to swing</li> </ol>
Reasoning	That's right! Since the pendulums are all different lengths, it takes different amounts of time for them to swing. The shorter the length of the pendulum, the shorter time it takes to swing!
Question 2	What happens when you add mass to the pendulums
	
Answers	<ol style="list-style-type: none"> <li>1. <b>The oscillation period does not change</b></li> <li>2. The oscillation period of the swing is faster</li> <li>3. The oscillation period of the swing is slower</li> <li>4. The pendulum swings further</li> </ol>
Reasoning	That's right! Mass does not affect the time it takes for a pendulum to swing. The only thing that changes the time of the swing is the pendulum length and the effect of gravity. On Earth gravity is always the same! To observe how gravity changes the oscillation period, check out <a href="#">Jupiter Pendulum</a> in the Mechanics Sector.
Question 3	Who can swing faster on a swing, an adult or a kid?
Answers	<ol style="list-style-type: none"> <li>1. <b>They swing at the same speed</b></li> <li>2. The adult swings faster</li> <li>3. The kid swings faster</li> </ol>
Reasoning	That's right! When you are riding a swing on a playground, you are actually riding a pendulum! An adult and a kid would swing at the same speed on a swing because mass does not affect the time it takes to swing just like the three pendulums in the exhibit.
<b>Exhibit</b>	Bike Wheel Gyroscope (Velokreisel) - Mechanics
Hint	Look for the metal railing holding two bicycle wheels

Question 1	Spin the wheel and hold it by the handles. Tilt the wheel from side to side. What do you feel?
Answers	<ol style="list-style-type: none"> <li>1. The wheel pulls your arms up or down</li> <li>2. The wheel stops spinning</li> <li>3. The wheel begins to spin faster</li> <li>4. The wheel feels lighter to hold</li> </ol>
Reasoning	That's right! The spinning wheel acts just like a gyroscope! Changing the axis of the gyroscope changes the direction of the force, pulling your arms up or down.
Question 2	 <p>Following the instructions on the card, place the wheel on the stand and spin it really hard while holding onto one of the handles. Make sure you spin the wheel very fast so that you can see the phenomenon. What happens?</p>
Answers	<ol style="list-style-type: none"> <li>1. The wheel falls to the ground</li> <li>2. The wheel stays vertical and rotates around the stand</li> <li>3. The wheel moves up until it is horizontal</li> <li>4. The wheel moves randomly</li> </ol>
Reasoning	That's right! Just like it did in your hands, the force pulls the wheel upwards! This keeps the wheel spinning around the stand without falling! If the wheel does not spin fast enough, the force will be too small, and the wheel will fall.
Question 3	Gyroscopes are often used in planes, ships, and spacecraft, why is this phenomenon often used for navigational instruments?
Answers	<ol style="list-style-type: none"> <li>1. Gyroscopes assist in the lift of an aircraft which is one of the forces that keep planes in the air</li> <li>2. Gyroscopes resist changes in orientation</li> <li>3. Gyroscopes are able to detect objects in front of you</li> <li>4. Gyroscopes can keep vehicles moving during travel</li> </ol>
Reasoning	That's right! A navigational instrument that didn't resist changes in orientation would be very difficult to use everytime you changed direction. Checkout the <a href="#">Gyroscope in a Suitcase</a> exhibit after this tour to see a gyroscope resist your movements in real time!

## Appendix S: Scavenger Hunt HTML

A sample of the Scavenger Hunt HTML is included here. A full listing of files can be found at: <https://github.com/ifeeney/Technorama-Hunt>

Below is the HTML file for Clue 1, German:

```
<!DOCTYPE html>
<html>
  <head>

    <!-- Global site tag (gtag.js) - Google Analytics -->
    <script async src="https://www.googletagmanager.com/gtag/js?id=UA-147518616-1"></script>
    <script>
      window.dataLayer = window.dataLayer || [];
      function gtag(){dataLayer.push(arguments);}
      gtag('js', new Date());
      gtag('config', 'UA-147518616-1');
    </script>

    <meta charset="utf-8">
    <title>Clue 1 German</title>
    <meta name="viewport" content="width=device-width, initial-scale=1">
    <link rel="stylesheet"
href="https://maxcdn.bootstrapcdn.com/bootstrap/3.4.0/css/bootstrap.min.css"
">
    <link href="StyleSheet.css" rel="stylesheet" type="text/css">

  </head>
  <body id="grad">
    <div class="flex">
      <div class="container-fluid" >

        <header id="main-header">
          <h1>Hinweis 1</h1>
        </header>

        <section>

          <!-- All the text starts out being hidden. The appropriate clue
is revealed according to the Path number. -->
          <div class="well">
            <p id="cradle" class="hidden mainText"> Es ist an der Zeit, nach
Ihrem ersten Exponat zu suchen - dieses befindet sich im Bereich
<b>Mechanik.</b> Hier ist ein Tipp: Suche nach den silbernen Kugeln, die in
einer Linie hängen.</p>
            <p id="string" class="hidden mainText"> Es ist an der Zeit, nach
Ihrem nächsten Exponat zu suchen - dieses befindet sich ebenfalls im Sektor
```

```

<b>Mechanik</b>. Hier ist ein Hinweis: In der Nähe, wo die beiden Pendel
verbunden sind, suche nach der weißen Schnur an der Wand! </p>
  <p id=wheel class="hidden mainText"> Es ist an der Zeit, nach
Ihrem nächsten Exponat zu suchen - dieses befindet sich ebenfalls im Sektor
<b>Mechanik</b>. Hier ist ein Hinweis: Suche das Metallgestell mit zwei
Fahrrädern. </p>
  <p id=pendel class="hidden mainText"> Es ist an der Zeit, nach
Ihrem nächsten Exponat zu suchen - dieses befindet sich ebenfalls im Sektor
<b>Mechanik</b>. Hier ist ein Hinweis: Diese drei Pendel hängen
übereinander. </p>
</div>

<div class="panel panel-body">
  <div class="media">
    <div class="media-left">
      <span class="glyphicon glyphicon-search"></span>
    </div>
    <div class="media-body">
      <p>Sobald Sie das richtige Exponat gefunden haben, öffnen
Sie Ihre Handykamera und scannen Sie den QR-Code, um zum nächsten Schritt
zu gelangen.</p>
    </div>
  </div>
</div>

<!-- This will read the Cookie to reveal the clue associated with
the path number the user is on.
  If there is a problem getting the path number, it will
default to path 4. -->
<script>
  function getCookie(name) {
    var nameEQ = name + "=";
    var ca = document.cookie.split(';');
    for(var i=0;i < ca.length;i++) {
      var c = ca[i];
      while (c.charAt(0)==' ') c = c.substring(1,c.length);
      if (c.indexOf(nameEQ) == 0) return
c.substring(nameEQ.length,c.length);
    }
    return null;
  }

  var path = getCookie("pathNum");
  console.log(path);
  if (path == 1) {
    document.getElementById("string").classList.remove('hidden');
  } else if (path == 2) {
    document.getElementById("wheel").classList.remove('hidden');
  } else if (path == 3) {

```

```

        document.getElementById("cradle").classList.remove('hidden');
    } else {
        document.getElementById("pendel").classList.remove('hidden');
    }
}

</script>

</div>
</div>
</body>
</html>

```

Below is the HTML file for Question 3, German:

```

<!DOCTYPE html>
<html>
  <head>

    <!-- Global site tag (gtag.js) - Google Analytics -->
    <script async src="https://www.googletagmanager.com/gtag/js?id=UA-147518616-1"></script>
    <script>
      window.dataLayer = window.dataLayer || [];
      function gtag(){dataLayer.push(arguments);}
      gtag('js', new Date());
      gtag('config', 'UA-147518616-1');
    </script>

    <meta charset="utf-8">
    <title>Question 3 German</title>
    <meta name="viewport" content="width=device-width, initial-scale=1">
    <link rel="stylesheet"
href="https://maxcdn.bootstrapcdn.com/bootstrap/3.4.0/css/bootstrap.min.css"
">
    <link href="StyleSheet.css" rel="stylesheet" type="text/css">

  </head>
  <body id="grad">
    <div class="flex">
      <div class="container-fluid" >

        <header id="main-header">
          <h1>Du hast es geschafft!</h1>
        </header>

        <section>

```

```

    <div class="well">
        
        <p id=mainText> Hier gilt das gleiche Prinzip! Da auf beiden
Seiten jeweils eine Kugel aufprallt, schwingt eine Kugel auf beiden Seiten
nach oben. Der Impuls beider Kugeln bleibt erhalten. </p>
        <p> <b> Wenn sich ein Fußball und ein Tischtennisball mit der
gleichen Geschwindigkeit bewegen, welcher Ball hat dann mehr Schwung?
</b></p>
    </div>

    <div class="container-fluid">
        <div class="row">

            <a href="Clue4de.html" class="btn btn-block hidden
beginButtonde" id=path1Button role="button">Der Fußball hat mehr Schwung.
</a>

            <a href="Completede.html" class="btn btn-default btn-block
hidden beginButtonde" id=path2Button role="button">Der Fußball hat mehr
Schwung. </a>
            <a href="Clue2de.html" class="btn btn-block hidden
beginButtonde" id=path3Button role="button">Der Fußball hat mehr Schwung.
</a>
            <a href="Clue3de.html" class="btn btn-default btn-block hidden
beginButtonde" id=path4Button role="button">Der Fußball hat mehr Schwung.
</a>

            <a href="Question3Incorrectde.html" class="btn btn-block
beginButtonde" role="button">Beide Bälle haben das gleiche Schwung.</a>
            <a href="Question3Incorrectde.html" class="btn btn-block
beginButtonde" role="button">Der Tischtennisball hat mehr Schwung.</a>
            <a href="Question3Incorrectde.html" class="btn btn-block
beginButtonde" role="button">Auch die Dynamik hat nicht zugenommen.</a>
        </div>
    </div>

    <script>
    function getCookie(name) {
        var nameEQ = name + "=";
        var ca = document.cookie.split(';');
        for(var i=0;i < ca.length;i++) {
            var c = ca[i];
            while (c.charAt(0)==' ') c = c.substring(1,c.length);
            if (c.indexOf(nameEQ) == 0) return
c.substring(nameEQ.length,c.length);
        }
        return null;
    }

```

```
var path = getCookie("pathNum");
console.log(path);
if (path == 1) {
    document.getElementById("path1Button").classList.remove('hidden
');
} else if (path == 2) {
    document.getElementById("path2Button").classList.remove('hidden
');
} else if (path == 3) {
    document.getElementById("path3Button").classList.remove('hidden
');
} else {
    document.getElementById("path4Button").classList.remove('hidden
');
}
</script>

</div>
</div>
</body>
</html>
```

## Appendix T: Scavenger Hunt Maintenance Guide

The following guide was created for Technorama to continue to maintain the Scavenger Hunt:

### Hosting the Scavenger Hunt

1. Purchase a domain name. Right now, it is **technoramahunt.com**. This shouldn't be very expensive and will serve as the base for all of the sub pages.
2. Get a web hosting plan. Only the most basic plan is needed, as there is no back-end to the website. When you open the web hosting plan, there will be an option to link to the domain name. Then, you can upload all of the files so they can be available online. Every time you edit a file, you will need to upload it again.

### Editing the Scavenger Hunt

#### *English Version*

This version is fairly simple, as there is only one possible pathway. Below find a chart that correlates question numbers to their exhibit. These files are named things like **Question1.html**.

Exhibit	Vibrating Strings			Pendulum's Cradle			Triple Pendulum			Bike Wheel Gyro		
Question	1	2	3	4	5	6	7	8	9	10	11	12

Our clues for the students to get to these exhibits are always the same, as shown below

Clue1.html	Vibrating Strings
Clue2.html	Pendulum's Cradle
Clue3.html	Triple Pendulum
Clue4.html	Bike Wheel Gyro

Finally, at the end of Question 12, students are taken to the **Complete.html** page.

To change the **text** in these files, change what is written between the `<p>` `</p>` tags. You can create bold words, such as "Mechanics" in the example below, by surrounding the desired text with `<b>` `</b>` tags.



**<p id=mainText>** It's time to look for your first exhibit - this one is located in the **<b>Mechanics</b>** Sector. Here's a hint: Look near where the two pendulums are connected, for the white string on the wall! **</p>**

To change the **answer choices** in these files, let's look at the example below:

```
<div class="container-fluid">
  <div class="row">
    <a href="Question1Incorrect.html" class="btn btn-default btn-block" id=beginButton role="button">The string has no waves</a>
    <a href="Question1Incorrect.html" class="btn btn-default btn-block" id=beginButton role="button">The string moves in chaotic waves</a>
    <a href="Question1Incorrect.html" class="btn btn-default btn-block" id=beginButton role="button">Multiple waves go through the string</a>
    <a href="Question2.html" class="btn btn-default btn-block" id=beginButton role="button">The waves in the string appear to be stationary</a>
  </div>
</div>
```

You can see that each button has its own line. The “href” part is the name of the page to go to when the button is clicked. They should all go to the incorrect page except for the correct answer, which will bring the user to the next question or clue. Other than that, you can edit the text of the button by editing the words the same way you did with the text.

*German Version*

This version is a little more complicated, given that there are four possible routes through the exhibits to avoid crowding. How this works is that when the user begins, a path number (1-4) is chosen for them. That determines what order they will visit the exhibits in. I've put the four routes below.

Path	First Exhibit	Second Exhibit	Third Exhibit	Fourth Exhibit
1	Vibrating Strings	Bike Wheel Gyro	Pendulum's Cradle	Triple Pendulum
2	Bike Wheel Gyro	Triple Pendulum	Vibrating Strings	Pendulum's Cradle
3	Newton's Cradle	Vibrating Strings	Triple Pendulum	Bike Wheel Gyro
4	Triple Pendulum	Pendulum's Cradle	Bike Wheel Gyro	Vibrating Strings

Clues

Because of this, our clues change depending on the path number the user is on. If you want to edit a clue for an exhibit, you will have to edit it on all of the Clue files.

Path	1	2	3	4
Clue1de.html	Vibrating Strings	Bike Wheel Gyro	Pendulum's Cradle	Triple Pendulum

Clue2de.html	Bike Wheel Gyro	Triple Pendulum	Vibrating Strings	Pendulum's Cradle
Clue3de.html	Pendulum's Cradle	Vibrating Strings	Triple Pendulum	Bike Wheel Gyro
Clue4de.html	Triple Pendulum	Pendulum's Cradle	Bike Wheel Gyro	Vibrating Strings

As all the orders are different, the user will be taken to the **Completede.html** page after completing the last question at the last exhibit of the path they are on.

### Questions

Below find a chart that correlates question numbers to their exhibit. These files are named things like **Question1de.html**.

Exhibit	Pendulum's Cradle			Vibrating Strings			Triple Pendulum			Bike Wheel Gyro		
	1	2	3	4	5	6	7	8	9	10	11	12
Question												

You change the **text** in these files the same way you change text in the English version. However, changing **questions** can become tricky on question numbers 3, 6, 9, and 12 because the options must change depending on the path. Let's take a look at Question 3 to see this.

```

<div class="container-fluid">
  <div class="col">
    <a href="Clue4de.html" class="btn btn-block hidden beginButtone" id=path1Button role="button">Der Fußball hat mehr Schwung. </a>
    <a href="Completede.html" class="btn btn-default btn-block hidden beginButtone" id=path2Button role="button">Der Fußball hat mehr Schwung. </a>
    <a href="Clue2de.html" class="btn btn-block hidden beginButtone" id=path3Button role="button">Der Fußball hat mehr Schwung. </a>
    <a href="Clue3de.html" class="btn btn-default btn-block hidden beginButtone" id=path4Button role="button">Der Fußball hat mehr Schwung. </a>
  </div>
  <div class="col">
    <a href="Question3Incorrectde.html" class="btn btn-block beginButtone" role="button">Beide Bälle haben das gleiche Schwung.</a>
    <a href="Question3Incorrectde.html" class="btn btn-block beginButtone" role="button">Der Tischtennisball hat mehr Schwung.</a>
    <a href="Question3Incorrectde.html" class="btn btn-block beginButtone" role="button">Auch die Dynamik hat nicht zugenommen.</a>
  </div>
</div>

```

The three buttons listing the incorrect answers are located on the bottom. I put a blue box around these. These are always visible to the user. The four buttons listed above, in the red box, all have the same text. That is because only one will ever show up, depending on the path the user is on. If you notice, each will send the user to a different page when clicked.

I don't expect you will be changing the functionality of these buttons, but just know that if you want to edit the correct answer on Question 3, 6, 9, or 12, make sure that you change the text on all four of the buttons in the HTML.

### Editing Images

If you wish to edit an image, you must add the new image file to the "images" folder. Then, find the line of HTML that is formatted like this:

```

```

The parts that you will need to change are bolded. For example, if you wanted to replace the current image with an image you added to the images folder called "Stefan.jpg" you would need to change the HTML line to be the following:

```
img class="img-responsive" src="images/Stefan.jpg" alt="Stefan Picture">
```

The src is the image file name exactly. The alt is just a name you come up with for the picture, and will not be displayed unless the image cannot be loaded.

### QR Codes

The QR codes should be made for the appropriate webpages as shown below. Replace "yourDomainName" with whatever your domain name is (for example, right now it is "technoramahunt"). Note that there are separate QR codes for English and German versions of the Scavenger Hunt. We placed these on the English/German sides of the Information Card for that exhibit.

Beginning QR code	<b><i>yourDomainName.com</i></b>
Vibrating String Exhibit - English	<b><i>yourDomainName.com/Question1de.html</i></b>
Triple Pendulum Exhibit - English	<b><i>yourDomainName.com/Question7de.html</i></b>
Bike Wheel Gyroscope Exhibit - English	<b><i>yourDomainName.com/Question10de.html</i></b>
Pendulum's Cradle Exhibit - English	<b><i>yourDomainName.com/Question4de.html</i></b>
Vibrating String Exhibit - German	<b><i>yourDomainName.com/Question4de.html</i></b>
Triple Pendulum Exhibit - German	<b><i>yourDomainName.com/Question7de.html</i></b>
Bike Wheel Gyroscope Exhibit - German	<b><i>yourDomainName.com/Question10de.html</i></b>
Pendulum's Cradle Exhibit - German	<b><i>yourDomainName.com/Question1de.html</i></b>

### GitHub

As a final note, if you happen to lose access to the files, a copy of the files I gave you are located on Github. You can download these from the link below:

<https://github.com/ifeeney/Technorama-Hunt>