The Impact of Staff Interaction in the Learning Experience of Visitors to a Science Centre: An Initial Framework for Facilitation

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Thank you.

Abstract

The purpose of this study is to investigate how the interaction with interpretative science centre staff impacts the learning of visitors who engage with exhibits at Science North (Sudbury, Ontario). Science North is a science center in which tailoring the learning experience for each visitor is of paramount importance. Staff and volunteers are affectionately known as Bluecoats, in reference to the bright blue lab coats they wear on the exhibition floors. Given the current understanding of unstructured visitor-staff interactions, it becomes evident that there is a need to further explore this rich and complex field, paying special attention to behaviours and attitudes of staff that are conducive to learning, independently of the particulars of an exhibit or its science topic.

Although researchers agree that learning happens in museums, and that staff play a meaningful role, assessing the impact visitor-staff interactions can be difficult and costly (Barriault & Pearson, 2010). For this reason, this study uses the Visitor Engagement Framework, a practical tool based on constructivist learning theories, which is effective in assessing the learning potential of exhibits. In this framework, Breakthrough behaviours are observable behaviours and activities which reflect that the visitor is fully engaged and committed to the learning experience and recognizes its relevance to their personal life (Barriault & Pearson, 2010).

This study has two complementary phases. In the quantitative phase, the goal is to determine what impact (if any) do Bluecoats have on visitors' learning behaviours. Using the Visitor Engagement Framework, we will compare the visitor engagement levels of multiple exhibits, with and without a Bluecoat present, paying special attention to the difference in the percentage of visitors that reach Breakthrough in each condition. In the qualitative phase, through an analysis of emergent themes, the goal is to explore what Bluecoats do and say to have that impact.

The presence of a Bluecoat has a clear, quantifiable, statistically significant impact on the percentage of visitors that engage in Breakthrough behaviours. When a Bluecoat is present, more visitors engage in Breakthrough behaviours. To produce this impact, Bluecoats resort to strategies and methods that can be grouped in 4 categories or Dimensions: Comfort, Information, Reflection, and Exhibit Use. These dimensions encompass different strategies and techniques of facilitation, all equally useful and powerful. A rich learning experience means that Bluecoats resort to many different strategies, in a variety of sequences, tailored to each visitor and exhibit. Furthermore, this framework can serve as an assessment tool for science centres, to help them better understand how their staff can make the visitors' learning experiences richer.

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Literature review

Learning theories

Learning is one of the most complex human endeavours. It is an active process, deeply rooted in culture, in which people engage with objects, experiences and other people to build mental models of the world. It is a process that largely defies full understanding and description. However, attempting to create models and theories for learning provides a framework for understanding and discussing behaviour (Hein, 1998). This, in turn, helps design, develop and deliver learning interventions that are effective, relevant and inclusive.

Socio-cultural theories of learning are based on the idea that people actively construct knowledge and recognize it as a transformation of schemas that occurs through making sense and meaning from experiences and observations. In these theories, meaning emerges in the interplay between individuals, mediators (tools, talk, symbol system, signs) and culture (Hein, 1998). Emphasizing the social aspect of learning, Vygotsky's Zone of Proximal Development is the "level of understanding that is possible when a learner engages in a task with the help of a more expert peer" (Hein, 1998). In this context, the challenge for museum educators lies in engaging the mind of the visitor to expand but not go beyond the limits of their grasp in terms of skills and development.

Learning in science centers and museums

Museums, aquaria and zoos are considered "informal" learning spaces and are often described as environments where "free-choice learning" happens. This type of learning recognizes that learning is constructivist in nature and the environment plays an important role. Free-choice tends to be non-linear, since it is driven by the learner's intrinsic needs and interests, and involves considerable choice on the part of the learner as to what, where and when to learn (Falk & Dierking, 2000).

When trying to investigate learning within a free-choice environment like a science center or museum, the Contextual Model of Learning is a helpful theoretical construct (Falk & Dierking, 2013; Falk & Storksdieck, 2005). This model, based on constructivist theories, states that a museum visit exists and is constructed in the interplay of three contexts: personal, sociocultural, and physical. The personal context is unique for each visitor since it incorporates their experience, interests, attitudes, motivations and knowledge, as well as their developmental level and preferred modes of learning. This context determines what the visitor seeks and enjoys in their visit and is crucial in understanding who visits the museum and how they learn. The physical setting of the museum shapes the physical context visitors are free to enter and engage with. Even if the visit is not voluntary (for example, when it is part of a school trip), there is a high degree of freedom in what visitors look at, discuss and do. Finally, the socio-cultural context develops from both the visitor and the institution. Part of it stems from the visitor's culture, beliefs and values, along with their previous ideas of what a museum is and feels like, while the other part comes from the museum as an institution. The museum experience is mediated by micro-sociocultural interactions with others (members of the visitor group, other visitors or staff). Furthermore, this experience begins before the visitor enters the building, and ends a long time after they leave. Visitors arrive at museums with their own personal contexts and use the physical context to build upon it, which influences their sociocultural context (Falk & Dierking, 2013). It could be argued that, in this setting, museum staff are uniquely situated to engage with visitors by integrating these three contexts. This can happen through the invitation to explore and discover the physical setting (a whole floor or a single exhibit) and creating opportunities for social interactions that shift the personal context and lead to the making of meaning for the visitor.

Visitors are not a uniform, homogeneous group, each person who visits a museum has their own unique interests and motivations, which can also vary from visit to visit. Visitor studies researchers have to strike a balance between comprehensiveness and detail to study how visitors behave in a museum

setting. Visitors can be grouped in five identity-related categories: explorers, facilitators, experience seekers, professional/hobbyist and rechargers (Falk, 2006). These are based on visitors' motivation to go to and stay in a museum and can shift during a visit. Explorers visit museums because it satisfies their curiosity and are likely to be attracted by opportunities to learn and expand their horizons. The primary goal for facilitators is to satisfy the needs and desires of someone they care about. Experience seekers want to engage in the experience for the experience sake ("been there, done that"). Professionals/hobbyists come to the museum with a clear and specific goal in mind, like finding information on a topic. Last, but not least, rechargers see museums as respite from the world, a place to reflect and wander. Regardless of what category they belong to, all visitors stand to gain from the learning opportunities museums and science centres provide.

The Visitor Engagement Framework

Although most researchers agree that museums are rich learning environments, it can be costly and difficult to evaluate the learning experience (Barriault, 1999). By observing visitors and analyzing their interactions and conversations, Barriault and Pearson (1999, 2010) directly addressed this concern and developed a practical tool based on constructivist learning theories. In the resulting Visitor Engagement Framework, the assessment of the learning taking place is not focused on cognitive gains but considers the conditions, processes and engagement that are conducive to learning. The Framework forgoes classical, narrow definitions of what learning encompasses and could be, focusing on the visitor and their experience.

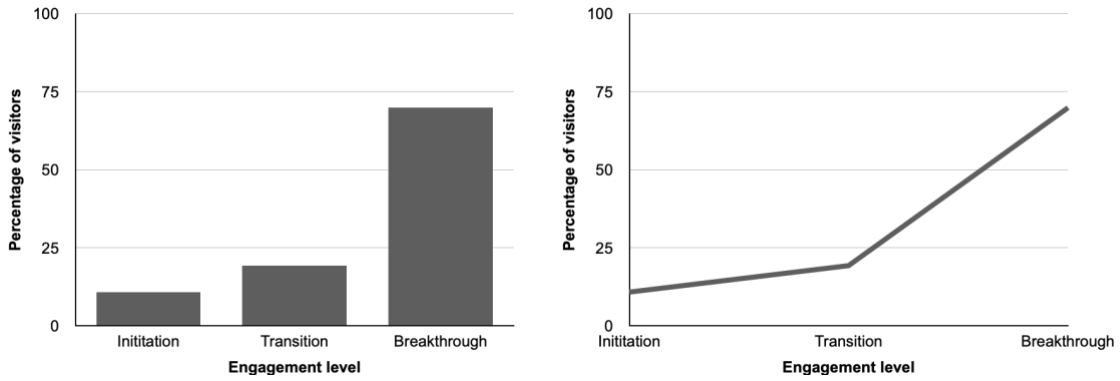
The tool consists of seven discrete learning behaviours that visitors show when engaging with exhibits, which are grouped into three categories (Initiation, Transition and Breakthrough). These categories reflect increasing levels of engagement and depth of the learning experience. Initiation behaviours (doing the activity, spending time watching others engaging in the activity) happen when

visitors take the first steps in engaging with an exhibit but are not completely involved yet. Transition behaviours (repeating the activity, expressing positive emotional responses in reaction to engaging in the activity) are characterized by positive body language and outbursts of emotion. They indicate the visitor is comfortable and is able and willing to engage more thoroughly in the activity. Finally, Breakthrough behaviours include referring to past experiences while engaging in the activity, seeking and sharing information with others, and being engaged and involved. These behaviours reflect a commitment; the visitor is fully engaged with the experience, as they recognize the relevance of the activity (and its associated learning gains) to their personal life. In this category, it is evident that the visitor is making meaning beyond the purely physical interaction: they build on their previous experience and engage in further exploration and inquiry (Barriault & Pearson, 2010).

The percentage of visitors that reach each category can be plotted to produce the exhibit's Visitor Engagement Profile (VEP). This tool does not measure the attracting power of an exhibit since the baseline for a VEP is the number of visitors who approach an exhibit and pay attention to it. The line connecting the midpoint of the summit of the bars in the VEP is the engagement curve (Figure 1.1). This curve provides immediate visual information about the exhibit's ability to engage visitors in learning (Barriault & Pearson, 2010).

Figure 1.1

Example of a Visitor Engagement Profile and Engagement Curve



Staff-visitor interactions

The informal or unstructured interactions between staff and visitors in museums encompass a largely unexplored research territory. The majority of studies conducted on visitor-staff interactions so far have focused on structured interactions, such as school group tours and scheduled stage presentations. Studies suggest that visitors have positive feelings about engaging with museum staff (Anderson, 2002), and also have found that visitors value interactions with staff more than getting information from signs and reading materials (Mony, 2008). Furthermore, visitors report that they learn something new more frequently when they interact with staff (Lindemann-Matthies, 2005). Finally, Falk and Dierking (2013) report that "the few studies conducted with casual visitors do suggest that staff positively influence the experience, particularly when they are skilled interpreters, helping to facilitate and make the experience meaningful for visitors".

Without a doubt, Pattison and Dierking are front and center researching unstructured staff-visitor interactions. Although most of their research centers on family learning at interactive math exhibits, facilitated by experienced museum educators who are trained in their approach (Pattison 2012, 2013, 2017 and 2018), their findings are an incredibly useful starting point and support the need for more research. Their facilitation model has three major interconnecting components: the exhibit experience informs the responsive facilitation approach, which in turn shapes the exhibit experience, all in the context of social, personal and physical influencing factors. Their facilitation methodology was iteratively developed and tested to support staff professional development and provides great insights into what facilitation strategies yield good results (Pattison, 2013).

In the method used in Pattison and Dierking's research, facilitators employ five facilitation strategies: orient, challenge, provide explanations, show appreciation and establish visitor ownership. When using strategies to orient, the facilitator provides visitors with an overview of the exhibit and guidance on how to begin the activity. The second strategy is when the facilitator presents challenges to

solve or complete using the exhibit. When providing explanations, the facilitator shares information about the key mathematical quantities and relationships in the exhibit. The facilitator shows appreciation by congratulating, encouraging or praising visitors. The final strategy consists in establishing visitor ownership by encouraging and supporting visitor control, leadership and agency during the experience. Challenging, orienting and providing explanations were the most frequently used strategies (Pattison, 2017). While this seems like a small number of strategies, they were employed in very different ways and were adapted in response to the particulars of the exhibit, the age of the children, the social goals of the visitor group and the roles that originated from their interactions with the adults (Pattison, 2017).

One important caveat, which the researchers address, is that they studied three exhibits that were specifically designed and refined to provide facilitation opportunities and support staff-family interactions. And even though the presence of a facilitator resulted in visitors spending twice as long engaging with the exhibit (compared with the same exhibit without a facilitator), math reasoning was only slightly higher for that condition, and visitor general satisfaction and math enjoyment was high for both conditions (Pattison, 2018). However, this could also be due to some degree of visitors self-selecting: the adult of a family that voluntarily attends a math exhibit is likely to report they enjoy math. In contrast to this approach, the Visitor Engagement Framework provides a way to analyze and modify the experience of an exhibit based on the visitors' actual learning experience, not on the exhibit designer's goals or the intended cognitive gains.

Our study investigates the impact staff interactions have on visitor learning, as assessed by the Visitor Engagement Framework. The goal is to take a closer look at the visitor-staff interactions, independent of particular exhibits' characteristics, to quantify their impact and develop an initial framework of the strategies facilitators use. This research fills a current gap in knowledge and aims to provide evidence to support the crucial role facilitators have in visitor engagement and learning in

museums and science centres. Therefore, this research seeks to answer two questions:

1. How does the interaction with the interpretative staff at Science North impact visitors' engagement levels as defined by the Visitor Engagement Framework?
2. What do the members of the interpretative staff say and do to have that impact?

Methodology

Data collection

The research team from Science North has collected video and audio data from visitors engaging with exhibits, in both the science center floors and travelling exhibitions, in the past 10 years (2011 – 2019). At least 100 visitors were recorded interacting with each exhibit. In order to ensure the emotional, physical and intellectual well-being of the participants, "Notice of Research" signs were placed at the main sales counter or entrance to the exhibition, and at each exhibit being recorded. The development team was conscious not to overwhelm visitors with cameras, in case any visitors were uncomfortable with being filmed. It was always an option for a visitor to ask for the cameras to be turned off for the duration of their interaction with the desired exhibit (Henson, 2011; Kivinen-Newman, 2016; Pisani, 2013; Pisani, 2015).

This vast dataset is without a doubt a rich source of insight into visitor-staff interactions which has not yet been examined in-depth. Although the Bluecoats were aware that the exhibit was being recorded to evaluate its learning potential, and that they were consequently recorded along with it, this set still provides an excellent sample of "natural" (as opposed to staged) staff-visitor interactions. This is because the recording was not for individual evaluation and had no direct impact on the recorded Bluecoats. The Bluecoats did not have any reason or incentive to perform a certain way. We, therefore, believe that these videos present interactions between Bluecoats and visitors that are as close as possible to how they occur spontaneously.

Analysis methods

This study has two complementary phases of data analysis, one quantitative and one qualitative. In the first, quantitative phase, the goal is to determine what impact (if any) do Bluecoats have on visitors' learning behaviours and engagement levels. In the second, qualitative phase, the goal is to explore what Bluecoats say or do to have that impact, through the analysis of emergent themes and patterns of Bluecoat behaviour.

Quantitative phase

The footage was originally analyzed by Science North's Research Team using the Visitor Engagement Framework. The first 100 visitors recorded at each exhibit were coded for behaviours that are indicative of learning and whether a Bluecoat was present, among other parameters. This phase of our study works with the tabulated data from several exhibits and different exhibitions (see Appendix 1 for a list of the exhibitions and exhibits analyzed). The parameters of interest for this study are the percentage of visitors that reached Breakthrough and whether or not a Bluecoat was present.

We selected 48 exhibits that have at least three Bluecoat interactions (defined as an instance where a Bluecoat interacts with one or more visitors at an exhibit) to have a representative sample and avoid overestimating the interaction's impact. From a personal communication with the Research Team (A. Henson, October 23, 2019), we learned that they estimate that when exhibits are being recorded, Bluecoats interact with less than 5-10 percent of visitors, perhaps to avoid interfering with the exhibit's performance. If the data from an exhibit showed fewer than three Bluecoat interactions, then the engagement levels with Bluecoat would be determined by that one or two interactions, which could skew the sample and misrepresent the impact the interaction has on the exhibit.

Impact on each exhibit's Breakthrough Level. To quantify the impact of interacting with a Bluecoat on each exhibit's Breakthrough Level, we compared the percentage of visitors that reach

Breakthrough with and without a Bluecoat present. This allowed us to sort the exhibits into 9 groups, according to their Breakthrough Level (Low, Medium or High), with and without Bluecoat interaction (Figure 2.1). A Low Breakthrough Level exhibit is defined by Science North as an exhibit that engages less than 20 % of visitors in Breakthrough behaviour. A Medium Breakthrough Level exhibit engages between 20 % and 39 % of visitors in Breakthrough, and a High Breakthrough Level exhibit engages at least 40 % of visitors in Breakthrough (Henson, 2011; Kivinen-Newman, 2016; Pisani, 2013; Pisani, 2015).

Figure 2.1

Groups for comparison

		Breakthrough Level with Bluecoat interaction		
		Low	**Medium**	**High**
Breakthrough Level without Bluecoat interaction	**Low**	Low - Low	Low - Medium	Low - High
	Medium	Medium - Low	Medium - Medium	Medium - High
	High	High - Low	High - Medium	High - High

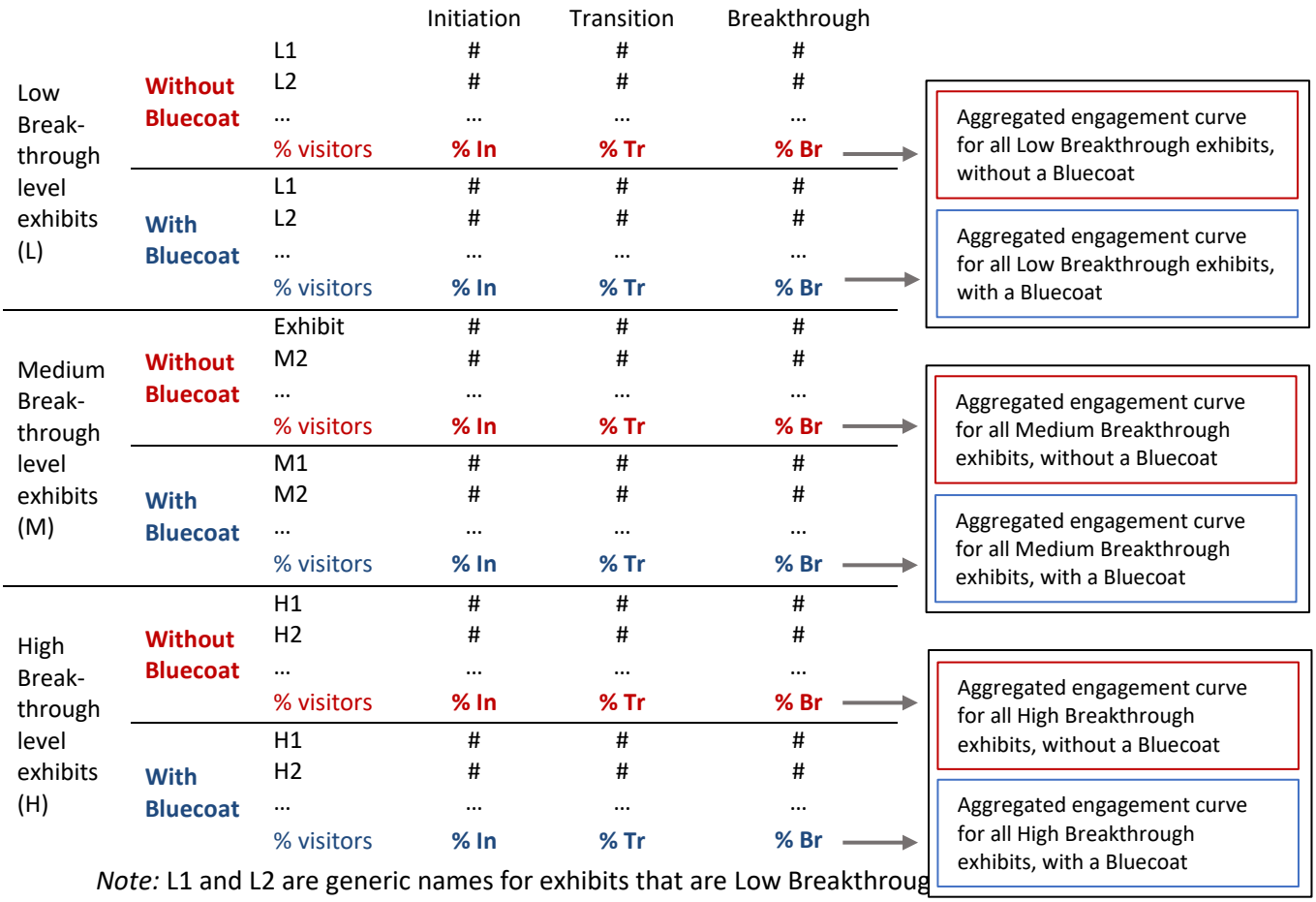
Overall impact on Low, Medium and High Breakthrough Level exhibits. To quantify the overall impact interacting with a Bluecoat has on the percentage of visitors that reach each engagement level for Low, Medium and High Breakthrough exhibits, we created three aggregated engagement curves. We started with tabulated data that included, for each exhibit, the number of visitors that reached Initiation, Transition and Breakthrough with and without Bluecoat interaction, and the Breakthrough Level of the exhibit without a Bluecoat (considered the baseline). Exhibits were then sorted into three groups, according to the percentage of visitors that reached Breakthrough.

Exhibits for each Breakthrough Level were further divided into two groups, with and without a

Bluecoat present. Then, we added the total number of visitors that reached each engagement level, which allowed us to find the percentage of visitors that reached each engagement level. Finally, we plotted the percentage of visitors that reached Initiation, Transition and Breakthrough, with Bluecoat interaction and without. Please see Figure 2.2 for a diagram of this process.

Figure 2.2

Creation of the aggregated engagement curves



Note: L1 and L2 are generic names for exhibits that are Low Breakthroug Bluecoat interaction, M1 and M2 are generic names for exhibits that are Medium Breakthrough Level without Bluecoat interaction, H1 and H2 are generic names for exhibits that are High Breakthrough Level without Bluecoat interaction, %In is the percentage of the aggregated number of visitors that reach Initiation, %Tr is the percentage of the aggregated number of visitors that reach Transition, and %Br is the percentage of the aggregated number of visitors that reach Breakthrough.

Qualitative phase

In this phase, we employed qualitative data analysis in the form of emergent pattern or thematic analysis of Bluecoat behaviours in the interaction. For this analysis, we first reviewed all available video from the exhibits studied in the quantitative phase. Using DaVinci Resolve software, we created separate video segments that included visitors interacting with Bluecoats. Each segment begins when the Bluecoat walks into the space of the exhibit being recorded, or is brought there by a visitor, and ends when the Bluecoat walks out of that space. This created a pool of 227 Bluecoat-visitor interactions which were analyzed using an inductive approach that draws from grounded theory.

Glaser and Strauss proposed grounded theory, a method for the "initial, systematic discovery of the theory from the data of social research" that lead to the development of categories grounded in the data. The basic rules of category building are that categories should emerge in the ongoing process of data analysis (that is, categories must not be forced on the data) and the researcher must be able to see relevant data and reflect upon it with the help of theoretical terms, which they called "theoretical sensitivity" (Bryant & Charmaz, 2007). The methodological design is emergent, and researchers work inductively to generate theories strictly from the data (O'Leary, 2017).

The key components of grounded theory as described by Glaser & Strauss (SAGE, 2007) are:

1. A spiral of cycles of data collection, coding, analysis, writing, design, theoretical categorization, and data collection.
2. The constant comparative analysis of cases with each other and to theoretical categories throughout each cycle.
3. A theoretical sampling process based upon categories developed from ongoing data analysis.

4. The size of the sample is determined by the “theoretical saturation” of categories rather than by the need for demographic “representativeness” or simply lack of “additional information” from new cases.
5. The resulting theory is developed inductively from data rather than tested by data, although the developing theory is continuously refined and checked by data.
6. Codes “emerge” from data and are not imposed a priori upon it.
7. The substantive and/or formal theory outlined in the final report takes into account all the variations in the data and conditions associated with these variations. The report is an analytical product rather than a purely descriptive account. Theory development is the goal.

In grounded theory, “coding” means categorizing segments of data with a short name that simultaneously summarizes and accounts for each piece of data. This requires researchers to stop and ask analytic questions of the data. The questions help further understand the topic and at the same time direct subsequent data-gathering. Coding is the pivotal link between collecting data and developing an emergent theory to explain these data. The codes take form together as elements of a theory that explains the data and directs further data gathering. Coding lets researchers “weave two major threads in the fabric of grounded theory”: craft theoretical statements that transcend specific times and places, and at the same time do a contextual analysis of actions and events (Charmaz, 2006).

We conducted coding using NVivo12. The observation and coding were open-ended, not a-priori, in the sense that we did not establish actions or behaviours to look for beforehand. The objective was to remain open to any behaviours or actions that arose, with broad guidelines based on the study’s aim. Coding was emergent and not predefined by any theoretical perspective, though it is important to note that we have experience as science centre educators, science communicators and training in the social sciences. We discussed the emergent codes and themes at length, to minimize observer bias and ensure the choices made were appropriate. As the research progressed, we systematically identified and

compared the different categories of behaviours. We also conducted several rounds of observations to further explore and refine the emergent categories and to ensure we achieved “theoretical saturation”.

Results

Quantitative phase

Impact of Bluecoats on each exhibit’s Breakthrough Level

Exhibits were sorted into 9 groups, according to their Breakthrough Level (Low, Medium or High), with and without Bluecoat interaction. Table 3.1 shows the number of exhibits for each combination of Breakthrough Level and clearly shows the changes in Breakthrough Level for each type of exhibit (e.g.: eight exhibits that are Low Breakthrough Level without Bluecoat interaction are Medium Breakthrough Level with Bluecoat interaction).

Table 3.1

Number of Exhibits for Each Combination of Breakthrough Level

		Breakthrough Level with Bluecoat interaction		
		Low	**Medium**	**High**
Breakthrough Level without Bluecoat interaction	**Low**	7 exhibits	8 exhibits	2 exhibits
	Medium	1 exhibit	5 exhibits	11 exhibits
	High	0 exhibits	2 exhibits	12 exhibits

Overall, more than half of exhibits (25 out of 48) are High Breakthrough Level when a Bluecoat is present. To further analyze the changes, Tables 3.2 to 3.4 explore each level in more detail.

Table 3.2 shows the percentage of visitors that reach Breakthrough, with and without a Bluecoat present, for exhibits that are Low Breakthrough Level without a Bluecoat present.

Table 3.2

Breakthrough for Low Breakthrough Level Exhibits

Exhibit name	%BT without Bluecoat	%BT with Bluecoat	Breakthrough Level with Bluecoat
Big chair *	3	0	Low
Skin crawl *	4	0	
Gate *	7	0	
Tornado chasers *	7	0	
Face recognition *	11	10	
Cloud wheel *	13	10	
Puzzle *	18	17	
Researcher hot zone	3	33	Medium
Slow-motion lightning	5	20	
Scavenger hunt	7	22	
Tornado sculpture	10	25	
Age yourself	16	33	
Panamanian frog	17	27	
Beetle	18	25	
Dino marvels	19	25	
Panda scale	14	40	High
Iberian lynx	17	71	

Note: (*) shows exhibits that have a lower percentage of visitors reaching Breakthrough (%BT) when a Bluecoat is present.

For Low Breakthrough Level exhibits (17 total), more than half of the exhibits (ten exhibits) have a higher Breakthrough Level when a Bluecoat is present; eight exhibits go from Low to Medium, two exhibits go from Low to High. The seven exhibits that are Low Breakthrough Level with Bluecoat interaction also have a lower percentage of visitors reaching Breakthrough.

Table 3.3 shows the percentage of visitors that reach Breakthrough, with and without a Bluecoat present, for exhibits that are Medium Breakthrough Level without a Bluecoat present.

Table 3.3

Breakthrough for Medium Breakthrough Level Exhibits

Exhibit	%BT without Bluecoat	%BT with Bluecoat	Breakthrough Level with Bluecoat
Hare challenge *	33	0	Low
Thundergames	32	38	Medium
Robotic Arm	33	33	
Tornado damage *	36	25	
Small challenge *	38	20	
Body heat alert *	39	33	
Vase	22	100	High
Amazing trunk	23	50	
Newcomers	25	60	
Robin	26	74	
Turtle crawl	31	50	
Forecasting tornadoes	33	83	
Gravity well	33	71	
Grip strength	34	67	
Xray	34	72	
Sturgeon	36	50	
IR cam	38	59	

Note: (*) shows exhibits that have a lower percentage of visitors reaching Breakthrough (%BT) when a Bluecoat is present.

For Medium Breakthrough Level exhibits (19 total), when a Bluecoat is present, 11 exhibits become High Breakthrough Level and one exhibit becomes Low Breakthrough Level. For the five exhibits that are Medium Breakthrough Level with Bluecoat interaction, there is no distinctive pattern for the

variation on the percentage of visitors that reach Breakthrough (two have a lower percentage of visitors reaching Breakthrough, one has the same percentage and the other two have a higher percentage).

Table 3.4 shows the percentage of visitors that reach Breakthrough, with and without a Bluecoat present, for exhibits that are High Breakthrough Level without a Bluecoat present.

Table 3.4

Change in Breakthrough for High Breakthrough Level Exhibits

Exhibit	%BT without Bluecoat	%BT with Bluecoat	Breakthrough Level with Bluecoat
Bear challenge *	40	36	Medium
Giant panda *	51	33	
Study your sweat	44	100	High
Turtle rehab	47	64	
Thunderstorm dangers	51	83	
Big globe	52	60	
Global connections	52	100	
Feed the chick	53	84	
Heartbeat	53	80	
Drought	54	83	
Elephant quiz	62	85	
Seabird rescue *	68	43	
Arctic map	76	100	

Note: (*) shows exhibits that have a lower percentage of visitors reaching Breakthrough (%BT) when a Bluecoat is present.

For High Breakthrough Level exhibits (14 total), no exhibit becomes Low Breakthrough Level, two exhibits go from High to Medium and the overwhelming majority (12 exhibits) are still High Breakthrough exhibits. Something of note is that for all but one of the exhibits that are High

Breakthrough Level without Bluecoat interaction, the percentage of visitors that engage in Breakthrough learning behaviours is higher with a Bluecoat present.

Impact of Bluecoat interaction on aggregated engagement curves

Table 3.5 shows the percentage of visitors that reach Initiation, Transition and Breakthrough, with and without a Bluecoat present, for all the exhibits on each Breakthrough Level (Low, Medium or High). The Breakthrough Level to which each exhibit belongs is determined by the Level of the exhibit without Bluecoat interaction. The percentage is calculated from the aggregated number of visitors that reach each engagement behaviour (Initiation, Transition and Breakthrough). Figures 3.1 to 3.3 show the aggregated engagement curves.

Table 3.5

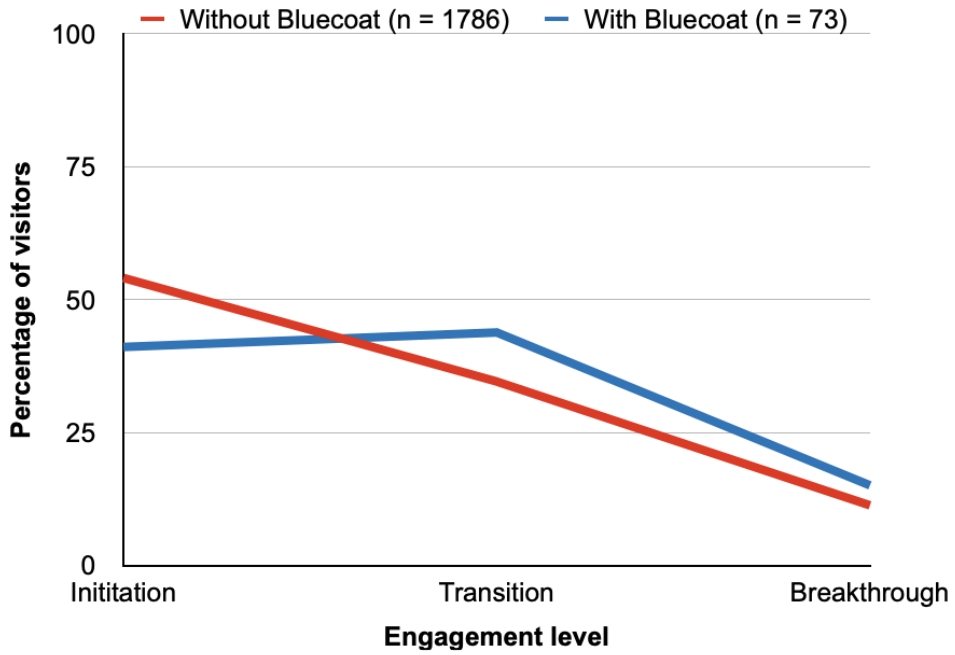
Percentage of Visitors for Aggregated Engagement Curves

		Initiation	Transition	Breakthrough
Low	Without Bluecoat	54	35	11
	With Bluecoat	41	44	15
Medium	Without Bluecoat	41	27	32
	With Bluecoat	34	36	30
High	Without Bluecoat	27	20	53
	With Bluecoat	11	19	70

Figure 3.1 shows the aggregated engagement curves for exhibits that are Low Breakthrough Level without Bluecoat interaction. The red line shows the aggregated engagement curve without Bluecoat interaction and the blue line shows the aggregated engagement curve with Bluecoat interaction.

Figure 3.1

Aggregated Engagement Curves for All Low Breakthrough Level Exhibits

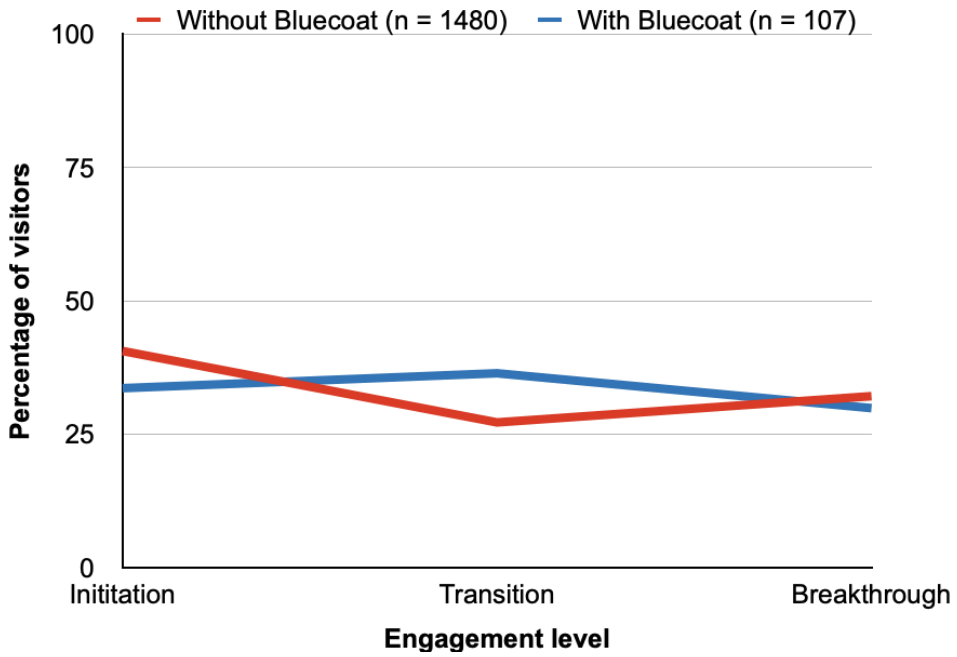


For Low Breakthrough Level exhibits, Initiation is lower (41 % vs 54 %), Transition is higher (44 % vs 35 %) and Breakthrough is higher (15 % vs 11 %) when a Bluecoat is present. This clearly shows that there is a reduction in the percentage of visitors that reach Initation.

Figure 3.2 shows the aggregated engagement curves for exhibits that are Medium Breakthrough Level without Bluecoat interaction. The red line shows the aggregated engagement curve without Bluecoat interaction and the blue line shows the aggregated engagement curve with Bluecoat interaction.

Figure 3.2

Aggregated Engagement Curves for All Medium Breakthrough Level Exhibits

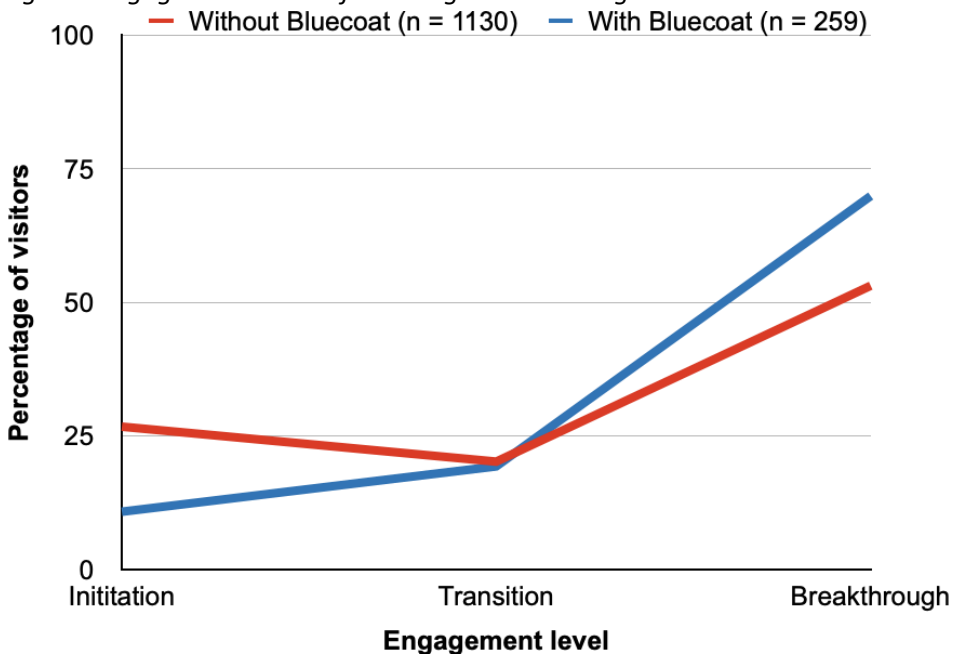


For Medium Breakthrough Level exhibits, Initiation is lower (34 % vs 41%), Transition is higher (36 % vs 27%), and Breakthrough is about the same (30 % vs 32 %) when a Bluecoat is present. This clearly shows that the change in Transition comes from Initiation.

Figure 3.3 shows the aggregated engagement curves for exhibits that are High Breakthrough Level without Bluecoat interaction. The red line shows the aggregated engagement curve without Bluecoat interaction and the blue line shows the aggregated engagement curve with Bluecoat interaction.

Figure 3.3

Aggregated Engagement Curves for All High Breakthrough Level Exhibits



For High Breakthrough Level exhibits, Initiation is lower (11 % vs 27 %), Transition is approximately the same (19 % vs 19 %) and Breakthrough is considerably higher (70 % vs 53 %) when there is Bluecoat interaction. This clearly shows that the change in Breakthrough comes from Initiation.

We tested for between-group differences in Breakthrough with or without a Bluecoat for the three types of exhibits (Low, Medium, and High Breakthrough) using a Generalized Linear Model (GLM) with binomial distribution. First, we used a model that included Bluecoat presence and Breakthrough Level and determined that one of the variables has an effect on Breakthrough percentage [$t(93) = -9.078$, $p < 0.001$]. Second, we tested the interaction between the presence of a Bluecoat and the Breakthrough Level of the exhibit and determined that it is non-existent [$\chi2(2, N = 94) = 4.821$, $p = 0.08975$], therefore Breakthrough Level was removed from the model. Lastly, we retested with a simpler model (Breakthrough percentage and Bluecoat presence) and found an interaction [$\chi2(1, N = 94) = 243.14$, $p < 0.001$]. Therefore, our data suggests that a higher percentage of visitors reach Breakthrough when a Bluecoat is present, for all types of exhibits.

Qualitative phase

Four themes of Bluecoat interaction behaviours (called Dimensions) emerged from the data: Comfort, Information, Reflection and Exhibit Use. We called them Dimensions because they encompass different strategies and techniques of facilitation that can and should be used in conjuction. Tables 3.6 to 3.9 show the codes on each Dimension, along with descriptions where needed, examples and frequency for each code. Frequency shows the amount of interactions in which each strategy was used (e.g: Bluecoats used Encouraging language in 59 out of the 227 interactions).

Table 3.6 shows the codes in the Comfort Dimension, which relates to things Bluecoats do to make the visitor feel comfortable and welcomed into the space.

Table 3.6

Codes for the Comfort Dimension

Code	Examples	Frequency
Encouraging language	"Great job!" "That's not quite right, keep trying!"	59
Welcoming (greeting, inviting visitor to use the exhibit, general introductory questions)	Hello, how are you today? "Would you like to spin the wheel?" (Cloud wheel) "So, are you any good at this?" (Feed the chick)	53
Laughter, joy (verbal and non-verbal displays of joy)	Laughing out loud Smiling	33
Focuses on visitor (body language that conveys they are paying attention to the visitor)	Looking people in the eye Facing people when talking	18

One of the most frequently used strategies consists of using encouraging language, which includes supporting visitors to keep trying when they get something wrong and celebrating the achievement when they get something right. Bluecoats also use strategies to welcome the visitor, either by greeting them, inviting them to use the exhibit, or asking how the experience is going. Finally, they resort to verbal and non-verbal cues that show the visitor they are appreciated and welcomed (laughing, displays of joy, body language that conveys they are paying attention to the visitor).

Table 3.7 shows the codes for the Information Dimension, which has to do with things that give visitors more information about the science content of the exhibit.

Table 3.7

Codes for the Information Dimension

Code	Examples	Frequency
Giving context and explanation	“There are electrical charges on the ground, often in something like a tower or a tall building, or something like that, like the CN tower… the charges build up on that and they go up trying to find an opposite charge and it finds it inside the cloud” (Slow-motion lightning)	45
Giving explanation	“The water is evaporating” (Drought) “This would be a lot easier for an elephant, because they have so many muscles in their trunk” (Elephant trunk)	24
Giving context	“The arctic is here [points at map] and we are in Sudbury, here [points at map]” (Arctic map)	17
Tells a story	“So what’s happening with this frog is that it’s very sick, so what we’ve been noticing… because this frog lives in Panama, very far away, and they live in mountain tops… so, they were disappearing… so what they [scientists] did, was they started analyzing the frog skin, so now they found that they had a fungus.” (Panamanian frog)	15
Explaining how the exhibit works	"There is an infrared camera there, which allows us to see the heat, things that are cold are blue, things that are hot are red and white” (IR camera)	9
Fun facts	"An elephant trunk has up to 40,000 muscles!” (Amazing trunk)	6

The most frequently used strategies for this dimension relate to giving context and/or explanation. This can be done by giving context that would aid the visitor in the making of meaning, by giving an explanation on the science topic the exhibit covers or using a mix of context and explanation. Bluecoats also provide information by sharing a fun fact that relates to the exhibit or even explaining the science involved in how the exhibit works, not the science content the exhibit is intended to

communicate (e.g. explaining how the IR camera works for an exhibit that is about how snakes see the world). Sometimes, but not always, Bluecoats tell a story to convey the information.

Table 3.8 shows the codes for the Reflection Dimension, which includes strategies to help visitors fully engage with the exhibit.

Table 3.8

Codes for the Reflection Dimension

Code	Examples	Frequency
Making connections	"Do you guys want to see why you're not quite as strong as an orangutan? Follow me!" [takes them to another exhibit] (Grip strength) Showing a narwhal tusk (Newcomers quiz) Showing a snake (IR camera)	27
Calling attention to phenomena	"The marbles near the center go faster" (Gravity well)	18
Proposing a challenge or experiment	"You can try and build something" (Amazing Trunk) [Visitor 1 interacts with the exhibit, then visitor 2 interacts with the exhibit] "How about together?" (Grip strength)	15
Inviting reflection	"Why do you think we take eggs from robins' nests?" (Robin)	15
Asking a trigger question	"So, how many eggs you think she laid" (Robin) [To a girl looking into a microscope] "Do you know what you're looking at in there?" (Panamanian Frog)	14
Asking the visitor for a guess or a hypothesis	"If I were to take an egg from a robin and give it to either a tomtit, a dunnock, or a starling, which one do you think would make the best adoptive parents? … Why?" (Robin)	11

The most frequently used strategies on this Dimension are making connections, either to other exhibits or using props, and calling attention to different phenomena. Bluecoats also resort to inviting (but never commanding) visitors to engage in critical thinking by asking questions that lead them to reflect or ponder, asking for guesses or hypotheses, and proposing experiments (sometimes phrased as a challenge).

Finally, Table 3.9 shows the codes for the Exhibit Use Dimension, which includes all strategies that have to do with exhibit use.

Table 3.9

Codes for the Exhibit Use Dimension

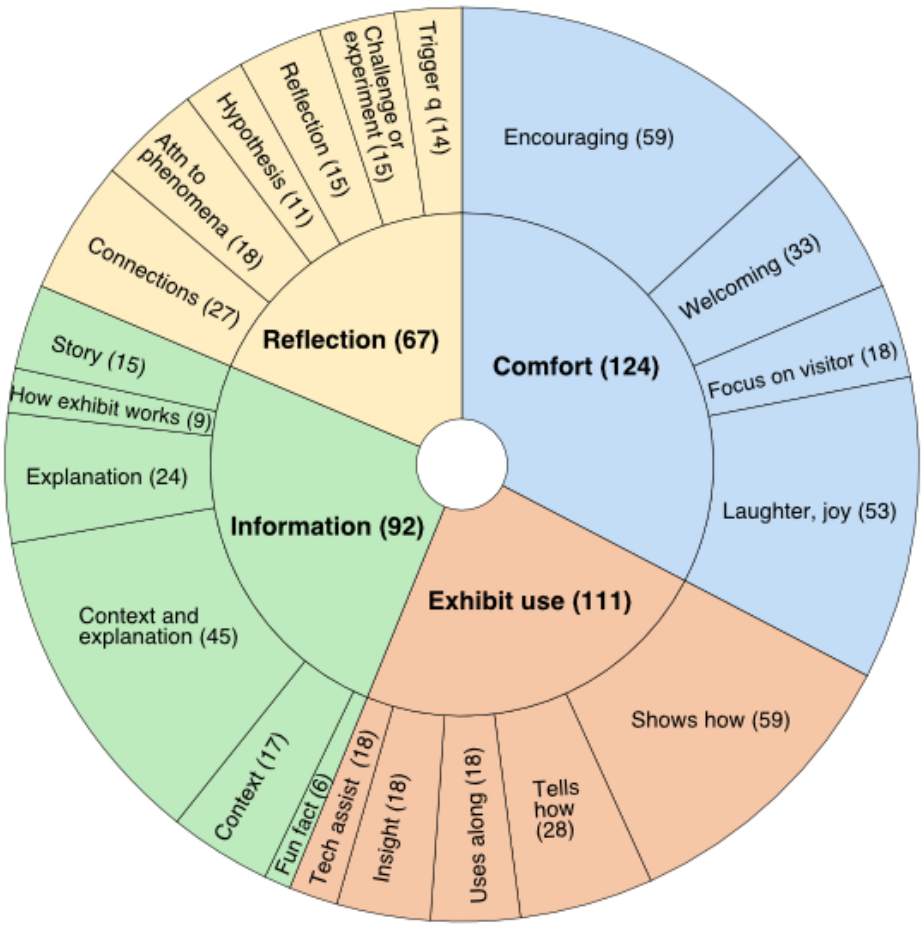
Code	Examples	Frequency
Showing how to use the exhibit	Physically demonstrating how to use the exhibit (Bear Challenge)	59
Telling how to use the exhibit (verbal commands)	“All you do is you squeeze the level and see how strong you are” (Grip strength)	28
Insight into exhibit use	"You can also try this, it’s fun!" “For one of them, I’ll give you a hint, you have to step back from the table” (Scavenger hunt)	19
Using the exhibit along with the visitor	Being player 2 on Thundergames exhibit	18
Providing technical assistance	Rebooting the system for Researcher Hot Zone	8

The most frequently used strategy is showing how to use the exhibit, followed by verbally explaining how to use the exhibits. Bluecoats sometimes give insight into exhibit use or use the exhibit alongside the visitor. Finally, although is rather infrequent, Bluecoats providing technical assistance to visitors.

Figure 3.4 shows show the frequencies of the codes on each Dimension relative to one another (hierarchy chart), and the codes on each dimension. Frequency shown in parenthesis is the amount of interactions in which strategies from each Dimension were used (e.g: if a Bluecoat shows a visitor how to use an exhibit and they then use it alongside the visitor, it counts as one instance of the Exhibit Use Dimension).

Figure 3.4

Hierarchy Chart of the Dimensions



The hierarchy chart shows that Bluecoats resort to strategies in all Dimensions, although Comfort is used the most frequently and Reflection is used the least frequently. The Dimensions do not describe the Bluecoat-visitor interaction experience sequentially or in isolation. A rich learning

experience for the visitor means that many or most of these Dimensions are used during an interaction. Furthermore, strategies from each Dimension can be used in different sequences, to tailor the experience to the visitor.

Discussion

Quantitative phase

The data shows that the presence of a Bluecoat has a clear, quantifiable, statistically significant impact on the percentage of visitors that engage in Breakthrough behaviours, which is a direct indicator of the learning taking place (Barriault & Pearson, 2010). This was predicted by Barriault and Pearson (2010), who posited that when comparing facilitated and unfacilitated visitor experiences, "the engagement curves will reflect the role of on the floor staff in encouraging a higher level of engagement". Our study goes beyond perceptions, feelings and anecdotal evidence to show that staff-visitor interactions have a positive impact on visitor engagement and therefore, visitor learning.

Impact on exhibit Breakthrough Level

In general, Bluecoats promote visitors engaging in Breakthrough learning behaviours. It is important to keep in mind that a well-designed exhibition or science centre floor cannot be comprised only of High Breakthrough Level exhibits. That would create an excessive cognitive load for the visitor and would lead to "museum burnout", which is a less than desirable experience. Falk and Dierking (2013) express this beautifully, saying museum design should be "like a piece of music with areas within exhibitions (and the museum as a whole) that are more interactive and flamboyant, along with areas that also are quiet and more contemplative" (p. 108). Science North purposefully designs their exhibitions so that about one third of exhibits are Low, one third are Medium and one third are High

Breakthrough Level. Our sample of exhibits reflects this feature: 16 exhibits are Low; 19 exhibits are Medium, and 11 exhibits are High Breakthrough Level.

For nine of the 16 Low Breakthrough Level exhibits, visitors reach a higher engagement level (Medium or High) when a Bluecoat is present. We could argue that this is because Bluecoats provide the opportunity for social interaction, and the back-and-forth of engaging with a Bluecoat allows them to go beyond Initiation-type behaviours. Something of note is that the seven exhibits that remain Low Breakthrough Level, have a lower percentage of visitors reaching Breakthrough when a Bluecoat is present. This could be due to the exhibits' characteristics; they are rather didactic and do not provide many opportunities to experiment or engage. However, this is not to be interpreted as a failure or an undesirable feature, just a feature of exhibit design. We could further speculate that for these exhibits there is no benefit to the Bluecoat interacting with the visitors, and the interaction could become a source of distraction for visitors who would like to engage with the exhibits by themselves. Some authors have discussed that staff interaction might be unwelcome and staff might interfere with visitor learning (Marino & Koke, 2003; Pattison & Dierking, 2018). We could also argue that, for some visitors, Bluecoats could interrupt their "flow experience", described as a state in which attention is concentrated on a limited field of stimulus, and the person feels competent and in control (Csiksentmihaly & Robinson, 1975). This is without doubt an aspect of unstructured interactions that should be further explored, since knowing if and when staff should engage with visitors would be as valuable as knowing how.

For Medium Breakthrough Level exhibits (19 total), when a Bluecoat is present, 11 exhibits become High Breakthrough Level and one exhibit becomes Low Breakthrough Level. For the five exhibits that are also Medium Breakthrough Level with Bluecoat interaction, there is no distinctive pattern for the variation on the percentage of visitors that reach Breakthrough (one has a lower percentage of visitors reaching Breakthrough, one has the same percentage and the other three have a higher

percentage). As Medium Breakthrough Level exhibits sit in the middle, it is harder to identify a pattern for the impact Bluecoat interaction has, and therefore it would be difficult to determine what, if anything, has a bigger impact or contribution to the changes.

Finally, for High Breakthrough Level exhibits (14 total), no exhibit becomes Low Breakthrough Level, two exhibits go from High to Medium (which by definition implies that the percentage of visitors that reach Breakthrough is lower with Bluecoat interaction) and the overwhelming majority (12) remain High Breakthrough Level. Something of note is that for all but one of those exhibits (Seabird Rescue, which goes from 68 % to 43 % Breakthrough when a Bluecoat is present), the percentage of visitors that engage in Breakthrough learning behaviours is higher with Bluecoat interaction than without. This further supports our claim that interacting with a Bluecoat facilitates reaching Breakthrough, even for exhibits that are designed to promote Breakthrough behaviours. This could be due to Bluecoats providing further avenues to explore, by engaging in conversation with the visitor and providing a richer experience (and thus influencing the personal and sociocultural contexts), or by inviting them to explore and discover the physical characteristics of the exhibit (Falk & Dierking, 2013).

Impact on aggregated engagement curves

As shown in the aggregated engagement curves (Figures 3.1 to 3.3), interaction with a Bluecoat plays a statistically significant role in visitor engagement, which is a direct indicator of learning (Barriault & Pearson, 2010). Interacting with a Bluecoat does not make exhibits change overall Breakthrough Level (i.e. From Low or Medium Breakthrough to High Breakthrough exhibit), which is not unexpected, as these are aggregated curves, and give a more general view of the exhibits, diminishing the impact of outliers. Furthermore, as demonstrated in the statistical analysis, our data suggests that a higher percentage of visitors reach Breakthrough when a Bluecoat is present, for all Breakthrough Levels (Low, Medium and High). Something that is worth noting is that for the three aggregated engagement curves,

Initiation is lower when a Bluecoat is present (41 % vs 54 % for Low, 34 % vs 41% for Medium and 11 % vs 27 % for High Breakthrough Level). This indicates that Bluecoat interaction aids visitors in reaching higher engagement levels (Transition or Breakthrough). These findings support what Falk and Dierking (2013) expressed: “The few studies conducted with casual visitors do suggest that staff positively influence the experience, particularly when they are skilled interpreters, helping to facilitate and make the experience meaningful for visitors.” (p. 163).

For Low Breakthrough Level exhibits, the percentage of visitors that reach Initiation with Bluecoat interaction is lower (41 % vs 54 %), while Transition and Breakthrough are higher (44 % vs 35 % and 15 % vs 11 %, respectively). For Medium Breakthrough Level exhibits, the percentage of visitors that reach Initiation is lower (34 % vs 41 %), Transition is higher (36 % vs 27 %), and Breakthrough is about the same (30 % vs 32 %) when a Bluecoat is present. This means that the interaction helps visitor reach higher engagement levels. However, as discussed before, sometimes visitors need more quiet and reflective spaces within the science centre (Falk, 2006). The fact that Breakthrough is only slightly higher or about the same with a Bluecoat should not be interpreted as a failure in facilitation, but a feature by design.

For High Breakthrough exhibits, Initiation is Lower with Bluecoat interaction (41 % vs 54 %), Transition is approximately the same (19 % vs 20 %) and Breakthrough is higher (70 % vs 53 %). In this type of exhibits, the Bluecoat interaction cannot produce a change in Breakthrough Level for the exhibit (i.e. From Low to High Breakthrough), because High is the highest Breakthrough Level. However, it is interesting to note that, since Transition is the same, the increase in the percentage of visitors that engage in Breakthrough behaviours comes from the reduction in the percentage of visitors that engage no further than Initiation. Furthermore, these exhibits have even higher percentage of visitors reaching Breakthrough when a Bluecoat is present, meaning that Bluecoats promote visitors engaging in deeper learning, even for High Breakthrough exhibits, given that learning is an active process and a highly

contextual and social activity (Hein, 1991). This could also be due to Bluecoats providing the scaffolding needed for visitors to engage in deeper learning, through the Zone of Proximal Development (Vygotsky, 1978).

Qualitative phase

The four Dimensions: Comfort, Information, Reflection and Exhibit Use

This work provides an initial framework that describes the strategies Bluecoats use when interacting with visitors. This framework for facilitation has four dimensions: Comfort, Information, Reflection and Exhibit Use. We called them Dimensions because they encompass different strategies and techniques of facilitation, all equally useful and powerful.

The four Dimensions could be considered tools in a toolbox, and the key to good facilitation is to "read" the visitor, to know which strategies to use to fit each person's needs. Effective facilitation requires staff to be able to recognize the visitor's readiness to learn and respond accordingly and in a flexible way (Ash, 2012). Although some authors suggest that the identity model of visitors proposed by Falk in 2009 could provide a somewhat reductionist perspective (Dawson & Jensen, 2011), staff can use it as a starting point for a rich, meaningful interaction. We could argue that if staff keep in mind that each visitor has specific needs and wants and remember they can embody more than one identity at the same time, Falk's model could certainly bring value. Providing a rich learning experience for visitors means that Bluecoats resort to many different strategies, in a variety of sequences, tailored to each visitor and exhibit, which is the key to successful, effective facilitation.

The Comfort Dimension. Comfort relates to things the Bluecoats do to make the visitor feel comfortable and welcomed into the space. This is the most frequently used Dimension and we could argue that it is a crucial one, because if visitors feel uncomfortable, unsafe or unwelcomed, it would be

very difficult for learning to happen because their basic needs are not met (Maslow, 1943). Previous research determined that, for families, a positive experience with staff was associated with a safe, comfortable and welcoming environment (Brown, 2019). We feel that it would be the same for other visitor demographics, although further research would be needed to validate the claim. Using strategies in this Dimension, Bluecoats show respect and care for their visitors, which could allow them to reach higher levels in Maslow's Hierarchy of Needs, like esteem and self-actualization (Maslow, 1943).

The Exhibit Use Dimension. Bluecoats frequently help visitors with Exhibit Use. This can be done by explaining how to use an exhibit, using the exhibit alongside the visitor, giving them a tip or hint or providing technical assistance. Previous research determined that exhibits have a strong influence on the visitor's learning experience (Pattison, 2018). Even considering that our study is independent of the particular characteristics of exhibits, it is self-evident that being able to engage with the exhibit is a crucial step for learning in a science centre. In our opinion, Bluecoats provide added value for visitors, by helping them engage with the exhibit in a basic manner (by providing technical assistance or explaining how to do it) and also to go beyond the obvious affordances (by providing tips or hints), leading to a deeper, more meaningful experience.

The Information Dimension. Information has to do with things that give visitors more information about the science content of the exhibit. This is probably what people immediately picture when they think about facilitation in a science centre. When used correctly, the strategies on this dimension can provide a "scaffolding" for visitor learning and the making of meaning, through social interactions and the Zone of Proximal Development developed by Vygotsky (Ash, 2012).

The two most complicated aspects of this dimension have to do with delivery and timing. Bluecoats should be able to provide information in a way that is not too didactic, and they should also

be able to identify when would be the best moment to interac with visitors who are engaging with an exhibit (Brown, 2019). We believe that experienced facilitators are able to determine the best way to engage with each visitor, as this is learned with practice. Learning how to actively listen, observe and respond to visitors in a way that maximizes their opportunities for learning is a sizable task for facilitators (Ash, 2012). Our framework could provide tools for trainers to help less experienced facilitators more easily identify what would the most effective approach for each visitor.

The Reflection Dimension. "The mind is not a vessel to be filled, but a fire to be kindled", this phrase, attributed to Plutarch, perfectly encompasses the power, and also the predicament, of this dimension. The Reflection Dimension includes strategies to help visitors fully engage with the exhibit, by inviting (but never commanding) them to reflect, to propose hypothesis, to make connections and engage in critical thinking. This Dimension is used the least frequently and it could be argued that these strategies can only be fruitful when the visitor is already invested in the exhibit and somewhat attuned to delving deeper into the subject, to start thinking about the "why" instead of the "what". This could be related with Bloom's Taxonomy of Educational Objectives (1956), as exhibits by themselves allow visitors to apply their knowledge and make some connections (especially when they are High Breakthrough Level), but Bluecoats provide opportunities to engage in higher order thinking skills. Interacting with a Bluecoat could provide opportunities to critically evaluate the ideas presented (analyze), draw connections among ideas (evaluate) and conjecture and further investigate phenomena and ideas (create).

Building on previous research and final thoughts

Pattison and Dierking's research (2012, 2013, 2017, 2018) could be seen as complementary body of work that can provide insight into our research. Their approach is somewhat opposite and

complementary to ours, and it is interesting to note that we arrived at very similar conclusions. Our approach has three main differences with Pattinson's. First, their study focuses on families, while we analyzed all visitors that interacted with Bluecoats. Second, they studied math exhibits that were intentionally designed to support staff–family interactions through specific "facilitation affordances (e.g., props or tools to enhance the exhibit experience that only museum educators could make available)" (Pattison, 2018), while we analyzed all exhibits that had available data and the exhibits provide the same affordances with and without a Bluecoat present. Finally, they worked with facilitators that had at least two years of experience, were identified as effective, skilled exhibit facilitators and were provided extra training on their method. On the other hand, we worked with clips that showed Bluecoats, who although are trained in the Visitor Engagement Framework (K. Pisani, personal communication, October 9, 2020) did not receive any additional training for this research, to the best of our knowledge. Both works give very valuable insight into unstructured staff-visitor interactions, theirs from a very detail-level, specific, perspective and ours using a more general lens.

In Pattison and Dierking's research, facilitators employ five facilitation strategies that could be connected with our Dimensions. "Orient" overlaps with Exhibit Use, "Challenges" are part of the Reflection Dimension, "Provide Explanations" is one of the codes in the Information Dimension, and finally, "Show Appreciation" and "Establish Visitor Ownership" are both included in the Comfort Dimension. Both Pattison and Dierking's and our research focus on unstructured interactions between staff and visitors and were developed with insight from experienced practitioners, therefore it makes sense that there is a great deal of overlap between the facilitation strategies they have identified and the four Dimensions that emerged in this study.

The staff in Science North follow the “Characteristics of Excellence” which defines the values, standards and techniques which embody Science North “hands-on” philosophy of science communication (Bray, 2011). This document describes Bluecoats as follows:

> The term Bluecoat represents the Persona of the Science North person who involves people in the relationships between science and technology and everyday life… Bluecoats do more than “explain” or “steer” or “tourguide” or “host”. Bluecoats involve their customers in real science. They provide useful tools and an infinite variety of experience. They have fun with people and are comfortable to be with. And they learn with their customers (…) Bluecoats are the most essential ingredient of the Science North experience.
>
> At its essence, the Bluecoat is a step beyond interactive exhibitry, introducing human interaction into the mix. Visitors to Science North can approach a Bluecoat with questions, participate with a Bluecoat in a demonstration or be drawn into an activity by the enthusiasm that the Bluecoat brings to his or her task. Being a Bluecoat does not involve spouting facts or controlling the experience a visitor takes away with them. The Bluecoat is a facilitator, making exhibits come alive and allowing visitors to control their own experience of SN and grasp the science behind the exhibits in a very personal way. (pp. 77-79)

This document also describes the six standards of Bluecoat excellence. Bluecoats, regardless of their position, are:

- Caretakers (take care of visitors, ensure surroundings are clean are safe),
- Ambassadors (represent the attributes of the organization, act as a role model to visitors and peers),
- Troubleshooters (use problem solving skills, are flexible and adaptable, ensure visitors’ comfort),
- Initiators (actively engage visitors in science activities),

- Scientists (involve people in the scientific process, eliminate science intimidation, create and promote a sense of wonder), and
- Entertainers (make science fun and understandable through their energy and enthusiasm, be adventurous and spontaneous) (Bray, 2011, p.78)

It makes sense then, that the Bluecoat standards of excellence described also overlap with our Dimensions. Being Ambassadors, Initiators and Caretakers connect with the Comfort Dimension, and this could explain why codes in this dimension are more frequent than in the other three. Being Troubleshooters and Initiators relates to the Exhibit Use Dimension. Being Entertainers relates to the Comfort, Information and Reflection Dimensions, and finally, being Scientists relates to the Information Dimension.

As stated in the beggining, we aimed to determine how the interaction with a Bluecoat impacts visitors' engagement levels and what do they say and do to have that impact. Our research goes beyond perceptions, feelings and anecdotal evidence to show that staff-visitor interactions have a positive impact on visitor learning. This study and the initial framework described above provide a strong starting point for staff to create and develop rich, meaningful experiences for visitors. We think this framework can serve as an assessment tool for science centres, to help them better understand how their staff can make the visitors' learning experiences richer and even contribute to the exhibit design process. Trainers and senior staff can use the framework as a starting point to help trainees (and even themselves) strengthen the dimensions in which they might be weaker, to become well-rounded facilitators.

In closing, we would like to reflect on a quote by Falk and Dierking (2013):

> It is time we revisit the way we describe and advocate for the "learning power" of museums. Museum learning is unique, multifaceted and inspires higher order affective and cognitive development. Yet, when museums describe their educational impact to stakeholders, it is often described narrowly, using the measures of formal education rather than focusing on

its capacity to model intrinsically-motivated, joyful, open-ended learning that supports self-knowledge and positive social behaviour. (p. 244)

Through social interactions, staff turn museums and science centres from mere curiosity cabinets into spaces to learn and flourish. We think this study shows they are a fundamental asset for these institutions, one that should be celebrated and given top priority when considering areas for investing.

Limitations and future research

Limitations

The biggest advantage of using a mixed-methods approach is the possibility to overcome some of the shortcomings and biases in qualitative and quantitative methods (O'Leary, 2017). This certainly does not mean this study is free of biases or limitations, especially in the qualitative phase.

The developers of grounded theory advise against comparing a theory that is emerging to the findings in the literature, as to avoid "forcing" the data into theoretical categories (SAGE, 2007), and that could certainly be a limitation for this study. However, a previous theory can be used to provide insight, direction, and an initial set of concepts to use as a starting point for developing new concepts and expanding old ones, as long as the researchers are open to the possibility that the old theory may not fit with the new data (Corbin & Strauss, 2015).

As proposed by Corbin & Strauss (2015), to control the intrusion of perspectives, biases and assumptions, along with research notes and memos, I kept a journal with a record of my biases and assumptions and thought through how these might affect the research and the themes that emerge. For example, my extensive experience in the field allows me to identify behaviours that contribute to quality facilitation, but some behaviours could have not been included in my analysis because they seemed obvious or basic to me. This is why my insights and assumptions were recorded and discussed

extensively with my supervisors. Furthermore, applying the method in a systematic manner, especially the constant comparisons of data, has the advantage of "built-in checks and balances" (Corbin & Strauss, 2015).

Another limitation of using grounded theory is that the laborious process of coding can make novice researchers lose sight of the research question and generate theories that have multiple limitations (El-Hussein, 2014). Working with experienced researchers and having a clear theoretical lens to explore data (socioconstructivism) guides the systematic approach to data analysis and generating theory. To address the potential drawback of one researcher giving a biased meaning to a witnessed action-interaction, the coding was systematically checked with both supervisors.

Finally, although there is limited generalizability inherent to working with an emergent methodological design, this study is not meant to be generalizable at this point.

Future research

This study demonstrates empirically that staff interactions with visitors increase the percentage of visitors that reach Breakthrough Level of engagement. Additionally, our study proposes an initial framework for facilitation and would certainly benefit from further research. We could investigate what the exhibits that get the biggest impact from Bluecoat interaction have in common, or what dimensions lead to Breakthrough more often. It would also be fruitful to engage in observations on the science floor and conduct interviews with Bluecoats, especially those who train other Bluecoats. Another potentially interesting avenue for research would be to examine how the strategies Bluecoats use are different for different types of visitors (different ages, different motivations, etc.) or different types of exhibits. Finally, including other science centres and museums as fields of study would contribute to strengthening the validity and stability of the findings.

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Appendix 1 – Exhibits analyzed

We analyzed a total of 47 exhibits from four travelling exhibitions (Arctic Voices, The Science of Ripley's Believe it or Not, Wild Weather and Wildlife Rescue) and from two different exhibit floors at Science North.

Arctic Voices (2015)

This is Science North's tenth travelling exhibition, developed in partnership with the Canadian Museum of Nature. This exhibit engages visitors while they explore the Arctic through the sights, sounds, and voices of this beautiful and changing place through interactive and object-based exhibits, and multimedia experiences. They discover the wildlife, marvel at the landscapes, and meet the people who call the Arctic home.

Exhibits analyzed (5):

Bear challenge	Visitors took the challenge to mimic an Arctic animal by pushing to compare their force to that of a bear. Visitors had fun repeating the task to see if they could change their results and competing with family and friends to see who would be best.
Global connections	Global Connections allows visitors to explore how the Arctic influences the weather we experience, and the impact it will have on the whole planet, through animations of changing and shrinking sea ice. Visitors watch the animations and videos of researchers as they discuss the information presented, engaging in a social learning experience about understanding the Arctic
Hare challenge	Visitors engaged in another Arctic animal challenge, attempting to reproduce the hopping of an Arctic Hare.
Newcomers quiz	In this multiplayer quiz, visitors compete against each other to answer questions that test their knowledge of species moving further and further north because of climate change.
The Map of the Arctic	The Map of the Arctic engages visitors in a conversation about the location of the animals and people in this exhibit; the distance between our habitat to theirs; and the landscape of this area.

The Science of Ripley's Believe It or Not (2013)

Science North, in partnership with Ripley Entertainment Inc., designed a 6000 square foot travelling exhibition, The Science of Ripley's Believe It or Not!® This exhibition showcases the amazing and wonderfully unique features of our world, including animal and human biology, extreme earth events, amazing talents, unique art, and multiple illusions! Science North created this exhibition to engage visitors in discovering the science behind the weird world of Ripley's Believe It or Not!®

Exhibits analyzed (8):

Age yourself	Visitors take a snapshot of their face, input a few variables and then view images of what they may look like at intervals into the future.
Chair	The Big Chair gives visitors a feel for just how giant the owner was. This item is a great photo opportunity for families and groups and creates an exciting beginning for the exhibition.
Dinosaur marvels	Visitors can compare their height to a life-size 8-foot (2.5 m) tall replica of an elephant bird skeleton and its foot-long (30 cm) egg, engage with a La Brea Tar Pit block, examine fossils of some of the most extreme animals that have lived on Earth, and watch expert paleontologists answer common paleontology questions.
Gate	A trick gate, with a hidden lock mechanism that visitors have to figure out.
Make your skin crawl	Visitors can learn how optical illusions exploit the way our brains process visual information to turn it into an image. They stare into the center of a black and white pattern, then shift their gaze to the back of their hand to see an effect that makes their skin crawl.
Scavenger hunt	Visitors have to find 10 tiny animals on and around a table.
Small challenge	In small challenge, visitors marvel at the intricate microscopic sculptures. They watch a video to "meet" the artist, Willard Wigan, and learn about the physiological changes the sculptor must accomplish to work on such tiny art. They can then manipulate objects similar in size to the ones Wigan uses.
Vase	Visitors test out this "spin" on a classic optical illusion. They focus on a vase in the center of a cabinet, then spin a disk and take a step back to watch as the two faces start "talking" to each other.

Wild Weather (2016)

Wild Weather was developed by Science North, in partnership with the Ontario Science Centre. Through hands-on exhibits, multi-player challenges, and interactive multimedia experiences, this 6,000 square-foot travelling exhibition reveals how scientists are working to better forecast severe weather events and to help mitigate the impact on communities, infrastructure and lives. From the safety of the exhibit hall, this blockbuster exhibition also explores the effects of global climate change on severe weather and guides visitors on how to best weather the storm.

Exhibits analyzed (12):

Body heat alert	In this computer interactive, visitors can see the physiological symptoms of heat stroke.
Cloud Wheel	The Cloud Wheel is a mechanical graphic. The content of this exhibit describes the characteristics of different types of clouds, and it is presented in a wheel that visitors turn to access the information. When visitors move the wheel, they select a cloud formation, and different areas of the wheel display the rest of the content.
Drought	Drought: Before and After is a computer interactive where visitors can look at photos that display different areas around the world, and what they were like before they experienced severe drought, compared to the after. Each location photo has a slider on the screen that visitors can move to see each side of the overlaid images, giving them a direct comparison of how the area has changed.
Forecasting tornadoes	Kiosks that visitors can use to learn about forecasting tornadoes. The station engaged visitors of all ages, however, the content of them is very adult focused, discussing the detailed research of this weather and the serious impact climate change is having in our world.
Researcher hot zone	A life-size video projection of a scientist. Visitors interacted with the featured researcher by selecting from a preset series of questions on a touchscreen on the front of the projection.
Slo-mo lightning	Visitors can control the speed of a video of lightning, including the possibility to see it in slow motion.
Study your sweat	Visitors can use a microscope to see the sweat forming on their skin.
Thundergames	Visitors play a game in which one player sets the distance a storm is and the other player has to figure out how far the storm is by counting the seconds between the sound of thunder and the visual cue of lightning.
Thunderstorm dangers	In this computer interactive, visitors can explore the ramifications of different scenarios involving thunderstorms.
Tornado chasers	Visitors can watch different clips showing video interviews with real life scientists that are also tornado chasers.

Tornado damage	Using augmented reality, visitors can see the destruction created by different categories of tornados.
Tornado sculpture	The Tornado Sculpture is an iconic metal structure within Wild Weather. Mounted monitors seem to swirl with the spin of the storm, as wind and debris whirl past on subsequent screens, appearing to fly up into the tornado. Via two touchscreen interface stations, visitors can send various objects to be digitally swept up inside the tornado. Along with the options of a car or a cow, visitors can also take their own photos to see themselves fly by.

Wildlife Rescue (2011)

This 6000 square-foot travelling exhibition, designed by Science North, has 30 exhibits and experiences which include mechanical interactives, multimedia exhibits, computer interactives, large graphic panels, specimens and replicas, a video theatre, and scientific tools used by rescuers.

Exhibits analyzed (19):

Amazing trunk	Visitors can discover how the elephant trunk moves, how an elephant uses it, and how baby elephants must learn how to use their trunks properly. Visitors operate an elephant trunk with their arm.
Beetle	Visitors watch a video of the American Burying Beetle burying and preparing a dead mouse for its young. Visitors can then turn a crank to bury a mouse deep in the sand, just like the beetle.
Big globe	A giant rotating globe with a touchscreen interactive with videos of animals from all over the world.
Elephant quiz	Visitors at the Elephant Behaviour exhibit participate in a multi-player computer quiz. Video clips of elephant communication are played, and visitors must interpret and answer questions to identify behaviours and emotions expressed by the elephant.
Face recognition	N/A
Feed the chick	At Feed the Chicks: California Condor, visitors use the puppet adult condors attempting to pick up food pellets to feed the chick.
Grip strength	Visitors compare their grip strength to that of orangutans of different sexes and ages.
Heartbeat	Visitors listen to the heartbeats of different mammals using a stethoscope.
Iberian lynx	Visitors take the role of field researchers and examine the scat and tracks of Iberian lynx, European rabbit and red fox, to try and identify the ones left by the lynx.
Panamanian frog	At the Deadly Fungus: Panamanian Golden Frog exhibit, visitors use a touch screen video, micrographs of infected skin and a model of the frog to learn about the deadly fungus that is threatening amphibian populations worldwide.

Giant panda	Visitors at the Panda Weight exhibit step on a large scale to compare their weight to that of a panda. Visitors can also see a touchscreen interactive showing different skulls.
Puzzle	N/A
Robin	Visitors study model nests, eggs and life-size images of three birds (Chatham island tomtit, dunnock, starling) to determine which bird species would make the best 'foster parent' to incubate black robin eggs.
Seabird rescue	Visitors have to touch different objects in a table.
Sturgeon	Visitors rub the side of a life-size sturgeon model just as scientists do to extract the eggs. This action triggers the start of a video showing the main steps used in restoration programs to re-populate sturgeon in the Great Lakes.
Turtle crawl	Visitors at the Turtle Crawl wear a turtle shell and crawl under an overpass while listening to the sounds of the zooming cars above.
Turtle rehab	Visitors do the procedure to rehabilitate a turtle.
Xray	At the X-Ray Station, visitors position the x-ray machine over animals' injuries to light up the x-ray.

Science North's floors

Science North is Canada's second largest science centre. On the third floor, visitors can take a voyage through Ontario's natural landscapes with Northern Ecosystems, visit Science North's animal ambassadors and learn about the wildlife found in their own backyards. On the fourth floor, visitors can tinker, play, and have fun, learn about space exploration or discover the latest Breakthroughs in biology.

Exhibits analyzed (3):

IR camera (3rd floor)	Thermal imaging camera and monitor setup, found next to the reptiles' habitat.
Gravity well (4th floor)	A gravity well simulates the gravitational pull of large objects on smaller objects in space.
Robotic arm (4th floor)	Model of the International Space Station's Shuttle Remote Manipulator System (aka Canadarm) that visitors can operate to move and stack foam blocks of different shapes and sizes.

Appendix 2 – Exhibits by Breakthrough Level

Name	Breakthrough Level without Bluecoat interaction	%BT without Bluecoat interaction	Breakthrough Level with Bluecoat interaction	%BT with Bluecoat interaction
Big chair	Low	3	Low	0
Skin crawl	Low	4	Low	0
Gate	Low	7	Low	0
Tornado chasers	Low	7	Low	0
Face recog	Low	11	Low	10
Cloud wheel	Low	13	Low	10
Puzzle	Low	18	Low	17
Researcher hot zone	Low	3	Medium	33
Slo-mo lightning	Low	5	Medium	20
Scavenger hunt	Low	7	Medium	22
Tornado sculpture	Low	10	Medium	25
Age yourself	Low	16	Medium	33
Panamanian frog	Low	17	Medium	27
Beetle	Low	18	Medium	25
Dino marvels	Low	19	Medium	25
Panda scale	Low	14	High	40
Iberian lynx	Low	17	High	71
Hare challenge	Medium	33	Low	0
Thundergames	Medium	32	Medium	38
Robotic Arm	Medium	33	Medium	33
Tornado damage	Medium	36	Medium	25
Small challenge	Medium	38	Medium	20
Body heat alert	Medium	39	Medium	33
Vase	Medium	22	High	100
Amazing trunk	Medium	23	High	50
Newcomers	Medium	25	High	60
Robin	Medium	26	High	74
Turtle crawl	Medium	31	High	50

Forecasting tornadoes	Medium	33	High	83
Gravity well	Medium	33	High	71
Grip strenght	Medium	34	High	67
Xray	Medium	34	High	72
Sturgeon	Medium	36	High	50
IR cam	Medium	38	High	59
Bear challenge	High	40	Medium	36
Giant panda	High	51	Medium	33
Study your sweat	High	44	High	100
Turtle rehab	High	47	High	64
Thunderstorm dangers	High	51	High	83
Big globe	High	52	High	60
Global connections	High	52	High	100
Feed the chick	High	53	High	84
Heartbeat	High	53	High	80
Drought	High	54	High	83
Elephant quiz	High	62	High	85
Seabird rescue	High	68	High	43
Arctic map	High	76	High	100

Note: %BT is the percentage of visitors that engage in Breakthrough learning behaviours

Appendix 3 – Statistical analysis

```
> str(data)

'data.frame':	94 obs. of  6 variables:
 $ BC          : chr  "No" "No" "No" "No" ...
 $ Inititation : int  19 34 33 31 39 21 11 15 22 32 ...
 $ Transition  : int  0 12 14 13 15 25 2 58 23 16 ...
 $ Breakthrough: int  60 50 48 52 43 40 27 12 50 49 ...
 $ Exhibit     : chr  "Arctic map" "Global connections" "Thunderstorm dangers" "Drought" ...
 $ BTL: chr  "High" "High" "High" "High" ...

> # make the percentages fit the binomial distribution
> data$BT<-data$Breakthrough/100

> # use a glm with quasibinomial distribution
> require(nlme)
> require(car)

> # is Breakthrough affected by the presence of a Bluecoat?
> fit1<-glm(BT~BC, data=data, family=quasibinomial)
> Anova(fit1, type = "III")
Analysis of Deviance Table (Type III tests)

Response: BT
   LR      Chisq       Df      Pr(>Chisq)
BC         112.62      1       < 2.2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

> summary(fit1)

Call:
glm(formula = BT ~ BC, family = quasibinomial, data = data)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-0.6514  -0.2135  -0.0548   0.1887   0.6860

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) -0.98493    0.09561 -10.301  < 2e-16 ***
BCYes       -2.00991    0.22140  -9.078 1.99e-14 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for quasibinomial family taken to be 0.08506424)
```

```
    Null deviance: 17.6602  on 93  degrees of freedom
Residual deviance:  8.0802  on 92  degrees of freedom
AIC: NA

Number of Fisher Scoring iterations: 6


> # interaction of presence of BC and the class
> fit2<-glm(BT~BC*BTL, data=data, family=quasibinomial)
> Anova(fit2, type = "III")

Analysis of Deviance Table (Type III tests)

Response: BT
           LR      Chisq      Df     Pr(>Chisq)
BC                 141.432    1     < 2e-16 ***
BTL                104.355    2     < 2e-16 ***
BC:BTL             4.821      2     0.08975 .
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

> #as interaction is not significative, we can safely remove it from the model
> fit3<-glm(BT~BC+BTL, data=data, family=quasibinomial)
> Anova(fit3, type = "III")
Analysis of Deviance Table (Type III tests)

Response: BT
    LR   Chisq      Df      Pr(>Chisq)
BC      243.14   1          < 2.2e-16 ***
BTL     109.11   2          < 2.2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```