EXHIBIT DEVELOPMENT IN A SCIENCE CENTRE:

Internship at Glasgow Science Centre

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Internship Report

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Internship report submitted to fulfil the necessary requirements to get the Master's degree in Science Communication, conducted under the scientific supervision of Dr Robin Hoyle and Professor Joana Lobo Antunes.

To my mother

Acknowledgments

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Abstract

This report describes an internship at Glasgow Science Centre, in the city of Glasgow, Scotland. The internship was integrated into the Floor 1 Refresh Project and in the field of exhibit analysis and improvement. In this work, we consider that exhibits are the interactive objects that explain a certain scientific phenomenon through their use, in science centres and museums.

The F1 project consists in reorganising and improving the entire gallery on the Floor 1, but the internship itself focused on a specific cluster of exhibits and in testing new ways of interpretation (referring to the interpretative labels fixed on the exhibits). After doing a SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis on the Floor 1 and sharing some general ideas, the work focused on a Prototype Exhibit Cluster with four exhibits regarding the theme of the Sound: *the Singing Bowl*, the *How does the Sound move through air*, the *Guitar Oscilloscope* and *the Xylophone and the Soundbox.* Different interpretative labels were tried as well as different placements with a randomly selected audience. The original labels in the shape of prisms were tested, as well as some prototype new texts in simple panels with curiosities about sound. It started with front-end evaluation with one observation of the visitor's interaction with the exhibits as they were before. Then, the exhibits were moved to create the Prototype Sound Cluster and it was made a formative evaluation with two more observations with the new prototype texts. Time spent in each exhibit was tracked as well as signs of Learning Behaviours and the results were treated to access the Visitor Engagement Profile of the exhibits. Final interviews with other visitors and some staff were also made. The data collected, allowed to test gradually changes in the

exhibits during this short prototyping process. The interviews help to understand improvements to make in these exhibits for the future.

Key Words: Science centre; Exhibit; Interpretation; Visitors; Prototyping; Evaluation; Sound;

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Acronyms and abbreviations

APE – Active Prolonged Engagement

CERN - European Organization for Nuclear Research

EDGE – Exhibit Design for Girl's Engagement

F1 – Floor 1

GSC – Glasgow Science Centre

SMSTCs - Science Museums and Science and Technology Centres

STEM - Science, Technology, Engineering and Mathematics

VEEAM – Visitor Engagement And Exhibit Assessment Model

VEF - Visitor Engagement Framework

VEP – Visitor Engagement Profile

General Introduction

As a student in the MSc Science Communication (*Mestrado de Comunicação de Ciência)* in the University New of Lisbon (NOVA), I had the opportunity to do an internship as part of my Master's degree. The internship was held at GSC (Glasgow Science Centre) integrated into the Projects Team under the supervision of Dr Robin Hoyle, tutor in the internship institution and Dr Joana Lobo Antunes, tutor from University New of Lisbon.

To do an internship was a good challenge and gave me some of practical experience. Knowing that the UK is widely recognised as developed in Science Communication, and being able to speak the language, I decided to go to Scotland and do the internship on abroad. The internship lasts two and a half months from 19th September and extending to 2nd December. This period in GSC not only provided lots of lessons about exhibit analysis and improvement but also gave me some insight about the Scottish work in science centres.

1. Theoretical contextualization - science centres and the development of exhibits

1.1. Science centres

> *"Learning outside of formal institutions is certain to be of growing importance in relation to the formal school curriculum"* (Wellington, 1990)

The traditional form of education in schools, with formal learning, has been widely discussed, with terms like non-formal and informal education to be increasingly mentioned in the recent years (Colardyn & Bjornavold, 2004; Tolppanen & Vartiainen, 2015). Science centres have occupied a big part of the discussion in terms of their role in science education (Danilov, 1982; Eshach, 2007; National Research Council, 1996). McManus (1992) recognised two strands of science communication museums: the first

strand presents thematic exhibits portraying the big concepts of science like evolution and energy for example. The second strand presents a collection of interactive exhibits, where each exhibit represents a specific idea or concept. We can extend the term science centre to different types of museums and spaces that promote science in different ways, but this report is focused on the interactive hands-on exhibits type of centre which is close to the second strand. Nevertheless, it's important to take note that the terms "interactive" and "hands-on" are different. Rennie & McClafferty (1996) explain that hands-on exhibits require a physical move from the visitor, like pushing a button or touching an object, which doesn't mean that the exhibit will be responsive. Interactive exhibits respond to the action of the visitor and invite an additional response. The difference is that interactive exhibits offer feedback and invite a further interaction.

Though the major emerge of science centres started around 40 years ago (Danilov, 1982), the science centre movement began with the grand museums of science and industry in the begging of the XX century, with examples such as the London Science Museum (opened to public in 1928), the Deutsches Museum, Munich (1925) and the Museum of Science and Industry, Chicago (1933). Nevertheless, the "hands-on" philosophy in North America was also very important for the science-education reform (Beetlestone, Johnson, Quin, & White, 1998). It was with the opening of the Exploratorium, in San Francisco, USA, in 1969, with a "library of experiments" that the science museum traditional mould broke. As stated by the Exploratorium (2017), this science centre started the idea of allowing visitors to learn and explore by themselves. The founder, Frank Oppenheimer, among people in other institutions, suggested that designing interactive displays could captivate non-scientific people (Grinell, 1992).

Besides Mcmanus (1992), other authors like Danilov (1982) distinguished old-style museums as focused on cultural heritage through the presentation of objects and science centres as places to entertain with participatory and interactive exhibits. Recently, Monteiro, Martins, de Souza Janerine, & de Carvalho (2016) referred the importance of bringing schools and science centres together through collaborative actions. The same authors assume that science museums and science and technology centres (SMSTCs) and additional places of science communication are classical places of non-formal education, creating knowledge through exhibitions and activities. Candau

(2010, p.13) described the importance of recognising, supporting and expanding new educative places and exploring different ways of relating to knowledge, to deal with different people.

1.2. Design of exhibitions – conceptualization

Several studies have been made about the design of exhibitions for science centres. Part of the process of designing a science exhibition is like the art and history museums exhibitions. Science centres have people that act like curators and they start the creative process through investigation of a certain theme. Steps include reading books and catalogues of exhibits, conducting internet research, travelling to see relevant exhibitions and/or collections and writing down thoughts to clarify the idea of the project. Science Education Officers ask themselves other questions such as:

> "*What are the gallery's priorities in terms of exhibitions? What is the institutional context? How is the location of the space for exhibits? How is the configuration and size? Which staffing and equipment resources are needed?*" (Love, 2010).

When science centre's Education Officers have a clear idea for the project, they start choosing exhibits from catalogues or ask exhibition designers to project new exhibits. These exhibits must serve at the same time as a medium to educate about a science concept and as entertainment. However, some authors argue that learning loses out when focusing in the entertainment (Shortland, 1987; Wymer, 1991). The challenge of balancing the amount of fun and educative purpose is discussed by different researchers. Allen (2004) an investigator in Exploratorium, explains that although public spaces that promote science seem very appealing comparing to the science classroom, the same strengths ("*on the exhibit floor there is no accountability, no curriculum, no teachers to enforce concentration, no experienced guide to interpret and give significance to the vast amounts of stimulus and information presented*") can be the exact weaknesses in terms of learning. The researcher then emphasises that a good

design process must be supported by a strong program of research and evaluation and it's crucial to study the layout and orientation of the surrounding environment of the exhibit. There are still many questions to be answered regarding the aspects of learning such as:

> "*Should we make explanations of scientific phenomena easy to locate and understand, or do we want visitors to rise to the challenge of investigating phenomena in their own terms? Should we create more sequenced exhibits and linear paths to reduce the effort of navigation and connection-making among exhibits, or should we keep the floor-plan open because connection-making is exactly where we believe visitors should be spending their effort?".*

The same author says that when designing exhibits to extend engagement and self-direct inquiry by visitors and avoiding the "one-line" explanation of a phenomenon there is the risk of misunderstanding the scientific message.

Another approach in creating exhibits is idealising them to have "attraction power", "holder power" (Boisvert & Slez, 1994; Sandifer, 2003) and "engagement power". Attraction power happens when the visitor starts to interact with the exhibit. Holder Power happens when the visitor stays a certain time interacting. Engagement power is the feature of exhibits that can hold the attention of the visitor for some minutes and the subject shows clear signs of engagement. Exhibits can have attraction power, because of their shape or size, and not necessarily have holder power, as they don't stimulate the visitor for the interaction.

Concerning the educational value, the design of exhibits it's also important. A study (Afonso & Gilbert, 2007) analyses the short-term consequences of 125 visitor's use of two different types of exhibits: "*examplars of phenomena*" vs "*analogy based*". This description for interactive exhibits was proposed by Stocklmayer and Gilbert (2002a), being the "exemplars of phenomena" about a real-world phenomenon, providing direct experience with that phenomenon and the "analogy based" an analogical representation "of a consensual scientific model of a phenomenon". The study reveals that the type of exhibit constrains the nature of the understanding achieved, as the use of "analogy based" exhibits may lead to misconceptions.

Anderson and Lucas (1997) also studied how to design an effective exhibit and identified some design properties that influence the potential of the exhibit as educational material. On their study, the size of the exhibit, for example, draw the attention of 13-14-year-old students. Other particularity enhanced and very well studied, is that exhibits are effective if they have some sort of link to the everyday life. Moreover, Gilbert and Priest (1997), found that 8-9-year-old students recognising the familiar object in the exhibit was critical.

Aiming to reach the engagement of a specific public another project that studies the design of exhibits is the Exhibit Design for Girl's Engagement (EDGE) by Exploratorium (Dancstep & Sindorf, 2016). This is focused on identifying the most important design attributes for engaging girls at STEM (stands for science, technology, engineering and mathematics) exhibits. By creating a list of potential girl-engaging attributes, and testing around 300 exhibits, researchers select the most significant design features for scientific exhibits (fig. 1).

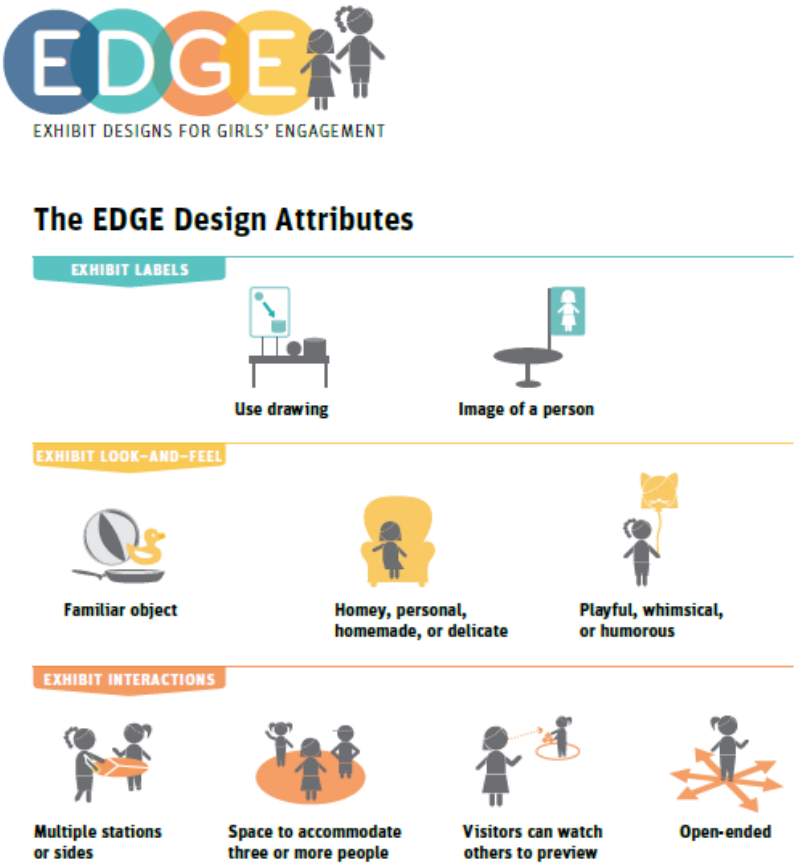


Figure 1 - EDGE design attributes selected after visitor research and evaluation made by the Exploratorium (Dancstep & Sindorf, 2016).

Gammon and April (2008) present a paper with some practical steps on how to make interactive exhibits. This is a list of characteristics to select the best interactive exhibits according to the authors:

> *"• Provides the visitor with choice and control over the experience;*
> *• Provides a challenge, with clear goals and immediate feedback on performance, that is (just) within the capability of the visitor;*
> *• Inspires playfulness among visitors;*
> *• Provides an experience that can be shared with other people;*
> *• Provides a reward that is beautiful, delightful, wonderful, unique, intrigue – i.e. is not just a lot of text;*
> *• Provides an opportunity to make something or achieve something visitors feel is worthwhile;*
> *• Are focused on a particular theme, message or experience. Try and avoid the temptation to shoehorn several ideas into one exhibit – this usually creates a confusing mess*"

Studies have shown the importance of children's free playful exploration, and the link to scientific work. DeWitt and Osborne (2010) had shown that importance, revealing exhibit design factors for engaging 9-11-year-old students such as hands-on interaction, multiple opportunities for exploration, phenomena contrasted with previous experiences or that was perceived as cognitively challenging.

1.3. Interpretation

First, it's necessary to understand what interpretation is in this context. Veverka (2003) wrote a guide in which he uses the definition developed by Interpretation Canada which states: "*Interpretation is a communication process designed to reveal meanings and relationships of our cultural and natural heritage, to the public, through first-hand experiences with objects, artifacts, landscapes, or sites".*

In this report, “interpretative label” is considered to be all the titles, orientation/introductory labels, section or group labels (Serrel, 1996) accompanying the exhibits. The most part of the study during the internship focused on understanding ways to improve the delivering of the interpretative message in certain exhibits, whether through changes in the labels or in the exhibits themselves.

An “interpretative” exhibit holds information that visitors can comprehend, learn and relate to. Lots of exhibits are wrongly “called” interpretative, as mostly just present information. Veverka explains that in the exhibit development several details count to make the most interpretative exhibit.

In the same guide, Veverka warns that an exhibit, even if it’s very hands-on, it is limited if it’s not also “minds-on”. He gives the example of exposing objects to be held without stimulating further questions:

> *“So a person picks up and looks at a deer antler – then what? They put it down and pick up a turtle shell – then what? What is the point in the hands-on activity? To have these exhibit really work you need to have some “minds on” planning or outcomes for the exhibit activity. This exhibit could be enhanced by asking “Pick up the deer antler and see how many different tools you think you could make from it – what would those tools be?”. Now the mind has a focus or objective that goes with the activity.”*

This case also sustains, as well as other researchers in literature, that the label must act as a complement of the exhibit. Bitgood, (1996) suggests that this complement can be achieved by focusing the attention on details such as explaining science principals or explain what the visitors should look for. Labels and exhibits should have a “dialogue” between them, answering the visitor’s questions first, and then try telling them what “they should know”, and direct the visitor for the most important characteristic/intention in the object.

1.4. The visitors

Science centres are public spaces where science is communicated and explored. Like museums, zoos, aquaria and botanical gardens, science centres are often mentioned as "*informal learning settings*" where "*free-choice learning occurs"* (Falk, 2001). However, it's not that simple to grab the attention of the visitor and allow them to engage effectively with the exhibit. The science centres are full of interactive exhibits, so usually visitors only interact with each exhibit for a few seconds. Allen (2004) argue that the experience (every intermediate step with it) must be sufficiently motivating for the visitor to engage in a successful way.

Yet, it is very difficult to "control" the steps that the visitors make. Even if the exhibits are designed and organised in a sequence, doesn't mean the visitor will interact in the intended "proper" order. Science centres did studies about possible changes, including the well-known Exploratorium, in San Francisco. Allen (2004) also found out that changes in the public space including more lighting, seating, acoustic baffling to reduce ambient noise and orientationally devices make a difference.

Nonetheless, the public can be very different: different ages, gender, interests etc. How diverse can be the public and how that can affect the way they perceive the exhibits? The clear majority of the public in GSC are children from school visits, but sometimes families also visit and occasionally some couples or groups of friends. In the same group, for example, a family, it can happen that different members want to explore the exhibits differently. The adults may want to explore deeply the scientific phenomena but they are conditioned by their children who are distracted more easily (Hsi, 2004).

Rosenthal and Blankman-Hetrick (2002) noticed the differences between families and a school trips in terms of their interactions. The schools move much faster and have less control of the children since they are so many at once. Even the school visits themselves are shaped by the teachers' agendas and their mediation during the visit. In practice when observing visitors interacting with exhibits, it's important to understand that different visitors interact with the exhibits differently.

A study by Falk & Storksdieck (2005) demonstrated that visitor learning can be affected by variables like prior knowledge, interest, motivation, choice and control, the different organisation and interaction within a social group, as well as the orientation, architecture and exhibition design. Which means that when studying a certain subject interacting with exhibits, lots of uncontrolled variables may take place.

1.5. Evaluation

A big part of the exhibit development work is based on studies of evaluation. The Exploratorium does evaluation quite often, one of the methods being the observation and analysis of the audience. As they are one of the most successful science centres in the world, GSC is very inspired by their studies and good practices. Barriault and Pearson (2010) emphasise a lot the conductive evaluation, not only at the end of the development of the exhibits but also the front-end evaluation, at the beginning of the prototyping.

It is also possible to find ways to know what needs improvement in a more direct way, by doing interviews with the visitors. Different kinds of questions are possible and in different ways. It has been noted (Brace, 2004) that an open question is made to get the own words from the visitors which can be followed by a short or long answer. The purpose is to seek for spontaneous responses. Closed questions have more predictable answers like the common “yes” or “no”. Though it’s easy to organise these answers it’s not likely to extract as much insight as in the open questions, but both approaches can be effective.

Tisdal and Perry (2004) explain the APE term for Active Prolonged Engagement, that is part of the Going APE! Research/development project in Exploratorium. The project uses research and evaluation to understand how the visitor’s experience is conditioned to the design and development of the exhibits (Humphrey, Gutwill & Exploratorium APE team 2005). After some studies, they realised that APE exhibits had a set of characteristics, and were very successful. For instance, summative evaluation (Tisdal & Perry, 2004) showed that APE exhibits engaged visitors twice longer than traditional exhibits. The study also showed that the APE exhibits lead the visitors to

make “driving questions” when approaching the exhibit. The traditional exhibits had more similar and fewer questions, like “what’s going on here”. Additionally, visitors physically interact in a more diverse manner in terms of pattern and sequence on APE exhibits (Allen, 2004).

The analyses of the studies from Exploratorium gave insight about characteristics in the exhibits in terms of interactivity:

(1) multiple options with equal salience can overwhelm visitors;

(2) interactivity by multiple simultaneous users can lead to disruption;

(3) interactivity, even by a single visitor, can disrupt the phenomenon being displayed;

(4) interactive features can make a critical phenomenon difficult to find, and

(5) secondary features can displace visitors’ attention from the primary one

(Allen & Gutwill, 2004).

1.6. Accessing engagement to identify learning

Barriault and Pearson (2010) methods were particularly interesting to use in this internship. Those methods of evaluation are based on learning theories and attempt to understand how to improve exhibits based on the visitor signs of engagement.

It’s difficult to understand if a visitor is learning (or how much) when is interacting with the exhibits. It is known that engagement is key to learning (Csikszentmihalyi & Hermanson, 1995) because engagement leads to the making of meaning. Rennie & McClafferty (1996) characterised visitor learning behaviour with approaching an exhibit, reading the signage, asking questions, discussing the exhibit, duration of time spent at the exhibit etc. Barriault and Pearson (2010) looked for the relation between learning-associated behaviours and the visitor engagement and exhibit assessment model. This

model that can generate real insights into the impact of exhibits on the visitor learning experience.

> "*The visitor engagement and exhibit assessment model consists of*
> *1. a visitor engagement framework (VEF) of observable behaviours;*
> *2. the arrangement of those behaviours into learning related categories;*
> *3. a visual representation of the level of engagement elicited by an exhibit; and*
> *4. a model that indicates where intervention might increase visitor engagement with an exhibit*."
> *(5) secondary features can displace visitors' attention from the primary one*
> (Allen and Gutwill, 2004).

The Table 1 is often used in the studies of Evaluation at GSC. Times spent at the exhibits and observable actions are tracked while watching the visitor's interaction with the exhibits. The learning behaviours are grouped in three categories, inspired in Barriault and Pearson paper (2010) (initiation behaviours, transition behaviours and breakthrough behaviours).

Table 1 - Table used in the observations of the visitors with the actions grouped in three categories of Learning Behaviours;

	Observable actions by the visitor	**Learning Behaviours**
1	Interacted with exhibit but left before complete or used exhibit incorrectly	**Initiation behaviours**
2	Observing others at exhibit or observing exhibit itself	
3	Repeated activity at exhibit	**Transition behaviours**
4	Read the label	
5	Expressed positive responses (smiling, excited, eagerness)	
6	Referred to past experiences whilst using exhibit	**Breakthrough behaviours**
7	Sought help with exhibit/encouraged others to join in/showed others how to use	
8	Significant engagement (3-5+ minutes)	
9	Comments	-

2. Practical contextualization - The Glasgow Science Centre and the internship

2.1. Glasgow Science Centre

The Glasgow Science Centre is an independent Scottish Charity and works as a public space on the south bank of River Clyde in the city of Glasgow, Scotland. Highlighted as one of Britain's must-see visitor attractions, the centre aims to be a place where people can learn science while having fun exploring interactive exhibits to feel like scientists for a day. The centre was opened in June 2001 by Queen Elizabeth II.

The design and construction of Glasgow Science Centre resulted from a victory of the National Competition – the largest Millennium Commission-funded project in Scotland as reported by the winners, BDP, a major international practice of architects, designers, engineers and urbanists. The Centre is composed of three main buildings: The Science Mall, The Glasgow Tower and the IMAX cinema (see fig. 2).

Figure 2- A photograph of the Glasgow Science Centre. Building on the left: Imax Cinema. Building in the middle: Science Hall. Tower on the right: Glasgow Tower. Source: http://www.mapsofworld.com/travel/destinations/scotland/glasgow-science-centre/attachment/glasgow-science-centre-2

The Science Mall has 3 floors of interactive exhibits, a planetarium, two theatres, a lab, a café, a shop and spaces to do workshops and science shows. The current exhibitions are “Bodyworks” on the Floor 3, “Powering the Future” on the Floor 2 and “Explore and Discover” on the Floor 1.

GSC mission is more than providing a fun experience to the visitors. Having this in consideration, when working in prototype exhibits it is necessary to balance the number of science facts while making sure the experience is fun for the visitor. It’s good that visitors learn something new, but at the same time, the exhibits cannot be too “boring” nor too “intellectual”.

On the other hand, having fun with science is as important as learning facts because it makes people trust in science, building a good science image in a long term.

Glasgow Science Centre tries to follow precisely that, the notion that science is much more than already known ideas.

Danilov made a description (1982) about science centres, that the GSC uses as motivation source.

> *“There is nothing as effective as a contemporary science centre in stimulating interest, communicating information, and entertaining the public in the fields of science, technology, industry and health.*
>
> *They have achieved this position by focusing on the present and future rather than the past; by emphasising enjoyable participatory techniques; and by being imaginative, flexible, and persistent in the furtherance of public science education.*
>
> *They will continue to evolve, improve, and develop new approaches as they respond to society’s changing needs.”*

In the creation and design of hands-on, interactive experiences, GSC seeks to be:

A place to learn

A place to have fun

A place to do science

A visitor attraction

A place to celebrate human endeavour

A place of curiosity and wonder

A place to be inspired

GSC philosophy in terms of designing exhibits goes along the APE project, to encourage visitors to bring more of themselves – their fascinations, desires, questions, goals and expectations – to the exhibit experience.

- **Active** visitors are in the driver's seat, deciding for themselves what to try next rather than following a set of instructions.
- **Prolonged** means that visitors spend more time with the exhibits, getting more involved with the phenomena than they might at other exhibits.
- **Engaged visitors** try a variety of things at the exhibit, with each action they take somehow building on their previous actions.

2.2. Excitement Gallery Design – Refresh of Floor 1

The Floor 1 (F1) Refresh Project of the Science Hall is about creating an exciting introduction to the wonders of science and the science centre. The philosophy is to inspire visitors in becoming scientists, focusing on hand-picked amazing scientific phenomena and opportunities to Explore & Discover. The Project covers the increase in the number of interactive, functioning phenomena based exhibits, the re-interpretation to increase connection for visitors to the interactive exhibits and the refreshing of the look & feel of the gallery.

Figure 3 – Part of the floor 1 (Physics area). Source at: https://www.expedia.com/Glasgow-Science-Centre-Glasgow.d6081475.Vacation-Attraction (Expedia, Inc, 2017)

F1 is about the fundamentals of science: magnetism, electricity, physics, maths, forces etc. At the moment, the exhibits of the floor present labels usually in two formats, either is a printed panel or a prism. Each label has a title, instructions and an explanation of the idea presented by the exhibit. The walls of the floor are free from interpretation and very empty except for a quote on the value of play "We don't stop playing because we grow old; we grow old because we stop playing." – George Bernard Shaw

The space has some organisation in terms of exhibits being related with science branches, but there is still some mixing and little sense of that context for the different zones (fig.4). There isn't a chronological organisation in the floor, all the exhibits are displayed without a beginning or an end. The visitors do not take a linear journey when exploring the floor. Each exhibit seems to be isolated, not contributing to a broader narrative or a sequence.

The F1 Refresh Project is necessary to find a better explanation for the visitor of what space "explore and discover" is about.

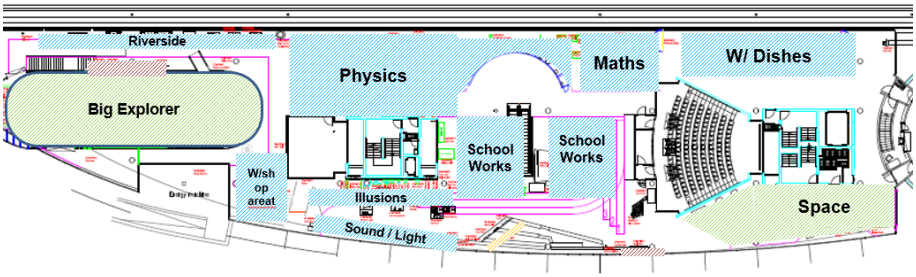


Figure 4 – Sketch of the Floor 1 exhibit themes location. All the floor is part of the F1 Refresh Project except for the Big Explorer and Space Zone.

Some ideas the team intends to cover within this gallery are:

- To be a space where visitors explore and discover the foundations of science;
- As it's the first floor, it is the initial experience in the centre. This should be a 'high energy' floor that encourages visitors to engage in an open exploration of the free-standing interactive exhibits.
- The hands-on exhibits will be in loose clusters that illustrate the principle phenomena and experiments associated with the broad subject areas. They will be designed to promote and facilitate exploration and self-discovery.
- Visitors will learn that exploration and discovery are the driving forces behind scientific research;

2.3. Internship relevance

By integrating the internship in this project, it was created a specific plan that involved experimenting new ways of interpretative content and trying to understand generally how to improve what was already in the exhibition of the F1. Starting by looking in the F1, it was considerate to create more organisation between the exhibits (for example chronologically) to consolidate better the knowledge.

Some of the exhibits in the F1 were there since the opening of the centre. The field of sound was later chosen to be tested on the Floor 2. It couldn't be tested in the Floor 1 because of an unforeseen event explained further in the Methods section of this report.

The personal goals in terms of knowledge, skills and competencies to be acquired by the end of the internship (Expected Learning Outcomes) were:

- To build knowledge of exhibition design processes
- To develop skills in research and interpretive writing
- To develop project management skills

I do feel that I got all those goals achieved.

Speaking of a wide range of impacts, this internship report used interesting methods that other science centres may want to reproduce. It's interesting particularly to me, coming from a Portuguese background, working in a Scottish science centre and following several guidelines from the USA science centres. Some of the evaluation tests done, such as the observation of single exhibits each time and tracing the data in terms of the engagement of the visitors, are not usual in Portugal, although being common in the USA and the UK science centres. It would be exciting if this work could inspire Portuguese science centres to test similar methods of evaluation.

After using those methods in the Sound Prototype Cluster, it was clear they were effective, so the observations and interviews could be reproduced in other clusters of the Floor 1. Basically, it's suggested to prototype with these types of tests the rest of the F1 project.

Finally, the more specific “results” of the Sound Cluster Prototyping can assist the GSC Projects Team, by suggesting new types of labels and interpretation and small details to be improved in the four exhibits tested.

3. Methods

3.1. Analysis and Creative Process

The process of building new parts of an exhibition takes a lot of time (months, even years) and requires a multifaceted team. The Projects Team is composed of graphic designers, exhibition designers, IT specialists, science education officers, project managers and exhibition developers.

The first days of the internship were about getting familiar with what GSC do, how they do it and understanding what they were trying to achieve with Floor 1. As I arrived at the GSC, I was instructed to start visiting all the floors, attend some science shows, go to the planetarium and visit the Glasgow tower.

3.1.1. General Ideas over the Floor 1

The interactive exhibits were explored, to get close to the experience of the visitor and general notes about the F1 were taken. I had meetings with different members of the staff and read over existing materials about the overall thoughts and plans of refreshing in floor 1. Part of this familiarisation with the centre was the task of collecting thoughts on the exhibits of F1, thus a list of the existent exhibits was made and catalogued in terms of science phenomena and science branches.

With the thoughts and ideas reunited, a SWOT (Strengths, Weakness, Opportunities and Threats) analysis was made to provide a critical review about the Floor 1 (Table 2). The SWOT analysis is a collection and portrayal of factors that might

have an impact (Pickton & Wright, 1998), commonly used in different companies and organisations to get a critical review of current situations. Literature shows some cases of success, such as the SWOT analysis of Dell Computer Corporation to implement mass customization, just-in-time manufacturing and direct interest sales (Collett, 1999).

Table 2- SWOT analysis of the Floor 1

STRENGTHS	**WEAKNESS**
• The view from the windows in the F1 is very nice • The floor is very spacious • Lots of exhibits to explore • Exhibits cover several fields (lots of possibilities) • Easy to relate to them and put in "groups" • There are some interpretation that fit well the exhibits (illustrations are very helpful) • Very cool and fun exhibits (e.g. points of view; rolling uphill; Bernoulli blower) • Simple information in the interpretation	• General organisation and decoration of the floor needs improvement, including the understanding of what the floor is about • Lack of some elements when talking about fundamental science (e.g. chemistry and composition of the matter, time and more about energy) • On the other hand, plenty exhibits about magnetism • The exhibits need to be put in "order" and in groups • Tables of exhibits could be more modern • Some exhibits lack information regarding natural phenomena, daily-related curiosities, general info • Some exhibit design may be confusing (e.g. the Big Spark is a red box in a wall – people might think that is some kind of electrical or fire material instead of an actual exhibit)
OPPORTUNITIES	**THREATS**
• To understand the F1 general potential • To put more information in the exhibits (e.g. Sight Test Eyechart, Bernoulli blower, rolling race) • To refresh the floor in order to tell a "story", starting at the end of the escalator with engaging wall. That	• The type of interpretation of the "ropes/get knotted" may not be suitable for every single exhibit – challenge is how to find interpretation suitable for all? • Need to be careful about giving the right amount of information to the public • Stuck with the tables already there

might be a way to start a logical pathway. • Challenge to put the space more "human" – need to build connection • To find new interpretation strategy (making new interpretative models) • To have a general decoration and organisation that indicates the main theme of the floor and also per group/field of the exhibits • To improve the first impression of the floor • To improve the exhibits technically and aesthetically speaking • Opportunity to have new exhibits or new fields (e.g. chemistry)	• The refresh of the floor cannot exceed the budget • To put the space more human or to do storytelling without neglect the scientific rigour • It is necessary to focus also in the science fields that are there • To put information in the exhibits without make it boring (and should some exhibits keep open-ended?) • Difficulty in moving exhibits • Attention with the introduction of chemistry (must be safe)

The improvement was needed on the floor 1: the ceiling, some grey walls (e.g. in the whispering dishes zone) and the floor (see whispering dishes zone in fig.4). Thoughts were formulated about having specific decoration to help in the organisation of the galleries and "guide" the visitor. A list of subjects was created (table 3) to understand if/how these different sub-themes could be related to the existing/new exhibits.

At this point, the exhibits concerning magnetism, sound, forces and other subjects were a little mixed in F1 and not completely separated by clear zones as in fig.4.

In terms of adding new exhibits, it was realised the lack of chemistry principles associated with the exhibits.

Table 2 - A list of possible sub-themes related to the exhibits on the floor 1;

Possible sub-themes to create in F1	
Senses	Mechanics
Maths/Geometry	Electricity
Illusions	Electromagnetism
Physics	Magnetism
Motion	Space
River Clyde	Fluids
Forces	Waves
Air	Light
Pendulum	Sound

3.1.2. Interpretation analysis

One of the main objectives of the Project was rethinking the interpretation. As referred in the introduction section, the labels on F1 were mostly in a prism shape. Although this makes the interpretative label to look very original, sometimes doesn't work well in interactive *hands-on* exhibits. For example, in the "points of view" exhibit, a person is in a moving circle and must kick a ball and hit the centre of the circle. While the visitor is exactly inside the exhibit, the subject cannot check the interpretation prism that is located on the wall, while playing with the exhibit at the same time. In this specific case, static interpretation like simple boards/panels could be more effective.

Some labels were quite simple, not giving much information about interesting facts concerning the scientific principle behind the exhibit in the everyday life. One example is the jet with the big beach ball (that shows the Bernoulli effect). It could be interesting to show that this effect is the same that happens in the wings of the planes because planes are familiar objects inherent to the everyday life of the public. This can work as an attractive feature in the label, as defended by some authors because it goes

along with characteristics of a good interpretative label. For instance, the fact that the visitor is driven by curiosity (Allen, 2004), the fact that when the label tells a story it becomes more interpretative (Serrel, 1996) and because planes are a topic that visitors can relate to (Veverka, 2003). To sum it, having this information could be a nice curiosity in the exhibit.

Suggestions

- ✓ Some exhibit labels could have more text regarding natural phenomena, daily-related curiosities (e.g. Sight Test Eyechart, Bernoulli blower, rolling race).

3.1.3. Idealisation of Clusters

Around 23 exhibits were chosen as examples (using 3 or 4 exhibits per sub-theme) and circles of clusters were draw in sketches (sketches in Appendix B and C), to think how they could relate to each other and have a logical order.

The team had already collected some ideas on how to divide the clusters (Appendix A). A general appreciation of these ideas was made and it was suggested to create around 7 sub-themes (Appendix D).

Suggestions

- ✓ Create organised spaces with the exhibits more related among them (e.g. clusters of around 7 fields in F1); They could be for example *Motion*, *Water*, *Air*, *Physical/Material*, *Light*, *Time*, *Interaction*;

Using sketches of possible clusters to create, (Appendix D and E) the F1 exhibits were carefully observed, with the goal to choose a group of them to study in detail. Any field could be selected, but some characteristics like the exhibits being movable were important to decide (Appendix F).

Finally, the sub-theme named "Sound" was chosen and idealised, to create the prototype exhibit cluster. A list of the Sound exhibits in GSC (table 4) was consulted in order to choose four exhibits to focus on.

Table 4 - List of exhibits about Sound in GSC

Exhibits in GSC about sound	
Echo Tube	Guitar Oscilloscope
Singing Bowl	Xylophone and Soundbox
Theremin	Whispering Dishes
Rippling Rods	Infrared Harp
Bucket Radio	How does sound move through air?

3.2. The Exhibits

3.2.1. Sound Cluster Prototype

The work was mainly about finding a new interpretation strategy for four exhibits and test them with the audience. The Exhibits chosen were the *Rippling Rods*, the *How does sound move through air*, the *Soundbox and Xylophone* and *Guitar Oscilloscope (fig. 5)*.

Changes in the planned Cluster

Rippling Rods was initially chosen because I thought it would be an interesting exhibit to show a wave. This exhibit was part of the first Observation along with the others. Later it was realised that this exhibit couldn't show a sound wave as it was transversal instead of longitudinal. Besides this, when getting ready to move the exhibits and group them all together, it was realised that Guitar Oscilloscope couldn't be moved

from the Floor 2, as it was extremely attached to the floor. It was an unforeseen event, and the engineers couldn't easily move the exhibit. The other exhibits were instead moved to the Floor 2 next to the *Guitar Oscilloscope* and the exhibit *Rippling Rods* was left off. *Singing Bowl* exhibit was chosen to replace it.

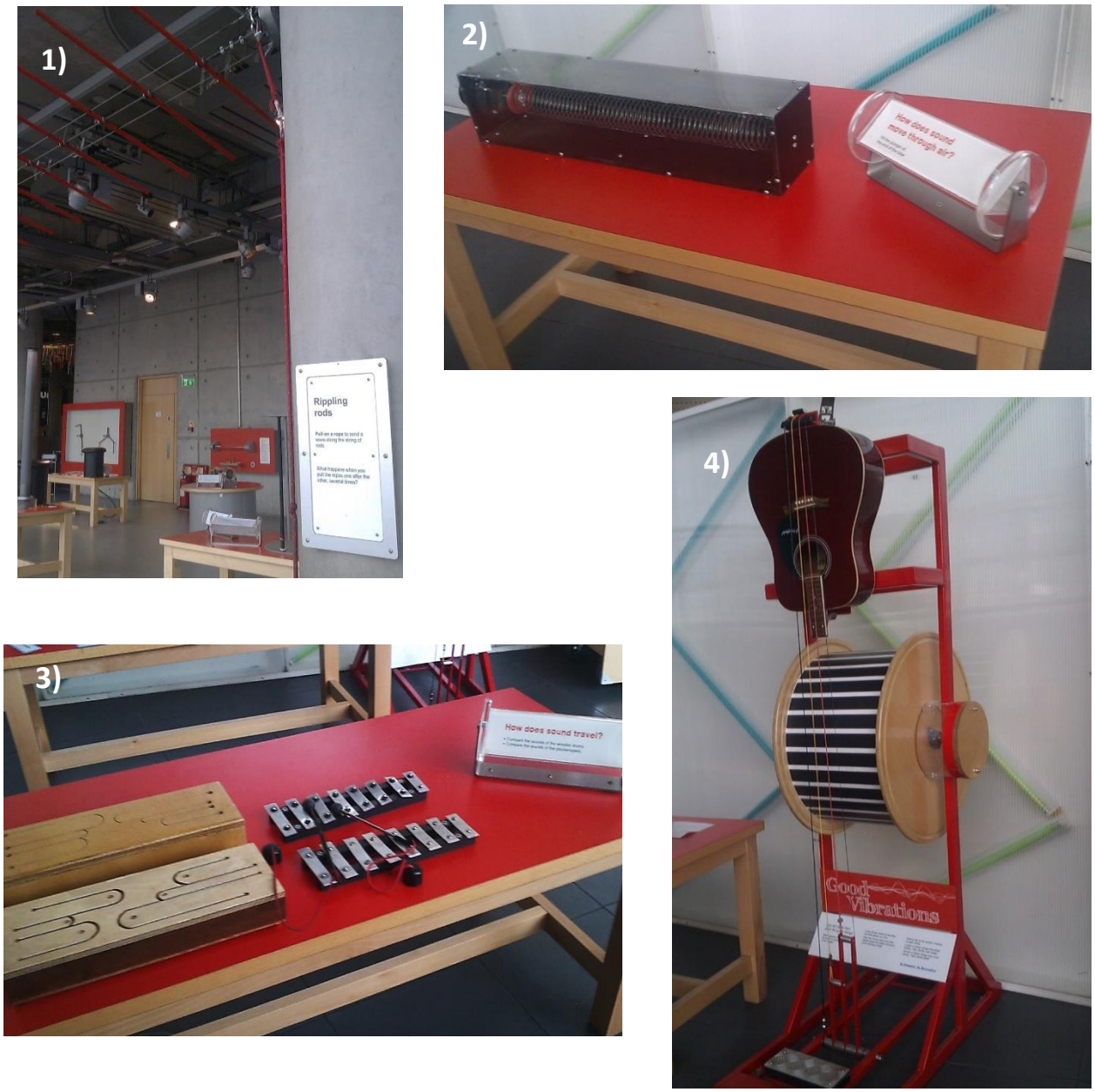


Figure 5. – Photos of the exhibits chosen initially for the Sound Cluster: 1) Rippling Rods; 2) How does the sound move through air 3) Soundbox and xylophone; 4) Guitar Oscilloscope

Telling a “story” between the exhibits:

These exhibits were very easily related. People could visit this as a “Small-Sound-exhibition”, and learn the simplest concepts by playing with each exhibit one after the other.

Rippling Rods it’s a simple model of a transversal wave created when the visitor pull a rope.

How does the sound move through air**?** It’s a box with a spring, that show how sound waves propagate by hitting a plunge. It’s about learning that sound is a vibration, how it is produced and propagated through air.

Guitar Oscilloscope with the shape of a upside-down guitar, it shows very clearly the vibration in the strings and how that vibration is affected with different types of strings. Visitors may learn that they can intensify the vibration when they play the strings after spinning the barrel.

Xylophone and Soundbox it’s like the musical instrument, but make different sounds depending on what’s inside. It could be used to explore different sounds caused by vibrations.

Singing Bowl - When the visitor wet his hands and rub them on the handles, the bowl produce vibrations visible in the water and those vibrations can be felt in the bowl and table.

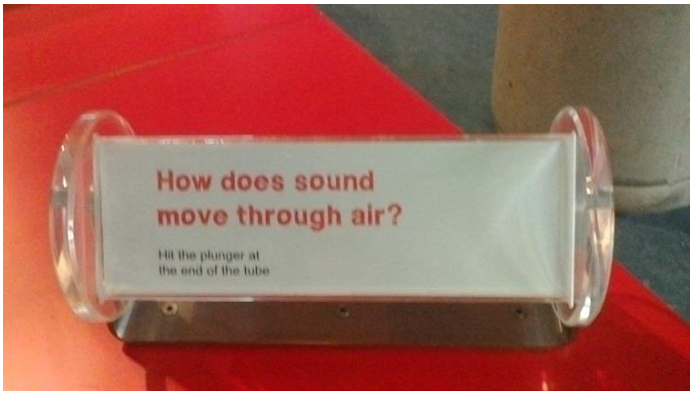
3.2.2. The information on the labels presented initially

Exhibit: *How does the sound move through air?*

The exhibit is placed on a table with the interpretation in the shape of a prism on the right side.

Figure 6– "How does Sound move through air" exhibit with its interpretation, in the first stage (when it was in F1)

Before – media: prism



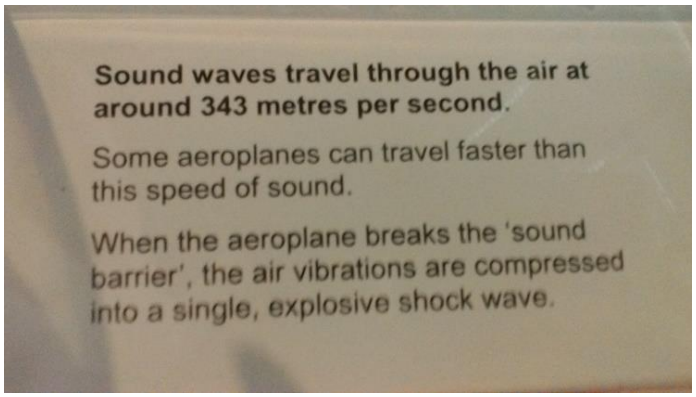
Text in the first side of the prism:

How does sound move through air?

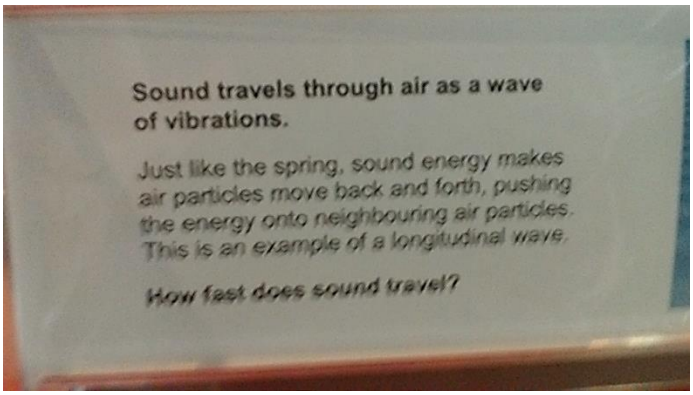
Hit the plunger at

the end of the tube

Text on the second side of the prism:



Text on the third side of the prism:



Text on the 3rd side of the prism:

Sound travels through air as a wave of vibrations.

Just like the spring, sound energy makes air particles move back and forth, pushing the energy onto neighbouring air particles. This is an example of a longitudinal wave.

How fast does sound travel?"

Figure 7 – Photos of the three sides of the prism, the initial interpretation in the Exhibit "how does sound move through air"

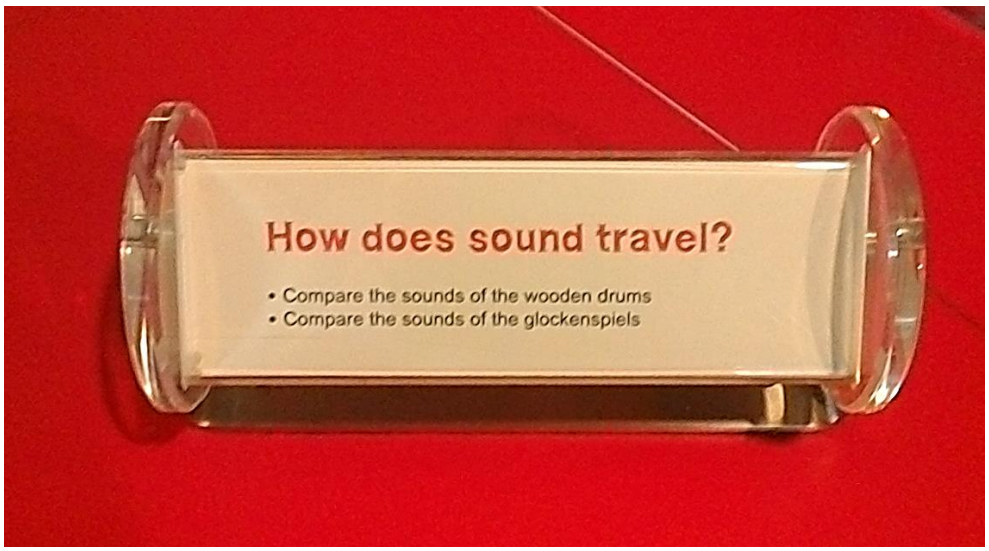
Exhibit: *Xylophone and Soundbox*

This exhibit was placed on a table, behind the Exhibit *How does sound move through air*. The interpretative label is the same media, a prism, and it in on the right side.

Figure 8- Exhibit Xylophone and Soundbox in the first stage, still in F1 with the old interpretation

Before – media: prism

Text on the first side of the prism:



How does the sound travel?

Compare the sounds of the wooden drums

Compare the sounds of the glockenspiels

Text on the second side of the prism:

Text on the third side of the prism:

Figure 9 - Initial Interpretation in the Exhibit "Xylophone and the Soundbox"

Exhibit: Guitar Oscilloscope

This exhibit is placed in the Floor 2, and the interpretative label is a flat panel placed below the cylinder barrel.

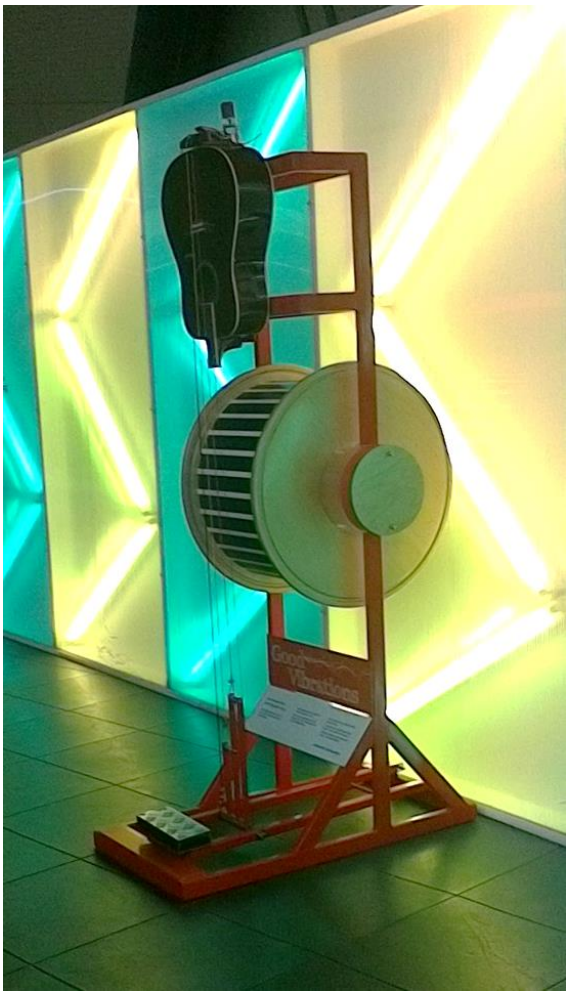
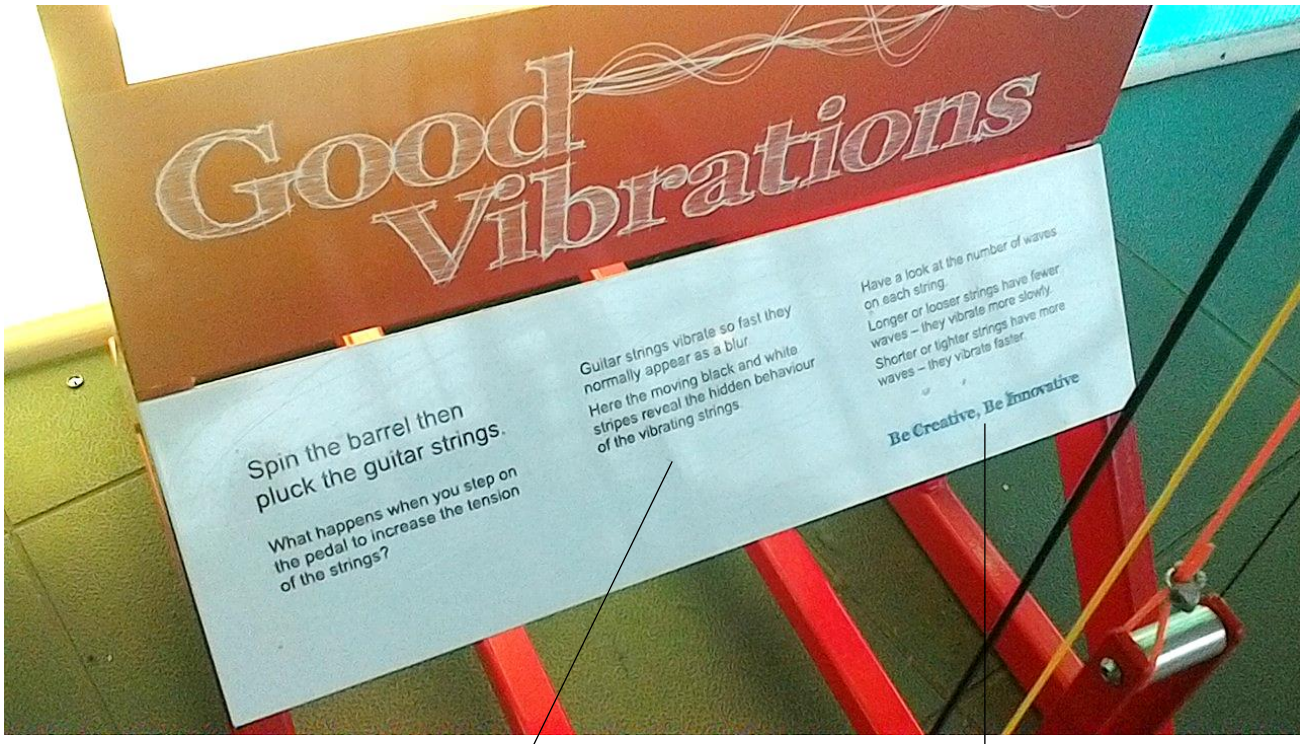


Figure 10- Exhibit Guitar Oscilloscope in the first stage, in Floor 2 with the old interpretation

Before – media: panel



Guitar strings vibrate so first they normally appear as a blur.

Here the moving black and white stripes reveal the hidden behaviour of the vibrating strings.

Have a look at the number of waves on each string.

Longer or looser strings have fewer waves – they vibrate more slowly.

Shorter or tighter strings have more waves – they vibrate faster.

Be creative, be Innovative"

Figure 11 - Initial Interpretation in the Exhibit "Guitar Oscilloscope"

Exhibit: Singing Bowl

This exhibit that replaced *Rippling Rods* was placed in the Floor 2, with a flat panel interpretation in the table.

Figure 12- Singing Bowl exhibit and the interpretative label, in a table.

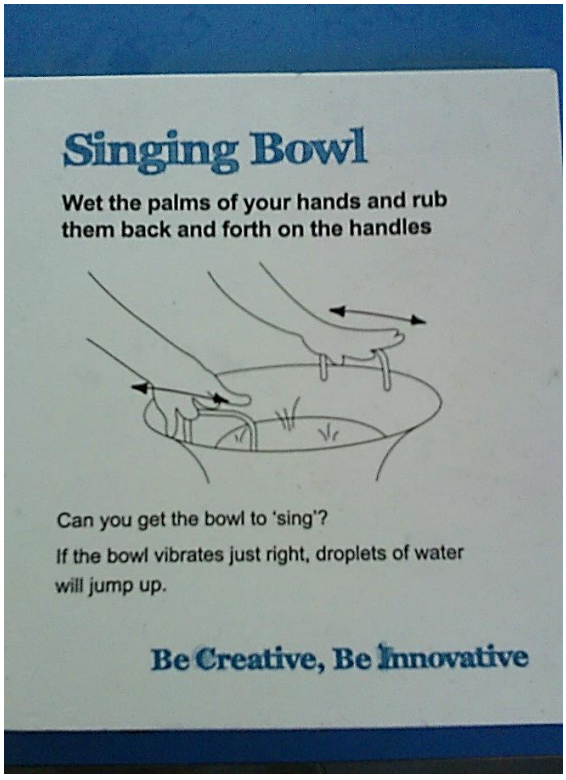


Figure 13 - Interpretation in the Exhibit "Singing Bowl"

Looking for curiosities and the link to human connection

A sound map in a sketch form was made as part of the creative process, to think of ideas and subjects related to Sound (fig.14). Bearing in mind that one of the goals of F1 was to find the human connection between exhibits and the visitors, we wonder about possible extra interesting stories, like presenting scientific curiosities.

Example of a scientific curiosity: 52Hz whale story

The 52-hertz whale is an individual whale that has a call of the frequency in 52 Hz.). Although the calls were detected the animal had never been seen. It seems that this is not usual in nature, so nobody knows which species the animal is and appears to be the only individual emitting a whale call at this frequency. The press described it as "the world's loneliest whale".

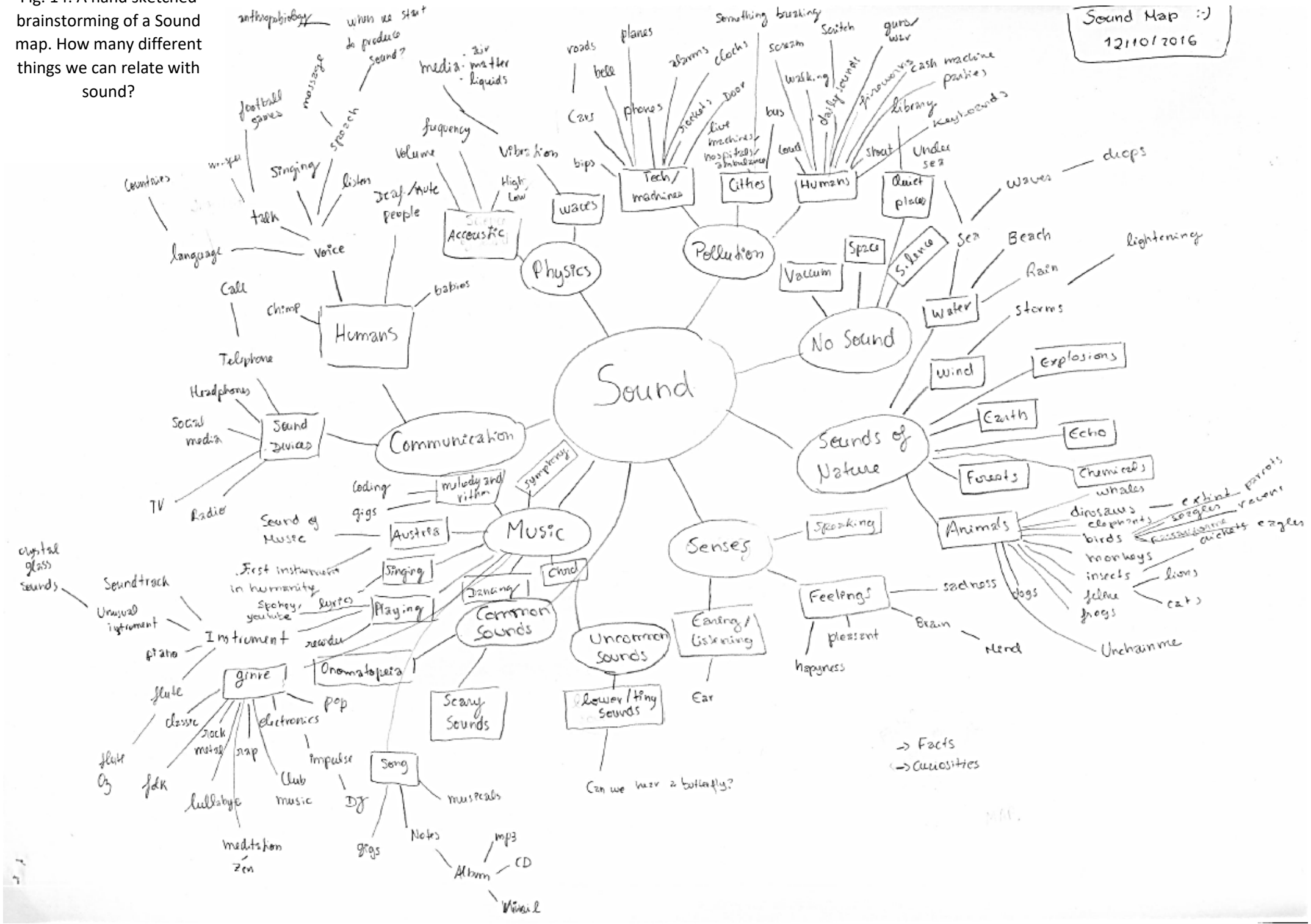
When planning this cluster, it was taken into consideration some "Knowledge and understanding" outcomes to provide:

1. What is a wave?
2. How to produce a vibration?
3. What is sound?
4. How to produce sound from vibration?
5. How are vibrations carried by waves?
6. How can we use waves?
7. What is sound pollution?

And in terms of "Enjoyment, inspiration and creativity":

1. It's a good exhibition for visitors to explore and experiment. Instruments like guitar and xylophone are the type of familiar objects that attract people.

Fig. 14. A hand sketched brainstorming of a Sound map. How many different things we can relate with sound?



3.3. Evaluation during the process

The evaluation of the Prototype Sound Cluster was made with different methods:

- Front-end evaluation – with one front-end evaluation (the 1st observation)
- Formative evaluation
    - With Open feedback – using sticky notes to let people write on a board;
    - Two Observations during the Prototype Sound Cluster - 2nd and 3rd observations;
    - Interviews using a simple questionnaire and open questions;

This section summarises the front-end (testing the interaction of the visitors before the organisation of the cluster) and formative stages (during the prototyping and organisation of the cluster) of evaluation. These tests were intended to identify potential barriers and search for suggestions, recommendations and features necessary to improve successfully the interactive exhibits.

3.3.1. Observations

The 1st Observation was with the first original exhibits (*Rippling Rods, How does Sound move through air, Guitar Oscilloscope and Xylophone and the Soundbox*) separated, in the original places with the original interpretation. The *Guitar Oscilloscope* was the only exhibit that was on the Floor 2.

Sample

Commonly to the three Observations, a sample of around 20 random people was selected for inclusion in the observation made for each exhibit. As literature refers that even small samples such as 10 or 20 visitors can show hidden problems with the interactivity (Allen, 2004) we considered the number 20 suitable. The individuals sampled could be just a single person or a subject inside a group. With the groups, the first person to interact with the exhibit was the subject observed and tracked. All the subjects were tracked through the exhibits and the time at each exhibit recorded. As it was intended to test the interpretative

labels, there were attempts to understand if people were reading the labels during the observations. It was somewhat difficult to understand this with only distant observation. Measurements with qualitative scales like "social interaction" were recorded but it's not discussed in this report since it's not very relevant for these specific exhibits.

The Observations were based mostly in children from school trips (because the observations were made during the week).

Table 5 – A table inspired in the Visitors Learning Behaviour Observational Plan provided by the Evaluation department. Numbers 1-7 correspond to the observable actions at table 1.

					Initiation		**Transition**		**Breakthrough**			**Comments**
Exhibit	Time spent (min)	Group size	No. children	No. adults	1	2	3	4	5	6	7	

Investigation during Prototyping

Using the table 5, while being guided by the system to measure specific learning behaviours (table 1), both tools sustained by the Evaluation Department at GSC, each line to be completed on the table would correspond to one single visitor tracked from the sample. The gross results are in Appendix G and the treated results in the Results and Discussion Section. The interaction between each visitor with the exhibit was observed, and measurements of the time spent, the size of the group, how many children and adults and other comments were recorded.

The "attraction power" was not considered in this case study since the data is concerning about any subject who started some sort of interaction with the exhibits. This way the Initiation learning behaviour is always considered for 100% of the people studied.

The Sound Prototype Cluster was finally composed by the following exhibits: *How does sound move through air?,* the *Guitar Oscilloscope*, the *Xylophone and Soundbox* and the *Singing Bowl* (fig.15).

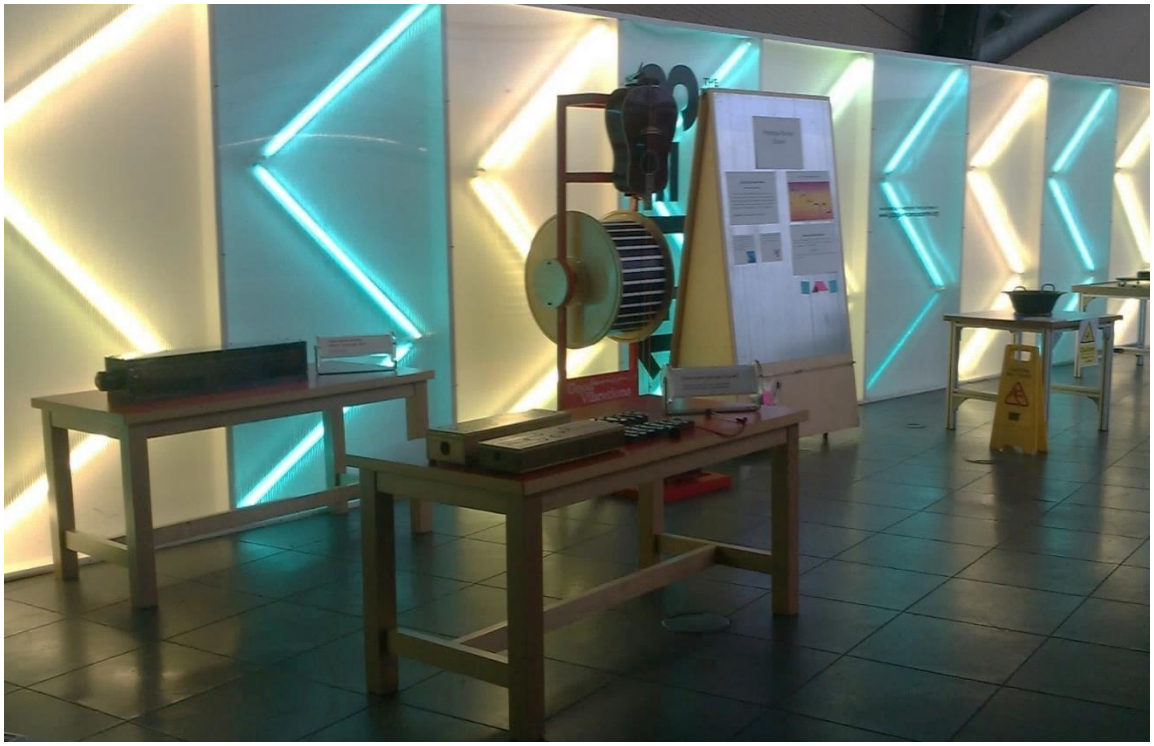


Figure 15 – Sound Prototype Cluster with the four exhibits together: How does sound travel is the first table on the left with the Xylophone and Soundbox in front. The Guitar Oscilloscope in the wall, then the board with information and the table of the Singing Bowl on the right.

For the second observation, to test new text prototype labels the old labels were covered with paper, to get the attention of the visitors for the new ones.

Results Treatment

As it was introduced in this report, the evaluation was very inspired by Barriault and Pearson studies. Their studies use the Visitor Engagement and Exhibit Assessment Model (VEEAM) (fig. 16), a model that can generate real insights into the impact of exhibits on the visitor learning

experience. Through the Observation data collected, a Visitor Engagement Framework is designed. Then it's made a quantification to access graphics of Visitor Engagement Profiles for each exhibit.

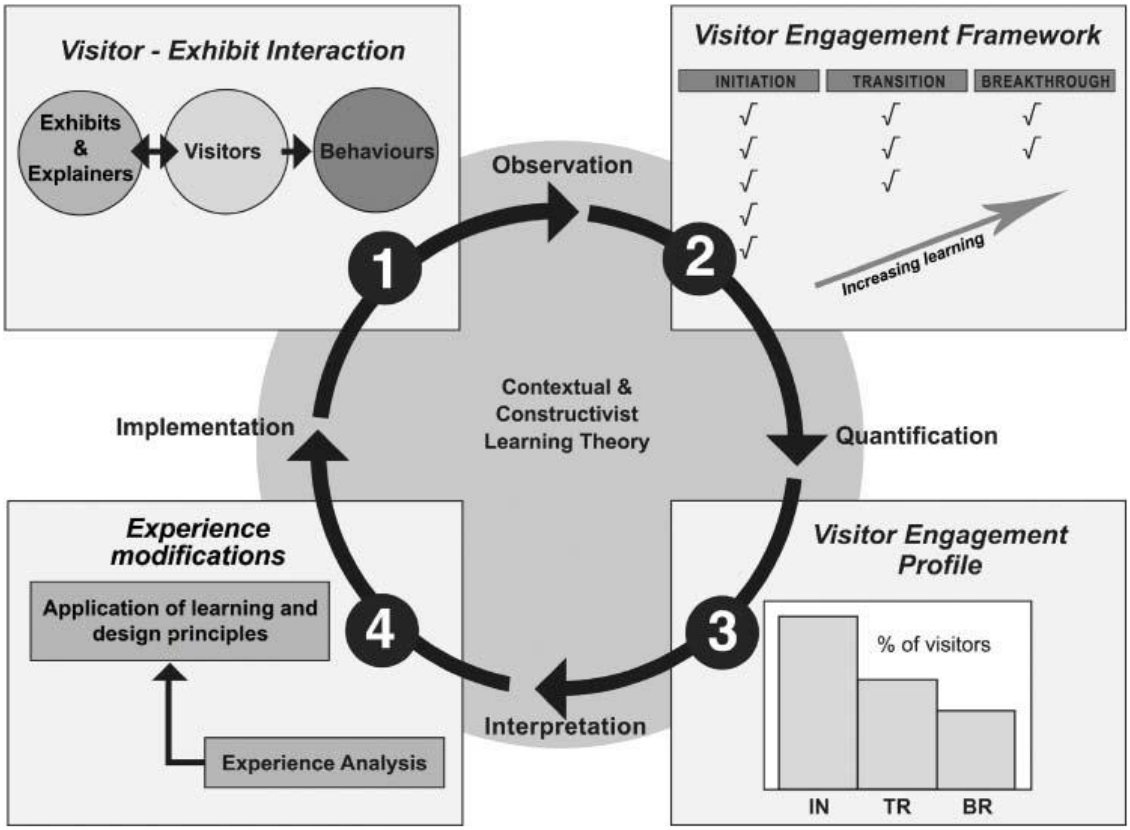


Figure 16 – Visitor engagement and exhibit accessment model: the model outlines the process for (a) analysing the engagement behaviors elicited by an exhibit and then (b) using the analysis to modify the visitor experience of that exhibit. It is, in essence, a visitor behavior-based method of formative evaluation (Barriault & Pearson, 2010).

3.3.2. Board of information and feedback

Once the four exhibits were together, a board with information regarding the prototype exhibit cluster (fig.17) was placed beside the *Guitar Oscilloscope.* This board (fig.17) was constituted by a title (Prototype Exhibit Cluster) follow by a description of what the prototype was about. Then it was fixed a big image about the hearing range of different animals and two curiosities in the shape of squares about sound. The rest of the board was used to collect visitor's feedback through sticky notes.

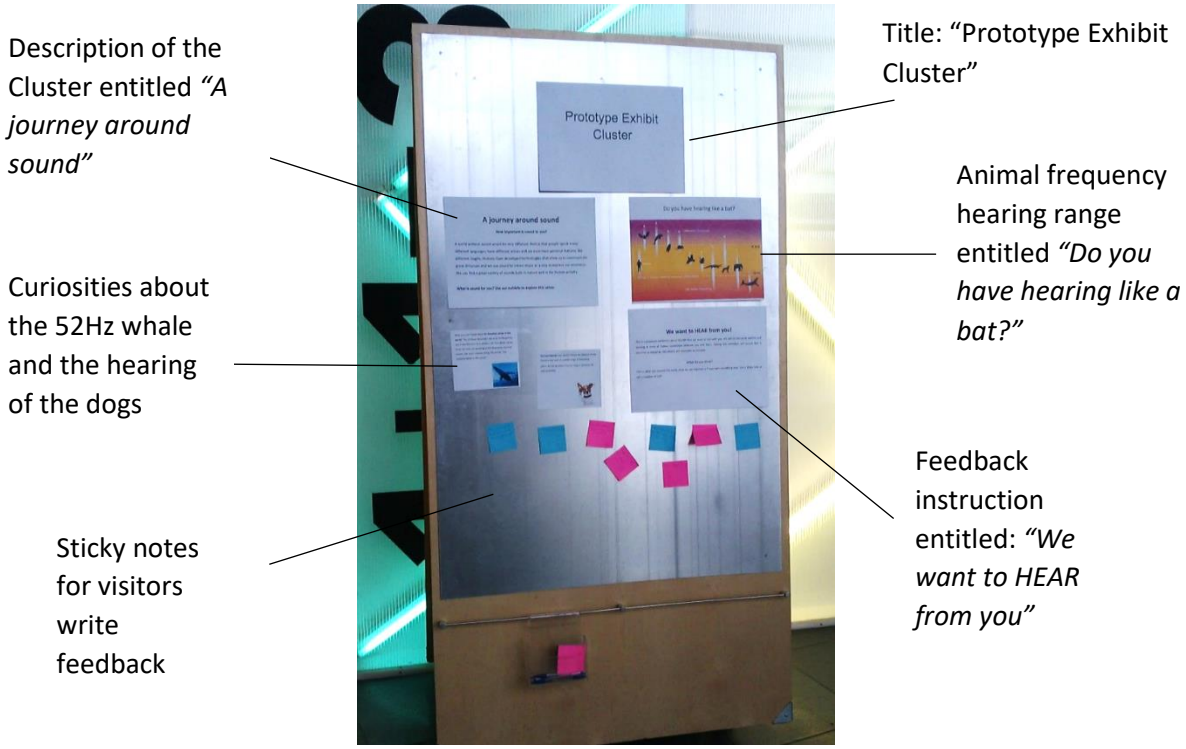


Figure 17 – First Board with information about the Prototype Exhibit Cluster.

The board had some changes over time, as it was a constantly being tested as a prototype. For instance, the initial title was just text but then was replaced with a title with a visual sound symbol (fig.18 A) hoping that this could take the theme more intuitive.

Other changes included switching the texts of the description and the instructions asking for feedback, with others with more pleasant infographics (fig.18 A) and B)). We test changing the placement of the feedback sticky notes. In the last model, different ways to access to feedback using some papers with pre-asked questions were created (fig. 18 B)).

Figure 18 – The board changed with the time. It was added a sound symbol in title "Prototype Exhibit Cluster", the first description was changed to a infographic and we used more colourful panels in the curiosities and feedback area.

3.3.3. Interpretation conceptualization

There were some questions to be considered:

Who is our audience? – Based on the first observation, the audience was mostly children, schools and families. In general, children don't read labels, so information was cut comparing with the original texts. There was an effort in putting the language in the panels accessible for children with eight years old at least.

How long do they stay? – Seconds. Checking from the first Observation (Results section), the interactions quick and usually, the subjects just want to play.

The Media

Panels were the media chosen to make the labels. They were the easiest to do for fast prototyping, the easiest to use, accessible, intuitive and less distractive than prisms. Stickers were also made, with the idea of drawing attention, and because it seemed that most visitors don't read the labels.

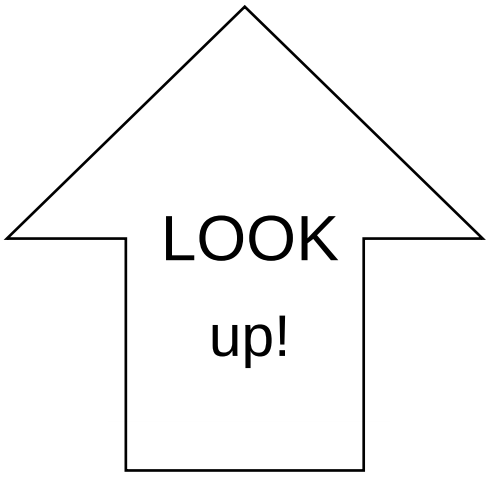
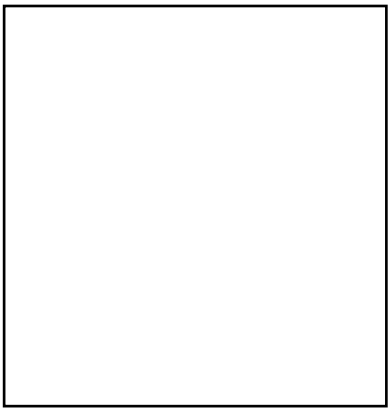


Figure 19 - An example of a sticker previously thoughted to use in the Rippling Rods. The exhibit is above the visitors' heads.

The Message

The information was divided into three layers: the sticker was the first layer, and draw the attention for the principal instruction. Then two texts were made: one to complete the instruction and explanation of the exhibit in very short sentences and the third layer (for those subjects that could want to know more), with a fun curiosity related to the subject.

Dimensions of the label and features of the font to make (like the *Singing Bowl* label)



16.99 cm x 18.99 cm

Font: calibri 20, head calibri 24 Bold

“How does sound move through air?”

Interpretation content

Instruction:

Make a sound wave

Hit the red button at the end of the tube.

You just made a sound wave.

Sound travels as a wave of vibrations in air, solids and liquids.

Curiosity:

Waves are everywhere

You can find other type of waves in nature such as the ocean waves and light waves.

Interpretation media visual

Make a sound wave

Hit the red button at the end of the tube.

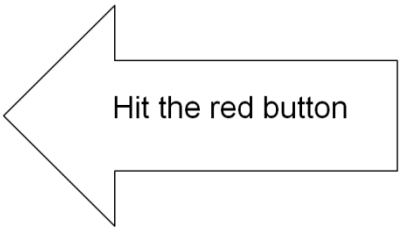
You just made a sound wave.

Sound travels as a wave of vibrations in air, solids and liquids.

Waves are everywhere

You can find other type of waves in nature such as the ocean waves and light waves.

Sticker



Interpretation placed in the exhibit

Figure 20 –Pictures of the development of the prototype interpretation for the exhibit How does the sound move through air?

Guitar Oscilloscope

Interpretation content

Music really makes you feel good

Do you have goose bumps when you hear a song that you love?

It is caused by your brain releasing pleasure hormones while anticipating the peak moment of the song.

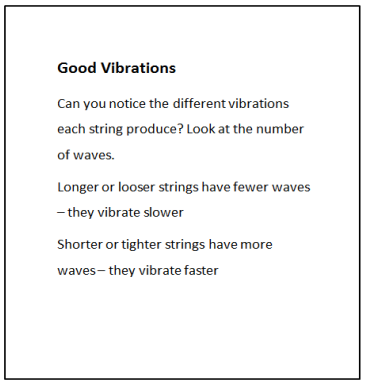
Good Vibrations

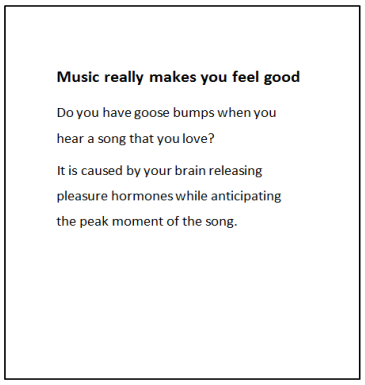
Can you notice the different vibrations each string produce? Look at the number of waves.

Longer or looser strings have fewer waves – they vibrate slower

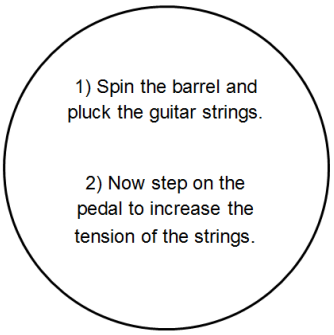
Shorter or tighter strings have more waves – they vibrate faster

Interpretation media visual





Sticker



Interpretation placed in the exhibit

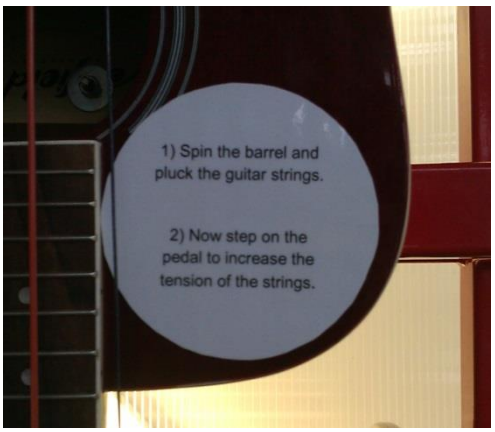


Figure 21 –Pictures of the development of the prototype interpretation for the exhibit Guitar Oscilloscope

Xylophone and Soundbox

Interpretation content

Instruction:

Explore different sounds

Sound needs something to travel through.

The shape and material of the instruments influences the sound you hear when you hit them.

One of the metal xylophones is fastened and one of the wooden drums has padding inside which causes them to make lower sounds.

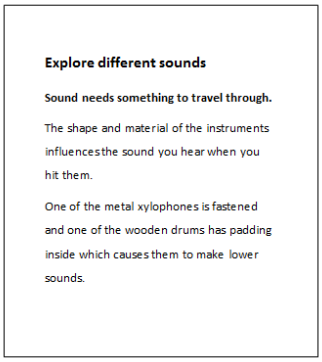
Curiosity:

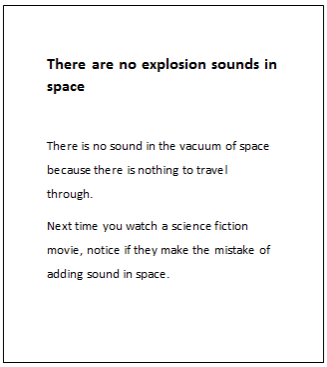
There are no explosion sounds in space

There is no sound in the vacuum of space because there is nothing to travel through.

Next time you watch a science fiction movie, notice if they make the mistake of adding sound in space.

Interpretation media visual





Sticker

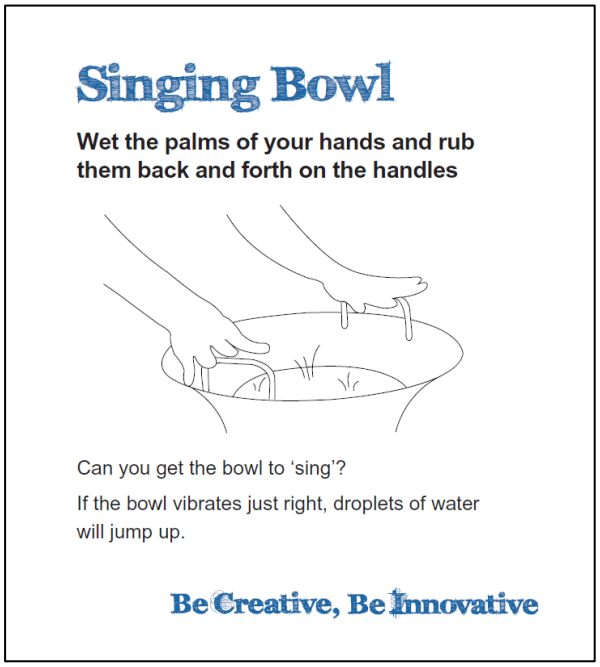
Interpretation placed in the exhibit

Figure 22 – Pictures of the development of the prototype interpretation for the exhibit Xylophone and Soundbox

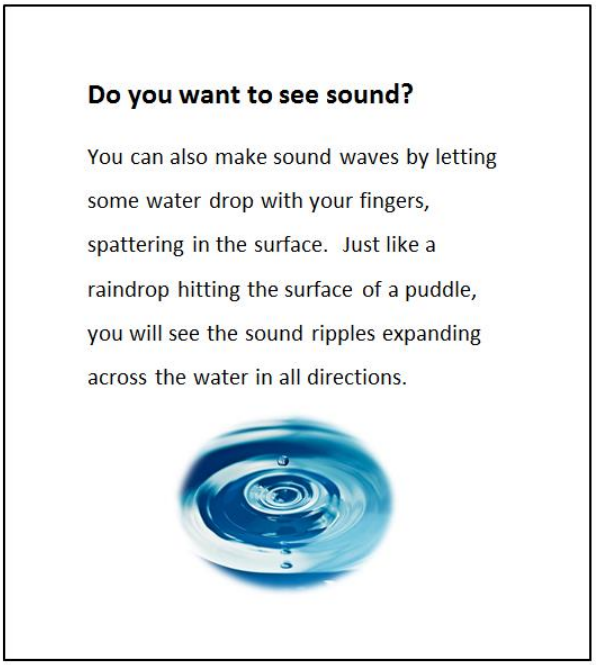
Singing Bowl

Interpretation labels

Instruction – we use the original because it was already good enough



Curiosity



Interpretation placed in the exhibit

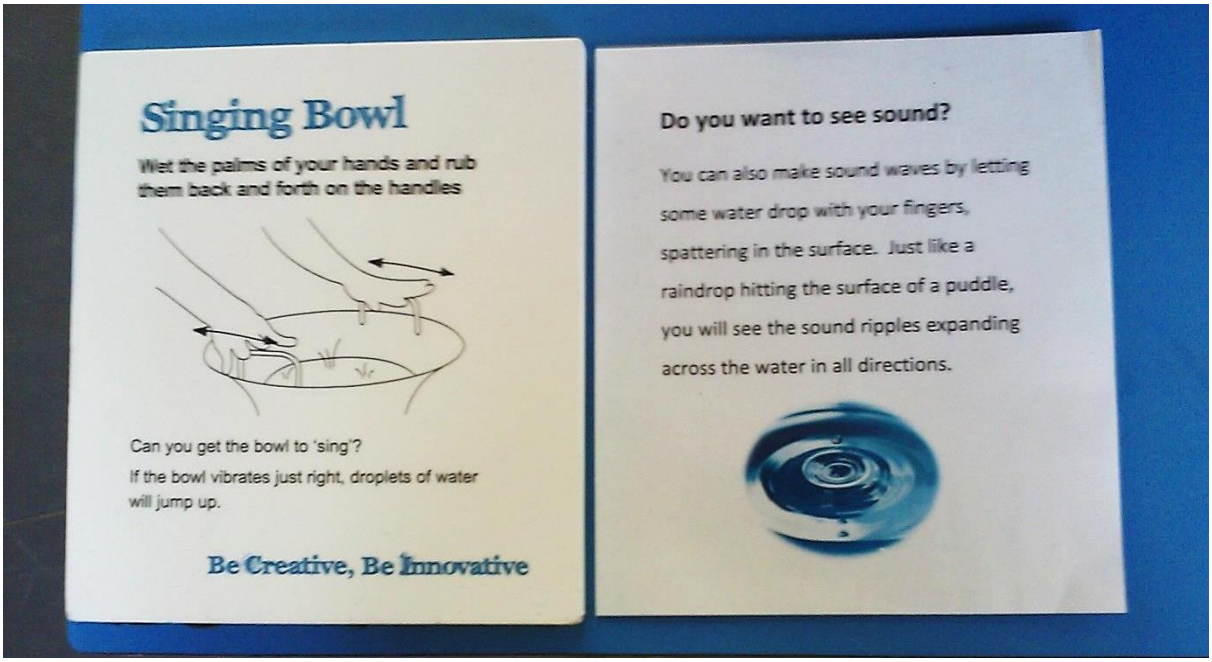


Figure 23 – We show in these pictures the development of the prototype interpretation for the exhibit Singing Bowl

3.4. Testing with the prototype labels

2nd Observation

After the new interpretation labels were fixed on the exhibits the formative evaluation was made. A second observation took place during two days with a similar sample as the first observation, methodology and the data was recorded. The results are expressed in the Results section.

3rd Observation

Since prototyping is based on testing different things, another change was made to make the labels more attractive. The text was the same but a colourful frame was added to the interpretation labels to provide a more understandable distinction between the instructions (blue frames) and the curiosities (green frames) (fig. 24 and fig.25). We also added the same sound symbol, presented in the title of the Board.

Figure 24 – New colourful frames in the prototype labels of the Singing Bowl on the left and Guitar Oscilloscope on the right.

Figure 25 – New colourful frames in the prototype labels of Xylophone and Soundbox on top and How does sound move through air on the bottom.

A third observation was conducted with the new interpretative media following the same process as the other observations.

3.5. Interviews

After the observations, to obtain more results concerning a broader public instead of mainly schools, face-to-face interviews were conducted during the two weekends. During the weekends there were more families in the Centre. The questions were made to random 39 visitors, within two categories: visitors or staff. The Visitors would be teenagers (age 14-18 years) or adults. The goal was to get more spontaneous and direct suggestions. The subjects were asked to play with the exhibits in the Cluster and to answer a few questions at the end:

- Question 1) How would you rate the overall experience?
- Question 2) What would you make this cluster of exhibits more interesting?
- Question 3) What did you think the science message of the exhibits is?
- Question 4) How easy to operate are the exhibits?
- Question 5) Anything else you want to say about the exhibit? Any improvements?
- Question 6) Would you like to know more about sound. If yes, what would you like to find out?

Table 6 – Distribution of the interviewed people's answers, distinguishing visitors/staff and the age group.

Number of questioned people	**Group**		**Age Group**	
39	Visitors	Staff member	Adults	Teens (14-18 years old)
	92%	8%	82%	18%

4. Results and Discussion

In this section, results obtained from the evaluation are presented (feedback through sticky notes, observations and the interviews). While doing the three observations It was noticed a difference between observing schools and families. Children who came with schools walk and play much faster. This is one of the reasons why the present results show short times of engagement.

4.1. Sticky Notes Feedback

I found out that this method was not very useful. People don't write much feedback if not asked directly and the sticky notes were mainly written by young children, making drawings and unrelated subjects. When the feedback "instructions" were changed to highlight the need for feedback about the Sound exhibits specifically, visitors still didn't offer much useful feedback. We understood that evaluation through observation and interviews is much more efficient.

Nonetheless, a few notes were collected that could relate somehow to the sound theme:

- *"More about superheroes"*

It's possible to relate sound with superheroes. E.g. we could have a fun curiosity about the DC superhero Flash and the relation of its speed with the sound speed.

- "*More about owls"*
- *"Animals noises would make it more interesting"*
- *"How loud is a mouse?"*

Suggestions

- ✓ To be in the interest of the younger visitors, it should be added curiosities in the interpretative labels about animal sounds and pop culture, like superheroes and their relation with science.

4.2. Front-End evaluation results

4.2.1. 1st Observation

The complete data can be found in tables in Appendix G. Those results were treated to create simpler tables who show results clearly. In table 7, we present the times tracked showing the minimum time a visitor interacted with the exhibit, the maximum time, the mean and the medium.

Table 7 – Tracking-and-timing Data (in seconds) for a visitor. N= number of visitors tracked. The values were treated from Appendix G annexe G.1.1 – annexe G.1.4.

Exhibit	*N*	*Time min (sec)*	*Time max (sec)*	*Mean*	*Medium*
Rippling Rods	20	1	67	18	14
Guitar Oscilloscope	20	3	80	35	33
How does the sound move through air?	20	1	79	19	14
Xylophone and Soundbox	20	5	108	42	42

In terms of mean time spent on each exhibit, this table shows that the *Xylophone and the Soundbox* was the exhibit where people spend more time, and the *Rippling Rods* was the exhibit where people spend less time. This may be because *Rippling Rods* is a very simple and intuitive exhibit, visitors just pull a rope and the wave is made quite rapidly. The xylophone is an open-ended exhibit that allows the visitor to explore in a more creative way. Children and teachers sometimes call for one another, while they are engaging with the exhibits, and for that reason, some visitors leave the exhibits earlier. *Guitar Oscilloscope* was also quite popular. Through the observation, it was noticed that in that place the exhibit *How does the sound move through air* it's often ignored.

In table 8, the results are presented for all exhibits in terms of quantities of people reaching the Learning Behaviours.

Table 8 – Tracking how many visitors reach the Learning Behaviours during the 1st observation. The values were treated from Appendix G annexe G.1.1 – annexe G.1.4.

1 -Rippling Rods, 2 - Guitar Oscilloscope, 3 - How does the sound move through air?, 4 - Xylophone and Soundbox

Learning Behaviour	*Exhibit*			
	1	2	3	4
Initiation	20	20	20	20
Transition	11	8	6	9
Breakthrough	1	1	4	3

As expected we can see a great decrease from the Initiation to the next learning behaviours in all three exhibits. Although people spend in general a few seconds interacting with *How does sound move through air?* It was the exhibit with more people reaching the Breakthrough. The exhibit seems to be of two extremes: either the subject just hit the button and goes off, without checking the result or stays a bit longer, try to understand the phenomena and engage with the exhibit.

Further Concerns:

Rippling Rods:

- People stayed in this exhibit for a very short period.
- Most visitors didn't read the label. It might have to do with the fact that the label was not placed strategically.
- The exhibit was accessible: physically and intellectually.

- This is one exhibit where putting a sticker with a drawing attention sign such as “Look Up!” (fig. 19, Methods section) could be beneficial.

Guitar Oscilloscope:

- The initial interpretation was too low. A support is needed to place the interpretation besides the guitar in the line with the eyes of the visitor.
- It was realised that a sticker could be added, for the Prototyping Observations. The sticker could say “play the strings and spin the barrel” and be attached to the guitar body. This way the instruction would be along the vision of the subjects.
- Although people spent a short time engaging with the exhibit, in general, there was some engagement with this exhibit.
- Seemed to be very popular. The familiar shape must be one of the reasons.

How does sound move through air?

- This exhibit went quite unnoticeable.
- It seems to need a new interpretation or a new place. Some children just played with the prims (the original media of interpretation in the exhibit), but they didn’t read them, which means this interpretation was being distractive. It was also rare that visitors turn prism and look to other sides of the interpretative media.
- It seemed that subjects didn’t find this exhibit particularly exciting.
- However, if compared with the other exhibits, people read more the interpretation (probably because it’s not so intuitive like the instruments for example).
- Some people gave up very soon. It was observed visitors hitting the button and not looking to the wave (the result). At this point, It was considered to put interpretation closer to the button.

Xylophone and Soundbox

- People recognised the shape of the xylophone and understand automatically what to do, so maybe for that reason, they read less the labels.
- Essentially people liked this exhibit and used it to play music.
- This exhibit got lots of variation in terms of time of engagement. It seems that whether people love it or don't find interesting at all. They might play for a long time, engaging in a more spirited way, especially if they are young children, or they might think is just a common instrument with no big science behind it and so, the exhibit might not be enough challenging to sustain engagement.

4.3. Formative evaluation

4.3.1. 2nd observation

The results of the second observation are presented here. The exhibits were already placed in the cluster on the second floor (exhibit 1- *singing bowl*; 2- *Guitar oscilloscope*; 3- *How does sound travel through air?*; 4 – *xylophone and soundbox*). For the first time, the exhibits were together with the old labels covered and the new prototype labels fixed.

Table 9 – Tracking-and-timing data (in seconds) for a visitor. N= number of visitors tracked. The values were treated from Appendix G annexe G.2.1 – annexe G.2.4.

Exhibit	*N*	*Time min (sec)*	*Time max (sec)*	*Mean*	*Medium*
Singing Bowl	23	4	162	49	37
Guitar Oscilloscope	24	8	84	27	22
How does the sound travel through air?	21	1	30	11	10
Xylophone and Soundbox	22	5	61	23	21

Like the first observation, a sample of around 20 visitors was used (table 9). *Singing Bowl* was the exhibit where people spent more time and *How does sound move through air* was the exhibit where they spent less.

Table 10 – Tracking how many visitors reach the Learning Behaviours during the 2nd observation. The values were treated from Appendix G annexe G.2.1 – annexe G.2.4.

1 -Singing Bowl, 2 - Guitar Oscilloscope, 3 - How does the sound move through air?, 4 - Xylophone and Soundbox

Learning Behaviour	*Exhibit*			
	1	2	3	4
Initiation	23	24	21	22
Transition	9	7	1	4
Breakthrough	9	2	0	4

Once again there aren't many people reaching the Transition and Breakthrough from the total sample. No visitors reached the Breakthrough at the *How does sound travel through air?* from the 21 people tracked. However, *Singing Bowl* success was very well evidenced. From the 21 people tracked 9 got to the breakthrough, which is about 42% of the visitors who interact with the exhibit.

During this observation, it was noticed some interaction with the new prototype stickers over the guitar, which mean that they probably were functioning well.

This floor had lots of things that may affect the attention of the visitor like science shows, the Theremin exhibit (which is a very noisy exhibit) and a dance floor very close.

Suggestions

- ✓ The ideal would be getting a new more isolated area in the centre with better acoustic specifically for the sound exhibits. Otherwise, it's necessary at the least to move the exhibit Theremin to not disturb the use of other Sound exhibits.

Some specific considerations

Singing bowl:

- Positive expressions like "*Oh my god!"* were spoken by the visitors engaging with the *singing bowl*.
- This exhibit itself is a bowl, so is not very intuitive, which lead people to read the interpretation to understand what to do. But the illustration and the instruction are very well done, and people use well the exhibit and enjoy. *Singing Bowl* was the most popular exhibit of the Cluster. People felt the vibrations in the hands and even on the floor and found that amazing.

Suggestions

- ✓ Getting a towel to put beside this exhibit since visitors need to wet their hands.

Guitar Oscilloscope

- *Guitar Oscilloscope* seems to attract the visitors, but do not have much engaging power.

How does sound travel through air?

- It was noticed people reading the sticker, which is natural since it was quite. It's a very simple and a direct instruction. The fact that some people engage with the exhibit so quickly might be a good thing: that they understood rapidly the instruction and the

phenomenon behind. However, some visitors were still struggling to understand the exhibit.

4.3.3. 3rd observation

The third observation was made with the new prototype interpretation with colourful borders. Table 11 presents the tracking-and-timing data of the observed visitors.

Table 11 – Tracking-and-timing Data (in seconds) for a visitor. N= number of visitors tracked. The values were treated from the tables in the Appendix G annexe G.3.1 – annexe G.3.4.

Exhibit	*N*	*Time min (sec)*	*Time max (sec)*	*Mean*	*Medium*
Singing Bowl	23	7	95	41	33
Guitar Oscilloscope	21	2	81	26	21
How does the sound move through air?	19	1	27	11	9
Xylophone and Soundbox	21	2	327	46	25

How does the sound move through air exhibit continues to have a short time spent and the *Xylophone* has a very big max time of time spent (327 sec). This high value happened because one the visitors, a child, played with the exhibit for a long time (more than 3 minutes, which was an incredible moment of engagement, part of the ultimate Breakthrough behaviour according to Barriault & Pearson (2010).

Table 12 – Tracking how many visitors reach the Learning Behaviours during the 3rd observation. The values were treated from Appendix G annexe G.3.1 – annexe G.3.4.

1 -Singing Bowl, 2 - Guitar Oscilloscope, 3 - How does the sound move through air?, 4 - Xylophone and Soundbox

Learning Behaviour	*Exhibit*			
	1	*2*	*3*	*4*
Initiation	25	22	20	22
Transition	13	9	4	8
Breakthrough	9	3	2	4

In table 12, we can see that during the 3rd observation some people reached the breakthrough in the 4 exhibits which is a very good sign. The exhibit 1, *Singing Bowl* was again the most successful. Around 36% of the visitors observed reach the last stage of Learning Behaviour, the Breakthrough. The other exhibits had some engagement too.

Specific comments

How does sound move through air?

- A very important detail was detected. The button in this exhibit wasn't working as it should. When someone hits the button, it gets stuck in the exhibit and doesn't come back to its original position. This means that when another person tries to hit it the effect of the exhibit is not going to be so clear. To see the wave undoubtedly, people would have to pull the button out again before hitting.

The Xylophone and Soundbox

- The *Xylophone and Soundbox* seem to attract mainly children (under age of ten).

4.4. VEP graphics and comparisons for each exhibit

The data regarding the "number of people tracked" was converted to percentages to allow comparisons (e.g. 20 people =100%). The observation data was used to get Visitor Engagement Profiles comparing the differences in terms of Learning Behaviours registered in the different observations. Fig. 26 is about the Singing Bowl exhibit.

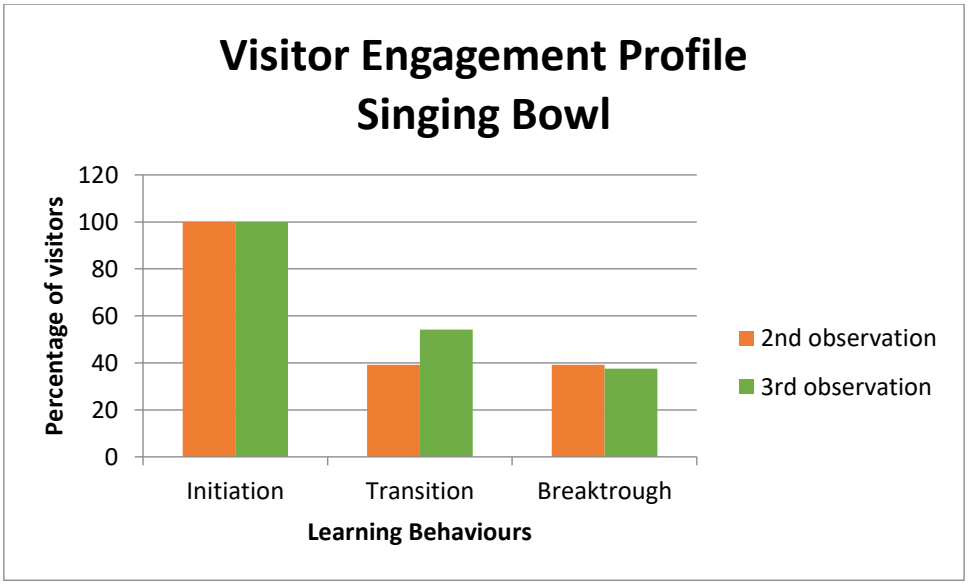


Figure 26 - The Visitor Engagement Profile for the Singing Bowl exhibit in 2nd and 3rd observations, that was already on the 2nd floor.

I remind that there is not a 1st observation because the study was started with the *Rippling Rods* and only after was switched to *Singing Bowl*. There's a slight difference between the Transition and Breakthrough moment, it means that most people who reach Transition also reach the Breakthrough. The interpretation prototype used in the 2nd and 3rd observation was almost the same (just changed for the colourful frame), which means it's understandable not observing major differences between the observations.

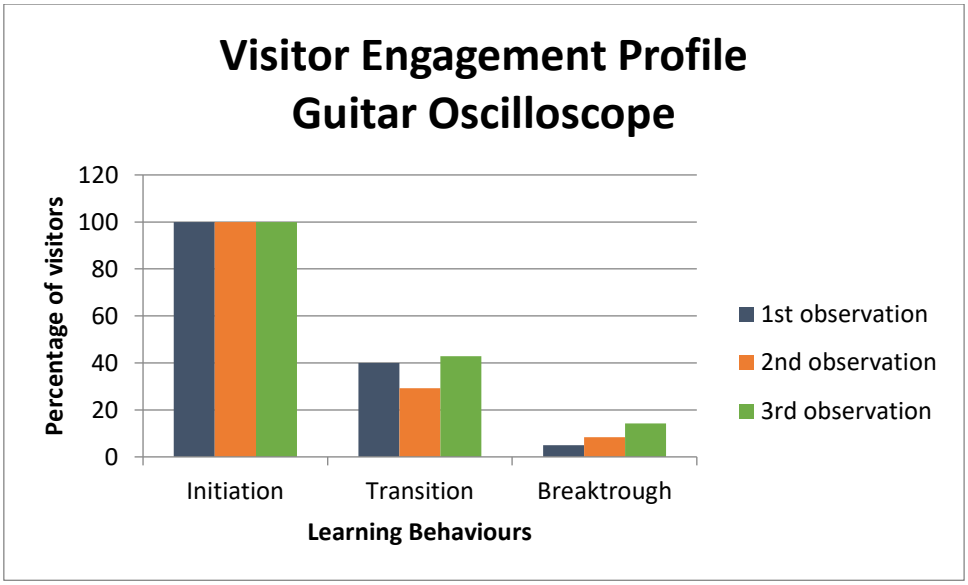


Figure 27 - The Visitor Engagement Profile for the Guitar Oscilloscope exhibit in the 3 observations.

This graphic (fig. 27) compares the differences in terms of Learning Behaviours registered in the three observations of the exhibit *Guitar Oscilloscope*. The visitor engagement profile decreases from the 1st observation to the 2nd observation but increased in the 3rd observation. It seems that the new interpretation was a little bit more effective than the first one. It seemed to me, through the observation of the visitors, that the sticker played a differential factor in this exhibit because the instructions got more visible.

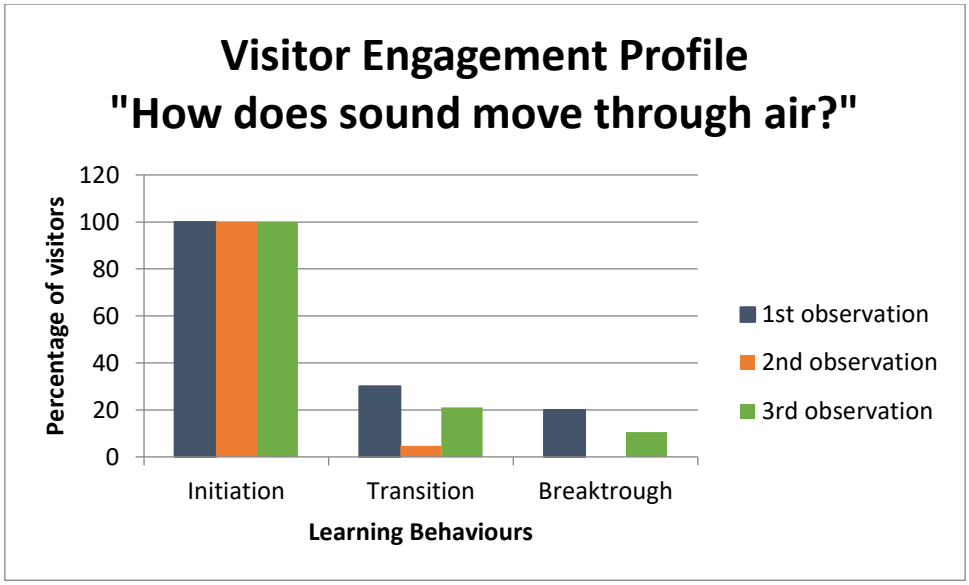


Figure 28 - The Visitor Engagement Profile for the How does sound move trough air exhibit in the 3 observations.

This graphic (Fig. 28) compares the differences in terms of Learning Behaviours registered in the three observations of the exhibit *How does sound move through air*.

The second observation had a very large decrease. Contrary to the other exhibits, in the 2nd and 3rd observations show fewer subjects reaching higher levels of Learning Behaviours in comparison with the first observation. It may be due to the fact that the exhibit was moved to a different place (and in this new place other exhibits were drawing more attention). Perhaps this exhibit does not work well in the Cluster.

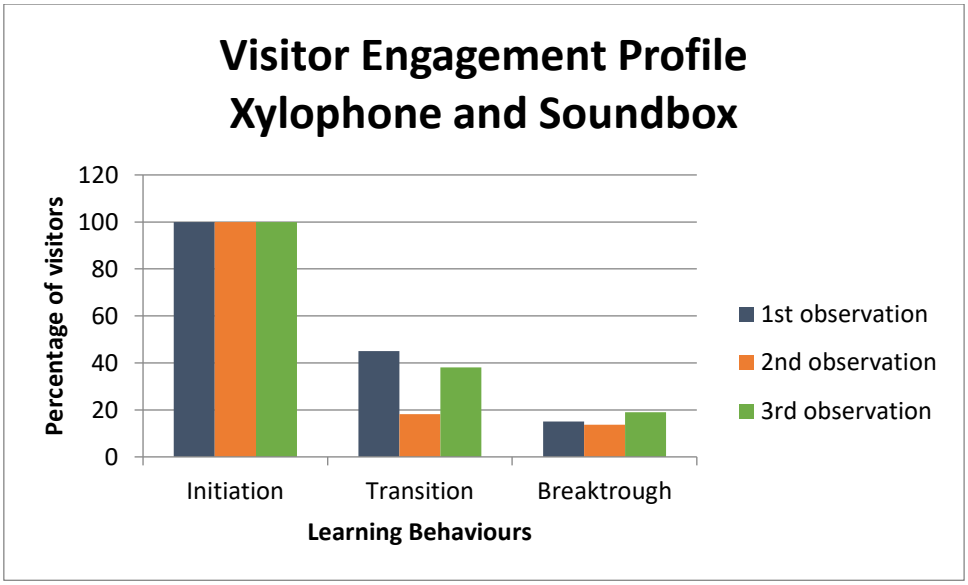
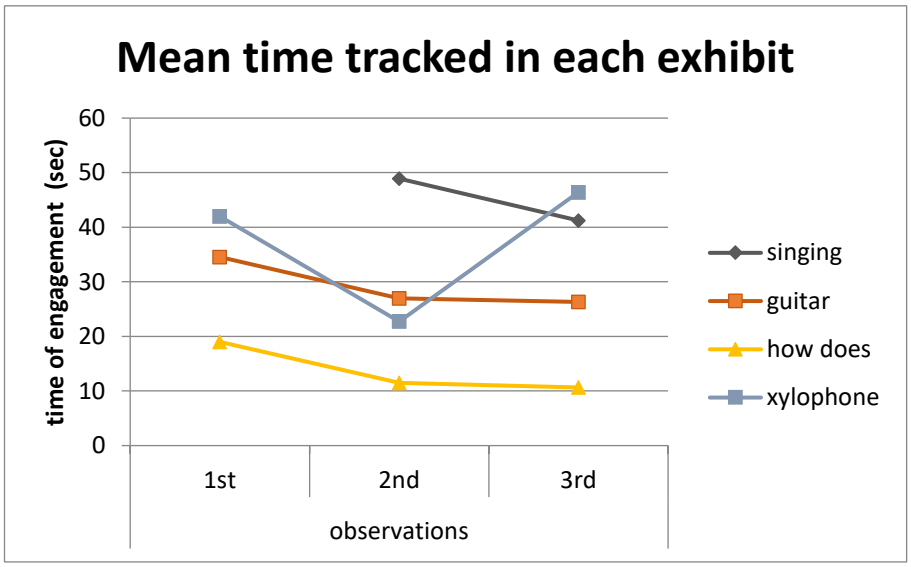


Figure 29 - The Visitor Engagement Profile for the Xylophone and Soundbox exhibit in the 3 observations.

This graphic (fig. 29) compares the differences in terms of Learning Behaviours registered in the three observations of the exhibit *Xylophone and Soundbox*. These results show that the 2nd observation was very low compared to the others. The VEP got better at the 3rd observation, it's possible to see a slight improvement in the Breakthrough.

4.5. Comparison of the mean times measures

Figure 30- Measures of the mean time spent by the visitors interacting in each observation.



From the 1st observation to the 3rd observation, all the exhibits (except for the *Xylophone and the Soundbox*) have a slight decrease in the time visitors spent interacting with the exhibits. The important difference between the 1st and the other observations is the fact that the exhibits were in different places and separated. When moved together to the Floor 2 the mean time spent by the subjects decrease. A possible reason for this might be that the visitors understood more quickly how to use the exhibits with the new prototype labels, or that they were walking faster through the exhibits on the floor 2. The *xylophone* is controversial comparing to the other exhibits, may need more observations with a bigger sampler or with selected categories (children vs adults for example).

It's also important to note, that it is normal that there's not a big difference between the 2nd and the 3rd observations since the interpretation changes were very subtle.

4.6. Interview results

Question 1) How would you rate the overall experience?

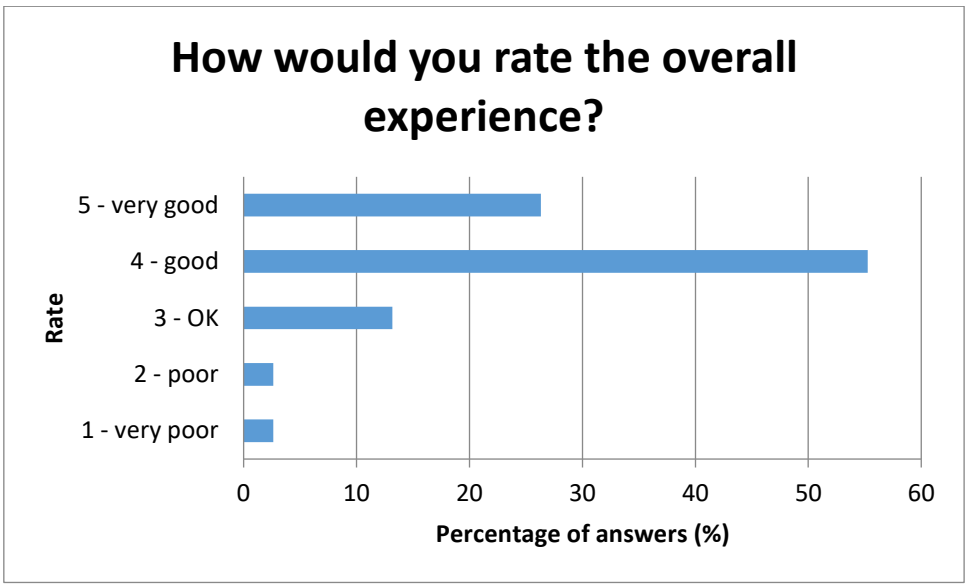


Figure 31 - Graphic of the answers to the Question 1) How would you rate the overall experience?

55% of the questioned visitors found the Prototype Sound Cluster good and 26% of people found it very good. Visitors commented positively about Singing Bowl:

> *"The singing bowl is my favourite, I love it"* (…) *"Singing bowl is amazing because you can feel and see the vibrations"*

The *How does sound move through air* exhibit had opposing comments. Some people found that the exhibit was hard because of the button problem which ultimately didn't show the sound wave clearly. But other visitors said "*is reasonable*", and "*it shows very well the sound wave*".

I think these differences happen because some visitors manage to use the exhibit properly and others don't. When well used, it's enjoyable and it shows a very simple concept. But if the visitor can't hit the button the way it is supposed, the wave is not distinct and so they find it uninteresting.

Comments were made about the *Guitar Oscilloscope* being confusing and the expectation to hear real guitar sounds.

> *"We expected to hear sounds from the guitar strings, so it's disappointing." (…) "I couldn't see the waves clearly (…)" "(…) is very confusing, the instructions don't help much and we expect to hear sounds"*

The Xylophone seemed to be one of the favourites of the children but adults found that the sounds should be improved.

> *"The xylophone is very old and the sound could be better, it should be replaced", "Get new xylophones with better sound"*

The exhibits of this cluster intent to show phenomena regarding sound, but the *Xylophone* is the only exhibit with a "real" musical sound. From the interviews, people expressed to want more musical and diverse types of sounds.

> *"Different sounds would make this better..." "Make a mini demonstration with a guitar and other instruments, teaching science through music…" "Explore more the music theme (e.g. improve the guitar).*

Suggestions

- ✓ The major recommendation is to get more exhibits where people can explore sound, musical sounds. It is also necessary to find a better place for the cluster and avoid noisy exhibits like Theremin.

Question 2) What would you make this cluster of exhibits more interesting?

Once again, some people comment on the fact that the *Guitar Oscilloscope* strings don't sound like the strings of a real guitar.

Some visitors suggest changing the S*inging bowl* to something with more different sounds.

"Instead you could use crystal glass to show different sounds, a wider range of sounds"

Visitors pointed out the simplicity of *How does sound move through air* saying:

"(..) needs more dynamic effects"

Other commented to get more interesting exhibits for adults and to put photographs and pictures in the interpretation.

Question 3) What did you think the science message of the exhibits is?

The clear majority of people understood that the cluster was about *"sound and vibrations", "how sound travels", "show that science is fun"*. One of interviewed from staff said that there was still lack of a logical path between the exhibits and that we should put more things related to music

"we need a more cohesive message to be clearer, you could pull out more about frequency and wavelength and also music".

Suggestions

- ✓ May be worth it, to make more studies to understand better the learning of the principle of each exhibit instead of the entire Prototype Sound Cluster.

Question 4) How easy to operate are the exhibits?

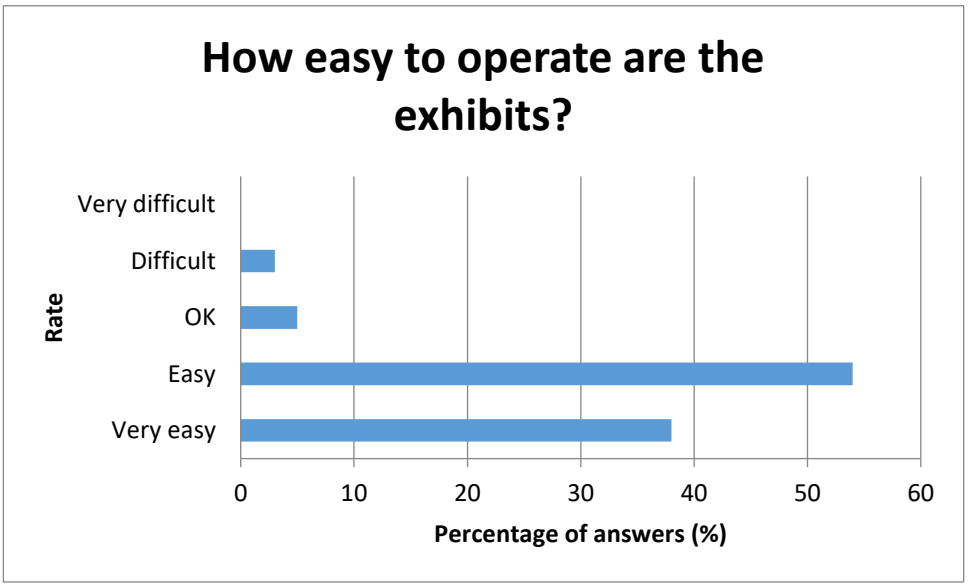


Figure 32 - Graphic with the answers to the Question 4) How easy to operate are the exhibits?

54% of the questioned visitors found that the exhibits were "easy" to operate, and 38% of the visitors rated "very easy".

I had varying and contrasting comments in the *Xylophone and Soundbox* such as "*Xylophone was hard*" and "*Xylophone was easy*". People also disagreed with the *How does sound move through air?* with some people saying *"(…) is the easiest exhibit"* and others saying *"Hitting button was not very intuitive"*

The big majority of comments was about the exhibits being very easy to operate excluding the guitar. The Guitar Oscilloscope was the exhibit more "tricky". Perhaps it's because of the complex format or the scientific message is not as simple as in the other exhibits.

Question 5) Anything else you want to say about the exhibit? Any improvements?

A woman that understands about music noticed that the sound in xylophone as wrong, pointing that the exhibit was not sounding as the real instrument:

"*bolted down the b key, is making the b flat noise*".

More requests were made about bringing more music, to make people interested. The interviewed commented about having a more acoustic space to help to focus on the exhibits and to move away from the Theremin (the noisy exhibit)*:*

"issue of loud noise"

Question 6) Would you like to know more about sound? If yes, what would you like to find out?

People asked about music again "*theme about music is good"*, and they said they wanted to find out more about sound in the real world.

Suggestions

- ✓ To explore the theme of music by getting exhibits with principals more close to this subject.
- ✓ The interpretation for visitors should be improved, with text that explains better why the two xylophones and the two soundboxes of that exhibit don't produce the same sound.

5. Conclusions

In the exhibit development area, when looking for a human connection between visitors and the exhibits, it's important to think of several things: the aspect of the exhibit, the ease in operating the exhibit, the scientific message and especially a link of interest for the visitor. This link can be just provided with entertainment, a familiar object or by teaching something that is interesting for the visitor. Everything counts in terms of interpretation, the

text, the existence of illustrations, the placement of the label and the media. It's necessary paying attention to the position of our labels (for example in the *How does sound travel through air?* worked much better when the prototype labels were placed closed to the button), the interactive part of the exhibit. *Guitar Oscilloscope* needs a better place to put the labels. It's essential to develop illustrations to get the interpretation more attractive and comprehensible.

With the observations, I could understand that a large portion of the visitors don't read the labels, which is also sustained by authors like Veverka (2003), though it's possible to improve this by using some characteristics (texts with less than 50 words, font type size with 30 points at least etc.). The shape of the exhibit can be very important in terms of attraction power but that doesn't mean that it's going to create engagement. The *Guitar Oscilloscope* is the best example. People are attracted to the guitar shape but got very disappointed because they didn't hear proper guitar sounds and found the exhibit to be confusing.

A clear conclusion is that the *Singing Bowl* was the favourite. It presents science in a fascinating way, has clear instructions and is very interactive. Another conclusion taken is that the interviews were the best and most completely way to get feedback from the visitors. Ask people's opinion can be very helpful.

We had conclusions like the space of the Cluster not being the most suitable. The Sound exhibits need a more silent place with less external distractions. From the interviews, people expressed interest in learning more and having experiences concerning music. The science behind our daily lives is another idea that can be more explored.

5.1. Future outcomes and suggestions

General F1 Project Refreshment

- ✓ Adding some elements about fundamental science (e.g. chemistry and composition of the matter, perhaps time and energy)

- ✓ Get more specific and refreshing decoration for the gallery in the theme "Explore and discover", for example, illustrations of compasses, magnifying glasses, telescopes;
- ✓ After creating a sense of an entire theme in the floor, it must be created the same sense for sub-themes (e.g. using clusters of around 7 fields, for example, *Motion*, *Water*, *Air*, *Physical*, *Light*, *Time*, *Interaction*;)
- ✓ Consider static interpretative labels for the exhibits that need lots of physical interaction (e.g. points of view), instead of prisms.
- ✓ It should be added in the labels more curiosities about the principal behind the interactive exhibit. It is interesting if it's related to the everyday life of the public (Sight Test Eyechart, Bernoulli blower, rolling race are exhibits could have more information).

Evaluation Methods

- ✓ The observations were very helpful but the interviews were the best and most completely way to get feedback from the visitors. GSC does a good work in terms of evaluation, they should continue to do it.

About the Sound Prototype Cluster exhibits

- ✓ Following the idea in the beginning of the report of getting the clusters of exhibits with specific decoration, the same approach must be followed for this cluster: to get more decoration and design a professional board that captivates the attention of the public.
- ✓ Using stories like the 52Hz whale may create a certain empathy and human connection regarding this cluster. More stories should be added.
- ✓ To be in the interest of the younger visitors, it might help adding curiosities in the interpretative labels about animal sounds.
- ✓ More studies are necessary to understand better the learning outcomes from visitors (do they learn with the exhibit?) and if they understand the scientific message.

- ✓ When introducing the new interpretative labels, it is necessary to pay attention to the position (for example in the *How does sound travel through air* worked much better when the sticker was placed closed to the button).
- ✓ GSC could try to use more stickers. They are helpful as a first layer of information since they have large font and are right in the middle of the exhibit, so people will almost naturally read it.
- ✓ If possible, it would be better to get a new more isolated area in the centre with better acoustic specifically for exploring the theme of sound. Otherwise, the exhibit Theremin should be at least moved because is very noisy and disrupts the sounds of the other exhibits. Besides, there are other distractions like the dance floor and science shows.
- ✓ More exhibits regarding music should be added, as well as stories regarding music.

How does sound move through air

- ✓ The *How does sound travel through air* needs immediately to change the interpretation or the exhibit itself must be changed in order people acknowledge how to hit the red button and use it correctly.
- ✓ A temporary way to solve this is adding the instruction in the sticker: “Pull out the red button. Now hit it.” In the future, the exhibit itself should be changed.

Singing Bowl

- ✓ This exhibit was successful because it’s very simple and has a very visible result of the interaction. The instructions are clear and it’s very interactive. GSC could get other exhibits with similar features.
- ✓ People wet their hands when they use the exhibit. For that reason, a towel should be added.

Xylophone and the Soundbox

- ✓ This exhibit can be very engaging but probably needs to be replaced with a new Xylophone with better sounds.
- ✓ However, temporarily the interpretation of the *Xylophone and Soundbox* must be changed to explain better the differences between the xylophones and soundboxes sounds.

Guitar Oscilloscope

- ✓ Although the principle behind Guitar Oscilloscope is the vibrations, the public wanted to hear some sounds from the strings. Perhaps it's possible to improve the strings of the Guitar or change the exhibit.

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Appendix A – List of the Projects Team's ideas for F1 Refresh Project

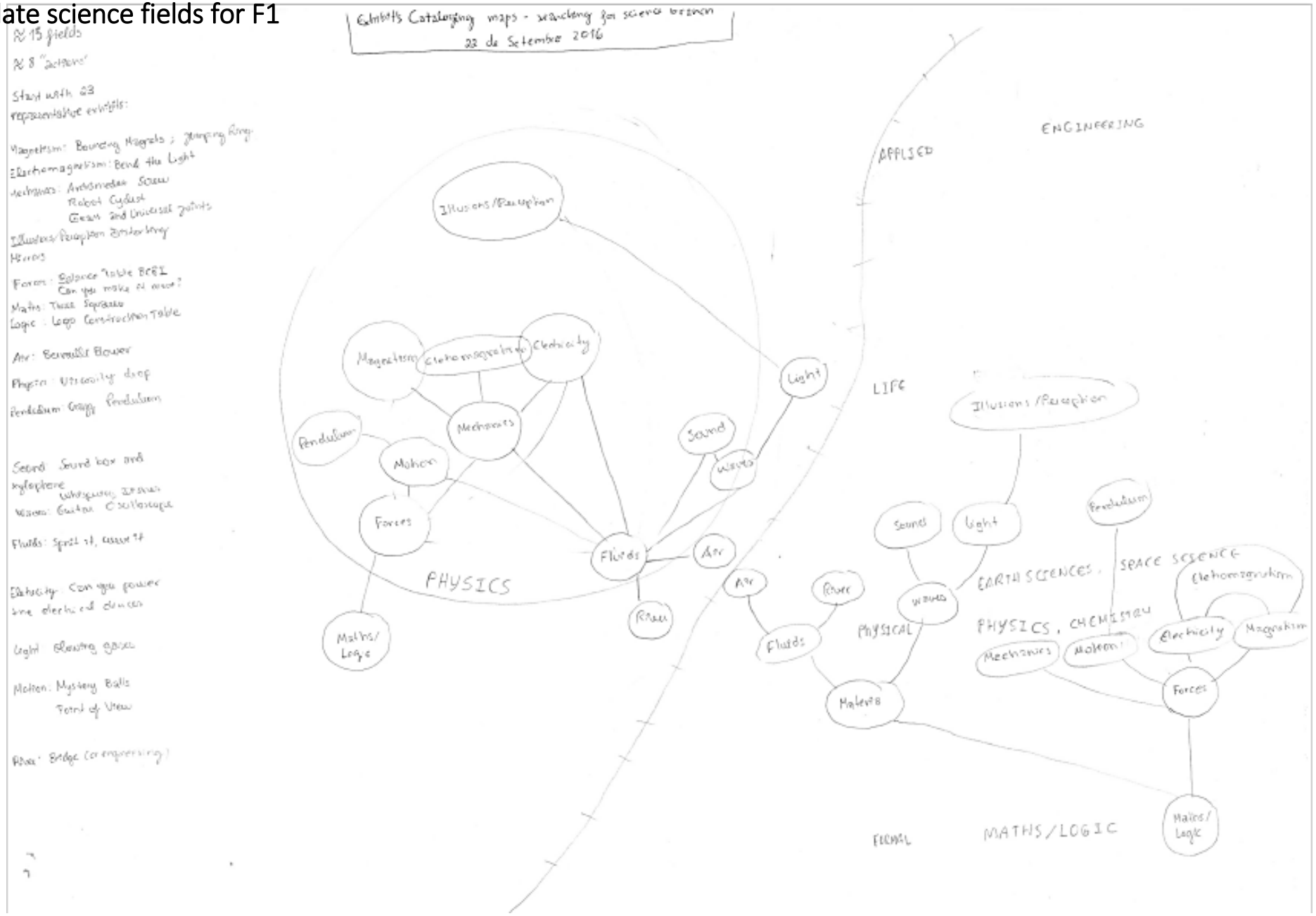
- **Idea 1 - Common Themes Systems**
- ***Models***
  - Physical Models
  - Conceptual Models
  - Mathematical Models
- ***Constancy & Change***
  - Constancy
  - Stability and Equilibrium
  - Conservation
  - Symmetry
  - Patterns of Change
  - Trends
  - Cycles
  - Chaos
  - Evolution
  - Possibilities
  - Rates
  - Interactions
- ***Scale***

- **Idea 2**
- **My Science World**
- **Natural Philosophy**
- **Discovering the World Around You**
- Motion
- Gravity
- Air & Pressure
- Beauty of Nature
- Vibrations and waves
- Mechanics & Machines
- Perception
- Magnetism
- Shapes, Forms & Patterns
- Time – Constancy & Change
- Scale – small & big
- Materials

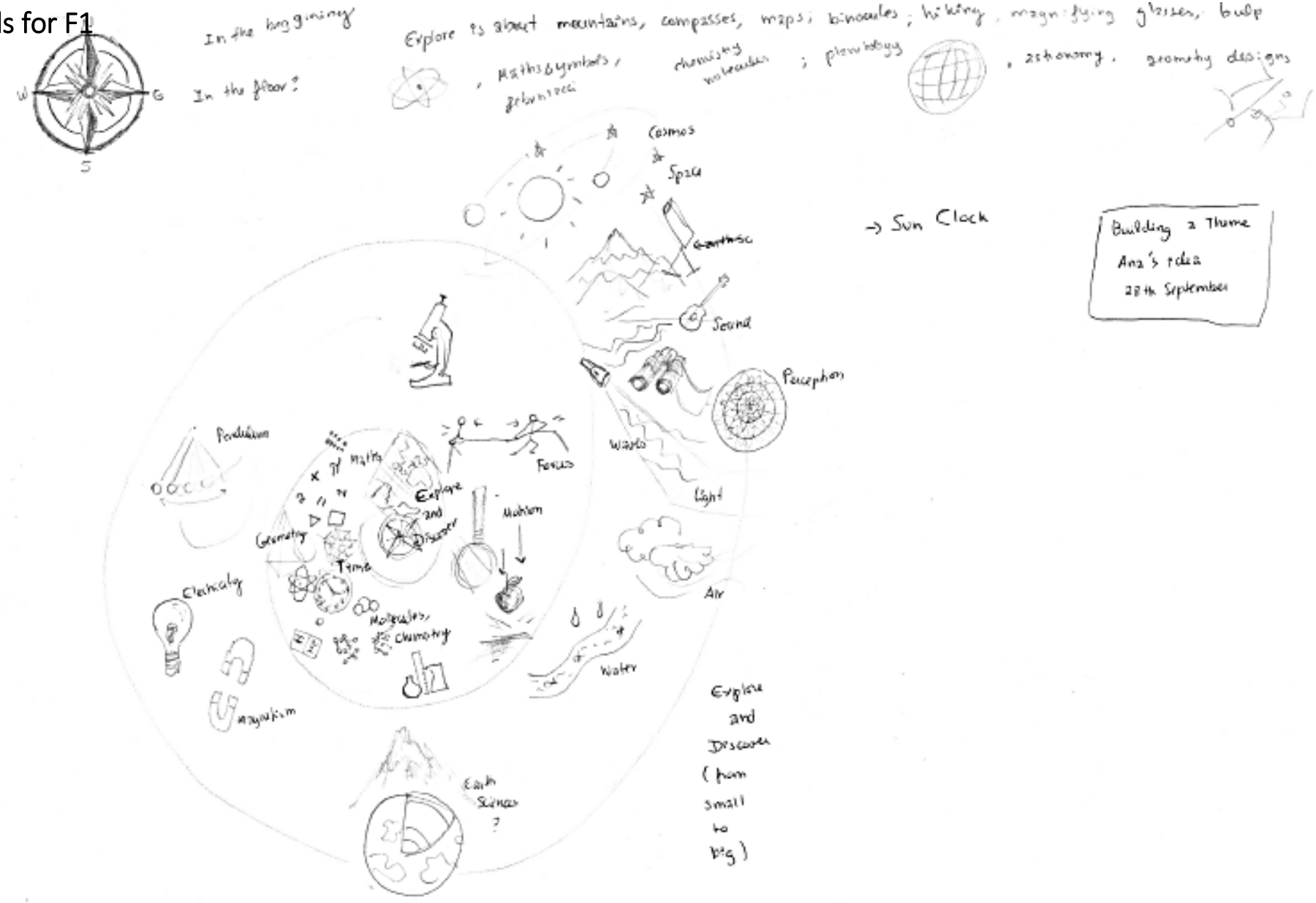
- **Idea 3 – Curriculum**
- Biodiversity and interdependence
- Energy sources and sustainability
- Processes of the planet
- Space
- Forces
- Electricity
- Vibrations and waves
- Body systems and cells
- Inheritance
- Properties and uses of substances
- Earth's materials
- Chemical changes
- Topical science

- **Idea 4 -**
- Sound & Light
- Illusions
- Forces
- Electromagnetism
- Flight
- Air
- Maths

Appendix B – Hand sketch brainstorming of ways to relate science fields for F1



Appendix C – Conception of F1 organization: Hand sketch brainstorming of ways to relate science fields for F1



Appendix D – Concept outline – hand sketched brainstorming about ideas inspired in the ideas of the Appendix A

Concept outline - ideas of their ideas
2nd week (26th - 30th September)

Idea 2 + Jargon Buster

Simple words with lots of concepts inside

; Scale ?

Idea 3 + Jargon Buster

science basics

Time

Energy - Energy sources & sustainability

Matter - Properties and uses of substances, Earth's materials

Interactions - Processes of the planet, forces, electricity; vibrations/waves; chemical changes

Bio - Biodiversity and interdependence; body systems and cells, inheritance

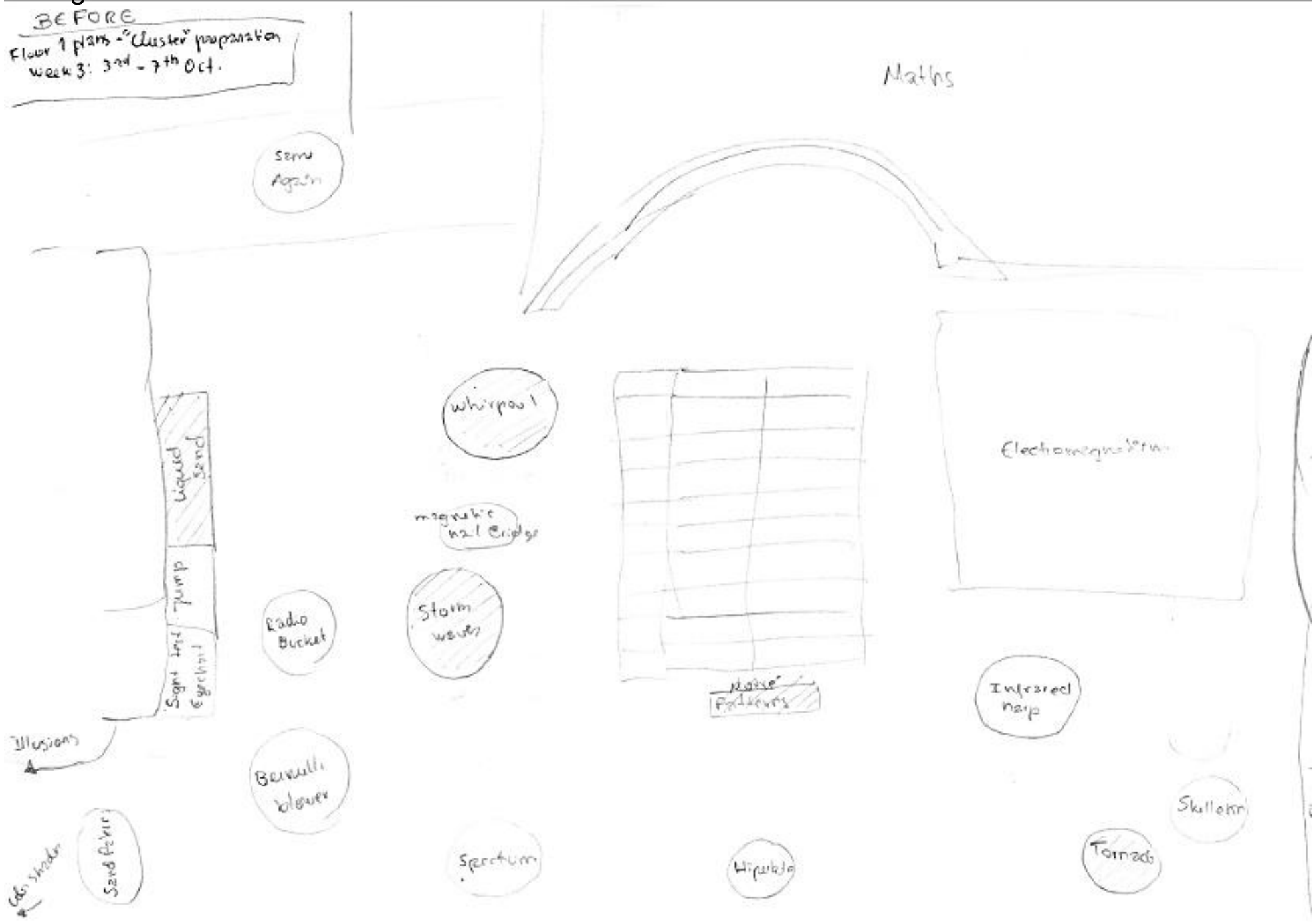
Air/Light -

Space - Space

Topical Science

Appendix E – Concept outline – hand sketched brainstorming
to choose a sub-theme for the Prototype Cluster

Appendix F – Hand sketched floor 1 plans – ideas about moving exhibits



Appendix G - Tables used for Observation

1	Interacted with exhibit but left before complete or used exhibit incorrectly	**Initiation**	**Exhibits** 1. Ripping Rods/Singing bowl 2. Guitar Oscilloscope 3. How does sound move through air 4. Xylophone and soundbox
2	Observing others at exhibit or observing exhibit itself		
3	Repeated activity at exhibit	**Transition behaviours**	
4	Expressed positive responses (smiling, excited, eagerness)		
5	Referred to past experiences whilst using exhibit	**Breakthrough behaviours**	
6	Sought help with exhibit/encouraged others to join in/showed others how to use		
7	Significant engagement (3-5+ minutes)		

Tracked user: a – adult c – children

Interactivity	
A	Work alone or split up
B	Some cooperation
C	High levels of cooperation

					Initiation		Transition		Breakthrough			Interactivity
Exhibit	Time spent (min)	Group size	No. children	No. adults	1	2	3	4	5	6	7	

Annexe G.1.1. - 1st observation gross results for exhibit 1 (Rippling Rods)

						Initiation		Transition		Breakthrough			Interactivity	Read labels
Exhibit	Time spent (sec)	Group size	No. childre n	No. adults	tracked user	1	2	3	4	5	6	7		yes
1	18	1	-	1	a		Yes		Yes				A	no
	16	2	1	1	c		yes		Yes				A	no
	20	2	2		c				Yes				B	no
	12	2	1	1	c								B	no
	12	2	1	1	c		Yes						A	no
	16	1	1		c		Yes		Yes				A	no
	16	2	2		c		Yes		Yes				C	no
	2	3	1	2	c	yes							B	no
	67	3	1	2	c			yes	yes				B	yes
	38	1		1	a		Yes		yes				A	no
	1	2		2	a	yes							B	No
	41	2	1	1	c		Yes		yes		yes		A	No
	19	1	1		c								A	no
	38	2	1	1	a			yes	yes				C	No
	2	3	1	2	a	Yes	Yes						**B**	No
	4	2	1	1	c		Yes		yes				A	No
	6	1	1		c		Yes		yes				A	No
	12	3	1	2	a				yes				C	No
	11	2	1	**1**	a		Yes						A	No
	7	1		1	a		Yes						A	no

Annexe G. 1.2. - 1st observation gross results for exhibit 2 (Guitar Oscilloscope)

						Initiation		Transition		Breakthrough			Interactivity	Read labels
Exhibit	Time spent (sec)	Group size	No. children	No. adults	tracked user	1	2	3	4	5	6	7		
2	46	1	1		c			Yes	Yes				A	yes
	33	4	1	3	c		Yes		yes				A	
	4	1	1		c	Yes							A	
	28	2	2		c								B	
	21	4	1	3	a								A	
	39	2	1	1	c								C	
	27	1	1		c		Yes						A	
	55	2		2	a			Yes					A	
	23	2		2	a		Yes						B	
	24	3	2	1	c		Yes		yes				B	
	42	2	1	1	c				yes		yes	yes	B	
	33	2	1	1	c			yes					C	
	43	3	2	1	c		Yes						B	yes
	25	1		1	a								A	yes
	21	1	1		c								A	
	51	3	1	2	c				yes				B	yes
	48	1	1		c								A	
	3	1	1		c	yes								
	45	2		2	a		yes						B	yes
	80	1		1	a				Yes				A	yes

Annexe G.1.3. - 1st observation gross results for exhibit 3 (How does the sound move through air?)

						Initiation		Transition		Breakthrough			Interactivity	Read label
Exhibit	Time spent (sec)	Group size	No. children	No. adults	tracked user	1	2	3	4	5	6	7		
3	49	1		1	a								A	yes
	1	1	1		c	Yes							A	No
	79	2	1	1	c		Yes	Yes	yes		Yes		B	No
	27	1	1		c		yes						A	yes
	45	2	1	1	a				Yes		Yes		B	Yes
	14	1	1		c	Yes							A	no
	28	2	1	1	c				Yes		yes		B	yes
	35	1		1	a			yes					A	yes
	2	1	2	1	a	Yes							A	no
	5	2	2		c	Yes							A	
	5	1	1		c	Yes								
	6	1	1		c	Yes								yes
	3	2	2		c	Yes								
	18	1	1		c									no
	25	1	1		c			yes					A	yes
	14	2	1	1	c		Yes						A	no
	60	2		2	a				yes		yes		B	yes
	17	1		1	a								A	yes
	10	2	1	1	c	Yes							A	no
	10	1	1		c	yes							A	no

Annexe G.1.4 - 1st observation gross results for exhibit 4 (Xylophone and soundbox)

						Initiation		Transition		Breakthrough			Interactivity	Read label
Exhibit	Time spent (sec)	Group size	No. children	No. adults	Tracked user	1	2	3	4	5	6	7		
4	29	2	1	1	c				Yes				A	no
	42	1		1	a								A	Yes
	42	1	1		c		yes						A	No
	108	3	2	1	c		Yes				Yes		C	No
	20	3	2	1	c								B	No
	35	2	1	1	c		Yes		Yes				C	No
	6	4	2	2	a	Yes							A	No
	60	2	1	1	c		Yes		Yes				C	No
	41	2	1	1	c								B	No
	6	1	1		c	Yes							A	No
	25	2	1	1	a				Yes		Yes		C	No
	50	3	2	1	a		Yes						A	No
	56	3	2	1	c				Yes				B	No
	12	1	1		c								A	No
	60	2	1	1	c		Yes		Yes				A	No
	5	1	1		c	Yes							A	No
	60	2	2		c		Yes		Yes				B	No
	79	2	2		c		Yes	yes	Yes				B	No
	29	1	1		c								A	No
	70	3	2	1	c		yes		Yes		yes		A	No

Annexe G.2.1 - 2nd observation gross results for exhibit 1 (Singing Bowl)

						Initiation		Transition		Breakthrough			Reading labels
Exhibit	Time spent (sec)	Group size	No. children	No. adults	tracked user	1	2	3	4	5	6	7	
1	45	2	1	1	c	yes			yes		yes		
	4	2	1	1	c	yes							
	150	2	1	1	a						yes		yes
	40	2		2	a		yes		yes				
	72	2	2		c			yes	yes		yes		
	35	1	1		c	yes							
	16	3	3		c	yes							
	20	2	2		c	yes	yes						
	10	1	1		c	yes							
	120	2	2		c		yes	yes	yes				
	10	1		1	a	yes		yes					
	67	2		2	a				yes				
	24	3	2	1	c		yes						
	162	6	6		c		yes	yes	yes		yes	yes	yes
	37	5	5		c								yes
	68	2	1	1	c		yes				yes		yes
	26	2	2		c				yes		yes		
	51	2	1	1	a		yes				yes		
	30	3	2	1	c		yes						
	47	2	2		c		yes	yrd	yes		yes		
	47	3	2	1	c						yes		
	20	2	2		c								
	24	3	2	1	c	yes	yes						

Annexe G.2.2 - 2nd observation gross results for exhibit 2 (Guitar Oscilloscope)

						Initiation		Transition		Breakthrough			Reading labels
Exhibit	Time spent (sec)	Group size	No. children	No. adults	tracked user	1	2	3	4	5	6	7	
2	33	1	1		c				yes		yes		
	51	2	1	1	c								
	84	3	2	1	c			yes	yes				
	28	1		1	a				yes				
	13	1	1		c	yes							
	29	2		2	a								
	14	4	2	2	c						yes		
	22	2	1	1	a		yes						yes
	11	1		1	a		yes						yes
	40	2		2	a								yes
	29	1	1		c								
	14	1	1		c								
	11	1	1			yes							
	50	1	1		c				yes				yes
	20	2	1	1	a		yes		yes				yes
	16	2	2		c								
	19	2	2		c				yes				
	14	3	1	2	c	yes							
	8	1	1		c								
	35	2	1	1	a								yes
	35	1	1		c								
	20	2	2										
	21	1	1		c				yes				
	30	1		1	a								

Annexe G.2.3 - 2nd observation gross results for exhibit 3 (How does sound move through air?)

						Initiation		Transition		Breakthrough			Reading labels
Exhibit	Time spent (sec)	Group size	No. children	No. adults	tracked user	1	2	3	4	5	6	7	
3	4	2		2	a								
	4	1	1		c	yes							
	9	1	1		c								
	18	3	3		c								
	30	1		1	a								
	10	1		1	a								
	1	1	1		c								
	16	1	1		c								
	23	3	3		c								yes
	8	1	1		c								
	10	1	1		c								yes
	21	2	2		c			yes					
	6	1	1		c								
	12	1	1		c	yes							
	6	1		1	a								
	20	3	2	1	c								
	3	1	1		c	yes							
	8	1	1		c								
	7	2		2	a								
	15	1	1		c								
	10	1	1		c								

Annexe G.2.4 - 2nd observation gross results for exhibit 3 (How does sound move through air?)

						Initiation		Transition		Breakthrough		
Exhibit	Time spent (sec.)	Group size	No. children	No. adults	Tracked user	1	2	3	4	5	6	7
4	61	3	2	1	c			yes	yes			
	19	2		2	a	yes						
	45	2	1	1	a	yes			yes		yes	
	21	2	1	1	c							
	35	3	3		c		yes					
	17	2	2		c							
	38	2	2		c		yes				yes	
	22	4	2	2	c		yes					
	8	1	1		c	yes						
	26	2	1	1	a							
	7	1		1	a	yes						
	25	1	1						yes			
	20	1	1		c							
	8	1	1		c	yes						
	27	3	3		c							
	28	1	1		c							
	14	2	2		c							
	6	1		1	a	yes						
	5	1	1		c	yes						
	11	1	1		c							
	12	1		1	a	yes						
	45	3	2	1	a				yes		yes	

Annexe G.3.1 – 3rd observation gross results for exhibit 1 (Singing Bowl) – colour board interpretation

						Initiation		Transition		Breakthrough			Reading labels
Exhibit	Time spent (sec)	Group size	No. children	No. adults	tracked user	1	2	3	4	5	6	7	
1	40	3	3		c								
	50	2		2	a		yes	yes	yes				
	72	2	1	1	a			yes			yes		
	33	4	4		c								
	10	2	1	1	a	yes							
	25	4	3	1	c	yes							
	11	2	2		c	yes							
	11	2	2		c	yes							
	73	3	3		c		yes	yes	yes				
	21	6	6		c	yes			yes		yes		
	32	1	1		c	yes	yes	yes					
	95	5	4	1	c		yes	yes	yes		yes		
	26	3	3		c		yes	yes			yes		
	66	4	4		c		yes						
	27	5	4	1	c		yes		yes		yes		
	36	2	2		c		yes	yes	yes				
	68	4	3	1	c		yes	yes	yes				
	35	2	2		c		yes				yes		
	28	1	1				yes						
	65	3	2	1	c		yes	yes	yes		yes		
	93	3	2	1	c		yes	yes	yes		yes		
	26	2	2		c		yes	yes			yes		
	7	2	2		c								
	8	1	1			yes							
	73	2		2	a		yes						

Annexe G.3.2 – 3rd observation gross results for exhibit 2 (Guitar Oscilloscope) – colour board interpretation

						Initiation		Transition		Breakthrough			Reading labels
Exhibit	Time spent (sec)	Group size	No. children	No. adults	tracked user	1	2	3	4	5	6	7	
2	24	2	1	1	a								
	54	2		2	a						yes		
	47	1		1	a		yes						
	23	4	4		c	yes	yes						
	9	1	1		c	yes	yes		yes				
	19	3		3	a		yes		yes				
	6	2	2		c	yes	yes						
	23	1	1		c		yes	yes	yes				
	14	2	2		c								
	18	3	3		c	yes							
	81	4	2	2	a		yes	yes	yes		yes		
	49	1	1		c		yes	yes					
	22	2	2		c		yes		yes				
	11	1	1		c	yes							
	8	1	1		c								
	33	2	2		c		yes	yes	yes				
	10	2	2		c								
	2	2	2		c	yes							
	60	2	2		c		yes	yes	yes				
	7	1	1		c	yes							
	7	1	1		c								
	52	2	2		c		yes	yes	yes		yes		

Annexe G.3.3 – 3rd observation gross results for exhibit 3 (How does sound move through air?) – color board interpretation

						Initiation		Transition		Breakthrough			Reading labels
Exhibit	Time spent (sec)	Group size	No. children	No. adults	tracked user	1	2	3	4	5	6	7	
3	9	2		2	a		yes						
	8	2		2	a	yes							
	3	1		1	a	yes							
	13	2	2		c	yes	yes						
	4	2	1	1	a	yes							
	22	1	1		c		yes	yes	yes		yes		
	1	1	1		c	yes							
	20	3		3	a	yes		yes					
	13	1	1		c		yes						
	5	1	1		c	yes							
	1	2	2		c								
	23	1	1		c	yes	yes	yes					
	6	1	1		c	yes							
	2	1	1		c	yes							
	21	2		2	a	yes							
	15	1	1		c								
	1	1	1										
	27	1	1				yes	yes	yes		yes		
	11	2	1	1	c	yes							
	8	1		1	a	yes							

Annexe G.3.4 – 3rd observation gross results for exhibit 4 (Xylophone and Soundbox) – colour board interpretation

						Initiation		Transition		Breakthrough			Reading labels
Exhibit	Time spent (sec)	Group size	No. children	No. adults	tracked user	1	2	3	4	5	6	7	
4	68	2		2	a		yes						
	25	3	3		c				yes				
	33	3	2	1	a		yes		yes				
	22	2	2		c		yes						
	42	1	1		c				yes				
	25	2	2		c		yes				yes		
	27	1	1		c								
	13	1	1		c	yes							
	327	2	2		c		yes	yes	yes		yes	yes!!!	
	136	2	2		c		yes	yes	yes				
	14	1	1		c	yes	yes						
	35	2	2		c		yes	yes	yes		yes		
	11	2	1	1	a	yes	yes						
	42	4	2	2	a	yes	yes						
	7	1	1		c	yes							
	5	2	2		c	yes							
	11	2	2		c	yes					yes		
	2	1	1		c	yes							
	102	2	1	1	a		yes	yes	yes		yes		
	6	3	3										
	14	2		2		yes	yes						
	54	1	1		c	yes	yes	yes					