J Sci Educ Technol (2017) 26:253–268
DOI 10.1007/s10956-016-9676-7

The Particular Aspects of Science Museum Exhibits That Encourage Students' Engagement

Neta Shaby[1] · **Orit Ben-Zvi Assaraf**[1] · **Tali Tal**[2]

Published online: 16 December 2016
© Springer Science+Business Media New York 2016

Abstract This research explores learning in science museums through the most common activity in a science museum—interaction with exhibits. The goal of this study was to characterize the learning behaviors exhibited by students as they engage with interactive exhibits in order to draw insight regarding the design of the exhibits. In order to do so, we used a qualitative method of observation as well as the Visitor Engagement Framework (VEF) model, a visitor-based framework for assessing visitors' learning experiences with exhibits in a science center setting. The combined method produced a framework of nine learning behaviors exhibited during the visitors' interaction with the exhibits, grouped into three categories that reflect increasing levels of engagement and depth of the learning experience. Our research participants consisted of a total 1800 students aged 10–12 (4th, 5th, and 6th graders) who came to the museum with their class for a day visit. We observed nine exhibits, each visited by 200 students. Our observations revealed several design elements that contribute to engagement with exhibits in science museums. For example, exhibits that have familiar activation encourage visitors' interaction, exhibits that facilitate social interaction are more likely to increase engagement, and the highest levels of engagement can be found in exhibits that support large groups.

Keywords Informal learning · Science museum · Exhibits

Electronic supplementary material The online version of this article (doi:10.1007/s10956-016-9676-7) contains supplementary material, which is available to authorized users.

✉ Neta Shaby
shaby@post.bgu.ac.il

Orit Ben-Zvi Assaraf
ntorit@bgu.ac.il

Tali Tal
rtal@ed.technion.ac.il

1 Program of Science and Technology Education, Ben-Gurion University of the Negev, P.O.B. 653, 84105 Beer-Sheva, Israel

2 Department of Education in Technology and Science, Technion, Israel Institute of Technology, Technion City, 32000 Haifa, Israel

Introduction

Though most education research to date has focused on learning that takes place in school, there is an increasing awareness in the field that science, technology, engineering, and mathematics (STEM) learning occurs across a broad range of contexts, including museums, afterschool programs, the internet, and other media, as well as family learning at home (Bell and National Research Council, U.S. 2009). As Potvin and Hasni (2014) claim, while interest in studying and pursuing a career in science and technology has been waning in school, interest in these topics in out-of-school settings is showing signs of improvement. Designed informal learning environments like museums can therefore be used to further science education.

Because research on the topic of formal environments is far more extensive than research of informal environments, the question of how precisely knowledge is constructed in such settings remains unclear (Osborne and Dillon 2007). Moreover, the research that has been conducted about learning in science museums has tended to be largely theoretical, while empirical studies of visitors and their exhibition experiences have been comparatively few (Kirchberg and Tröndle 2012). The study presented here takes an empirical look at the behavior of visitors in the informal environment of the science museum. It explores learning in science museums through the most common science museum activity—interaction with exhibits.

Our study is significant in both the type and the size of its target population. First, it focuses on students who have been brought to the museum by their schools, while most studies of science museums have examined free choice visitors. Second, this study observed 1800 students interacting with the exhibits. Observing such a large number of participants is unusual in museum studies. Our belief is that a large sample is important in order to draw a comprehensive picture of the nature of engagement.

Museum exhibits offer open-ended learning environments, where exhibit interactions are established by the visitor, rather than dictated by a human mediator like a teacher or a guide (Falk and Dierking 2000). In such an environment, opportunities to engage with and learn about science can be interpreted and used differently depending on time, context, and the student involved (Archer et al. 2016). Exhibits must therefore first attract visitors' attention and then compel them to become engaged with the exhibit long enough for learning to take place. In order to develop such exhibits, museum staff, museum educators, and exhibit designers need to better understand the variables associated with exhibits' attraction, holding power, and visitor engagement (Boisvert and Slez 1995).

Our study focuses specifically on how schoolchildren visiting the museum with their class interact with the exhibits. We observed schoolchildren as they interacted with various exhibits in the science museum, basing our analysis of these observations on Barriault and Pearson's Visitor Engagement Framework (VEF) (2010), which is designed to gauge exhibits' interactive and engagement potential. Our research population consisted of 1800 students aged 10–12 (4th, 5th, and 6th graders), who came to the museum with their class for a day visit. We observed nine exhibits, watching 200 students in each exhibit.

The goals of this study were (a) to understand and identify the form and extent of students' engagement with various exhibits in the science museum, and (b) to determine whether this engagement could be linked to any particular exhibit characteristics. We therefore asked the following:

1. What kinds of behaviors are observable in visiting students as they engage with the exhibits at the science museum? What do these behaviors tell us about the level of the students' engagement?

Having identified a range of student behaviors and associated them with three different levels of engagement, we further sought to determine whether there was any connection between particular student behaviors/engagement levels and the characteristics of specific exhibits. We therefore also asked the following:

2. How do the exhibits we observed differ from one another in the behaviors and levels of engagement they elicit?

Looking at the differences in the behaviors and engagement levels expressed by the visitors in each exhibit allowed us to discern which of the exhibits were most "successful" (i.e., which elicited the highest levels of engagement most often) and which were least successful (i.e., in which the highest level of engagement was most rare). We then looked more closely at the two most successful and the two least successful exhibits, asking the following:

3. What are the characteristics associated with the most "successful" exhibits? What are the characteristics associated with the least successful ones?

Context

Informal Learning Environments

In order to fully understand children's science learning, one should look not only at learning that takes place in school but also at learning that takes place out-of-school, since there is a growing body of evidence supporting the assertion that learning occurs in a variety of times and settings beyond the limits of school hours and school walls (Falk and Dierking 2000, 2012; Hein 1998). In this research, the out-of-school setting that was explored is a science museum.

Studies of in informal settings show that those who are more likely to visit a museum and be influenced by such experiences tend to be families comprised of college-educated parents and adolescent or younger children (Bell and National Research Council, U.S. 2009). Nevertheless, studies have also shown that museums and similar institutions benefit students from minority ethnic backgrounds and students from economically deprived areas too (Archer et al. 2016; Hooper-Greenhill et al. 2009). The museum in which our research takes place is located in a peripheral part of Israel. The marginalized communities that reside there do not tend to visit museums as a family, which means that most of their children will only visit a museum as a part of a school visit. While family visits are free choice by definition, school visits rarely provide students with the opportunity to engage with exhibits in free choice settings (Tal and Morag 2007). As a result, little is known about school students' uncontrolled engagement in a science museum setting, like the one which is the focus of the study.

Interactivity and Engagement in a Science Museum

As noted above, this research explores learning in science museums through interaction. The term "interactivity" covers a range of experiences that fully engage visitors personally, physically, and emotionally (Adams et al. 2004). Interactive experiences appear to be an effective means to create engagement and participation with museum exhibits and, subsequently perhaps, with the scientific issues they contain (Meisner et al. 2007). Drawing from that, the context of the research will apply to interactive exhibitions, engagement, and what we define as learning behaviors, based on the research of Barriault and Pearson (2010).

Little is known about how students interact with each other around the objects in museum exhibitions (Laursen 2012), but it is believed that interactions with and around specific exhibits are a particularly important element to be aware of in the case of schoolchildren. There is general agreement among museum professionals and scholars that the key feature of an interactive exhibit is reciprocity: as a visitor uses the exhibit, it responds in some way. This distinguishes it from more traditional exhibits that may be read or observed but do not change physically in response to visitors' actions (Allen 2015; Allen and Gutwill 2004). Active participation by learners is the key to providing an effective learning environment (Heath et al. 2005).

Interactive exhibits are designed to create engagement. We understand engagement as involving a number of aspects, including emotional connection between a person and an activity, object, experience, or role (Archer et al. 2016). Csikszentmihalyi and Hermanson (1995) described the "flow" experience and the significance of engagement in the learning process. Understanding that engagement leads to meaning making played a significant role in the development of theoretical frameworks about the nature of learning in science centers (Barriault and Pearson 2010). In this research, engagement with an exhibit can mean activating it once or twice (or more), watching others activating it, expressing negative or positive emotions, asking questions, and consulting with friends. In that sense, visitor engagement is the observed degree to which the visitor pays attention to the exhibit and participates (Serrell 1997).

Observable Behavior and Assessment—the VEF—Visitor Engagement Framework

A frequent assumption in visitor research that adopts a sociocultural perspective is that behavior indicates the occurrence of learning (Serrell 1997). This is of course an assumption since "We can't necessarily see that learning has occurred, that new knowledge is gained, a different opinion is held, or there is a disposition to modify behavior, for example. Rather, learning is observable in an individual's actions, that is, what that person does or says" (Rennie and Johnston 2004, p. S6). The benefits of understanding the impact of exhibits on science center visitors extend beyond the need to provide proof of learning to stakeholders. Science centers and their staff want feedback from visitors in order to improve the visitor experience and increase the impact of the interaction (Barriault and Pearson 2010). Educators, exhibit designers, and researchers have explored a variety of strategies for helping to guide and deepen visitor participation and engagement in such an environment (Pattison et al. 2012). Those research strategies are based on understanding what makes people engage. This is done by analyzing the behavior of visitors as they interact with the exhibit.

Behavior can be measured and analyzed in various ways. Many such studies of visitors' behavior examine the percentage of visitors that stop at a given exhibit (its "attraction power") and the average time visitors spend at an exhibit (its "holding time") (Yalowitz and Bronnenkant 2009). Other well-known measures address the time visitors talk to each other at exhibits, the time they interact or play with exhibits, and the time they spend reading at exhibits (Van Schijndel et al. 2010). These measures have been used to compare different science museums, exhibitions, and exhibits (Boisvert and Slez 1995; Sandifer 2003) and the behavior of different visitor groups (Boisvert and Slez 1995; Sandifer 1997).

Another way to measure the visitor engagement is by observing a wider range of the behaviors in which visitors engage while interacting with exhibits, and using these behaviors as indicators of the visitors' level of engagement. One framework that aims to assess exhibits that way is the Visitor Engagement Framework (VEF), a visitor-based framework for assessing visitors' learning experiences with exhibits in a science center setting (Barriault and Pearson 2010). The original framework consists of seven discrete learning behaviors that occur as part of a visitor's interaction with an exhibit (Barriault and Pearson 2010). The learning behaviors are grouped into three categories that reflect increasing levels of engagement and depth of the learning experience—Initiation behaviors, Transition behaviors, and Breakthrough behaviors. Initiation behavior, for example, includes *doing the activity* and *watching others or watching the exhibit*. A visitor who engages further with the exhibit will show Transition behavior, like *repeating the activity* and *expressing positive emotion*. The highest level of engagement is Breakthrough behavior, which reflects behaviors like *referring to past experience*, *seeking and sharing information*, and being *engaged and involved* (for detailed explanations, go to Table 1 in the "Method" section).

This study uses a slightly expanded version of the VEF to assess the behavior of school students, determining what sorts of behaviors they engage in and whether different exhibits elicit different behaviors.

Method

The ultimate goal of this research was to identify the particular aspects of science museum exhibits that encourage students' engagement. In order to do so, we observed schoolchildren as they interacted with various exhibits in the science museum, using Barriault and Pearson's Visitor Engagement Framework (VEF) (2010) to categorize their behavior and determine the extent of their engagement. Having identified the range of

Table 1 Exhibit description

Exhibit		Goal/instructions of the exhibit
1	Robots	Move the robotic arm in order to grab the cubes and stack them in to a pile.
2	Inclined Plane	Change the angle of the pulleys and pull the sack. When is it easier to pull? With greater or smaller inclination?
3	Air Pressure	Get the red ball as high as the yellow one by spinning the handle. There is an air regulator in the back. Can you use different air pressure to help you in this task?
4	Reaction Time	Stop the car as soon as you see the light turn red; use the hand break or the break paddle. How long did it take you?
5	Color Memory	Look at the color sequence and try to remember it. Repeat the color sequence to gain points, as the number of colors in the sequence increases.
6	Game of Mirrors	Look through the slot. Try composing a face by moving face parts (eyes, nose, and mouth) with the handles, in order to see their reflection in the main mirror in front of the slot.
7	Drops and Hits	Pull the weight to a certain height and then drop it on the paddle (that will bounce the ball). What height should the weight be at in order to get the ball to bounce through the hole?
8	The Solar Train	Aim the solar panels to the sun (light source). When you succeed, your train will start moving. Follow the movement of the sun to keep your train running!
9	Bicycles	Paddle the bicycle to win the race! When you paddle, the amount of energy “burnt” (as form of calories) will appear on the screen.

behaviors elicited by the exhibits, we then used the VEF to identify differences in the behaviors elicited by each of the nine exhibits. This analysis allowed us to determine which of the exhibits we examined were the most “successful” in engaging students and which were less so. We then examined the most and least successful exhibits in greater detail, combining the VEF results with content analysis of the students' verbal responses to the exhibits as they engaged with them, in an attempt to extract a more detailed account of those exhibits' particular strengths and weaknesses.

Study Participants

The research participants consisted of a total 1800 students, aged 10–12 years (4th–6th graders), who came to the museum with their class for a day visit. The classes were randomly selected from schools that coordinated their visit with the museum. The data collectors were entirely dependent on the museum's coordination of the class visits, and its pedagogical content.

Research Setting—the Exhibits in the Museum

The research took place in Carasso Science Park in the city of Be'er Sheva. The main visitors to Carasso Science Park are school students that come with their class to a day visit. For those students, the visits consist of three major types of settings—laboratory activities, indoor exhibition halls, and an outdoor science garden. This paper will focus on three indoor exhibition halls—Mechanics and Mechanisms (visited by 4th graders), Light and Sight (5th graders), and Energy (6th graders). As part of the day in the museum, every class visited one exhibition hall (according to age) for 30–45 min. The students did not get to choose which specific exhibition hall to visit, which allows little “real” free choice engagement, but once inside, they were free to choose which exhibits to explore, which makes their experience a “limited choice visit” according to Bamberger and Tal (2007).

Each of the three halls includes 9–12 available exhibits. We observed three exhibits in each hall, making a total of nine exhibits. These were as follows:

- Mechanics and Mechanisms exhibition hall—Robots, Inclined Plane, and Air Pressure
- Light and Sight exhibition hall—Reaction Time, Color Memory, and Game of Mirrors
- Energy exhibition hall—Drops and Hits, The Solar Train, and Bicycles

An effort was made to watch exhibits that varied in their characteristics and their approach to engaging the visitor (for more details about the exhibits, see Table 1).

Data Collection

Our main method of data collection for this study was observation. Our observations were gathered as follows: A researcher sat near one exhibit, while a random class (15–20 students) entered the exhibition hall. The students walked around freely and explored the entire hall, but the researcher observed and documented only students who approached the exhibit selected for observation (and were *doing the activity* or *watching the exhibit*, not just passing by). This generated a large body of written documentation that was then subjected to different forms of analysis in response to the various research questions.

We observed nine exhibits, with 200 students visiting each. The data collection took a schoolyear, since we were dependent on the museum's schedule for the coordination of class visits, and each class included only 15–20 students. In order to give our readers a sense of how long it took to collect the data, we present the number of classes observed for each exhibit in Fig. 1. The museum's schedule for a full schoolyear showed that each exhibition hall was supposed to "host" around 30 classes in the specific age group (4th, 5th, and 6th graders). Based on these numbers, we decided to observe 200 students in each exhibit, since that number of observations was small enough to be covered in a single year, but still large enough to make sure that all learning behaviors were expressed and observed.

Additional data for research question 3 was gathered by a semi-structured interview with Sharon (pseudonym), one of the guides in the museum. Sharon is the senior guide in the museum and has been working in it since the day it opened. She is also a qualified science teacher. Museum educators play a significant role in the institution's educational agenda as well as developing and implementing the educational programs that the students experience (Shaby et al. 2016). Their opinion on the relative merits of various exhibits is therefore worth noting. Moreover, Sharon's opinion was based on her continuous presence in the museum and her long-term impression of the reactions elicited by each of its exhibits.

During the interview, we asked Sharon to give us her general opinion about each exhibit and to tell us, based on her instructional experience, whether she thinks it is a "good" exhibit (meaning students engage with it) or "not so good," and why. Her responses were not factored into the data analysis in any way (i.e., they did not influence our VEF-based determination of the exhibits' relative success). Nevertheless, they are incorporated in our answer to research question 3 whenever her more general views lend additional insight to our specific findings.

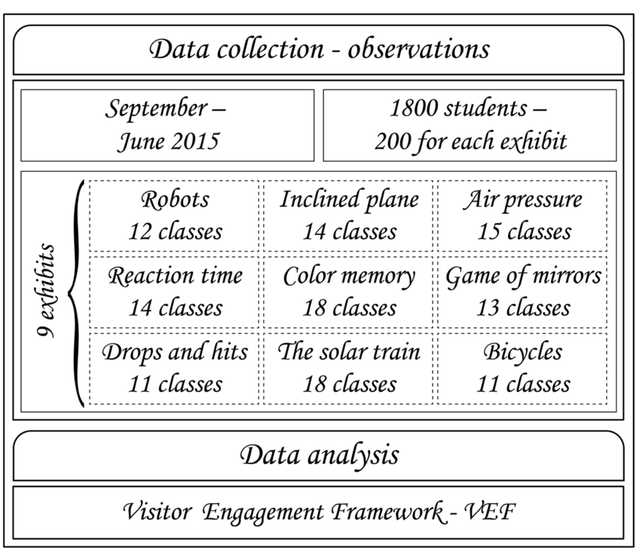

Fig. 1 Research plan

Data Analysis

Credibility

The data for this study were gathered independently by three individuals (the two first authors of this paper and an additional research assistant). We therefore performed peer review for one another, in which each researcher read the naturalistic observations of the others and matched them to the VEF categories. We made sure that all the three researchers observed all the exhibits at some point, which means that there was no situation in which all data on one exhibit were collected by the same person. To confirm credibility (Guba and Lincoln 1994), we performed repeated peer-debriefing sessions, comparing insights from the naturalistic observations that consisted of thick descriptions of the VEF classification. Verbal responses of the students were documented specifically during the observations, giving us the ability to gather them together for each exhibit and find related themes that emerge out of the data. This process was done by the first two authors. Furthermore, the naturalistic observations with the VEF analysis were given to the third author and another researcher from the field for additional peer review.

Observable Behavior Analysis—the VEF

The data for this research were analyzed using a modified version of the Visitor Engagement Framework (VEF). Before undertaking the study presented here, we performed a pilot study to test the applicability of the VEF's categories to our study population. We observed 336 students as they engaged in 13 different exhibits in the museum, over a period of 5 months. We analyzed the data and classified it into emerging categories, which we then compared to the VEF categories. We found that the seven categories of the VEF were aligned with ours, but that two additional learning behaviors were also worth adding. We therefore added *expressing negative emotion* (in the Initiation behavior category) and *asking others, consulting* (in the Transition behavior category) to the list of learning behaviors, providing a total of nine learning behaviors instead of seven. A detailed explanation of each category is provided in Table 2, and examples of the subcategories are presented in Appendix 1. The table was taken from the original paper published by Barriault and Pearson (2010), except for our two additional categories, which appear in the table in *italic*s.

Table 2 Types of activities that characterize learning behaviors

Learning behavior	Type of activity
Initiation behaviors	
1. Doing the activity	In passing, not done completely
	Doing the activity somewhat completely
	Doing the activity without further exploration or testing of variables
2. Spending time watching others engaging in activity or observing the exhibit	Looking at the exhibit working, or someone doing the activity
	Watching the exhibit or person using the exhibit with expressed interest in the activity (facial expression or verbal)
	Interested in learning outcome or in learning the activity; visitor does the activity after observing
3. *Expressing negative emotional response in reaction to engaging in activity*	*Displeased with the exhibit, making negative remarks*
	Leaving the exhibit after a short experience or after watching others engage, showing marks of displeasure
Transition behaviors	
4. Repeating the activity	Doing the activity two to three times to attain desired outcome, to master the exhibit's function.
	Enjoyment of outcome
	Changing the variables once looking for a difference in outcome; becoming involved/engaged
5. Expressing positive emotional response in reaction to engaging in activity	Smiling, pleased with exhibit
	Stronger signs of enjoyment such as laughter; verbal references to enjoyment
	Obvious signs of eagerness to participate; excited disposition
6. *Asking others, consulting*	*Asking questions regarding the operation of the exhibit or the outcome*
	Making general comments about the operation
	Not necessarily waiting for an answer
Breakthrough behaviors	
7. Referring to past experiences while engaging in the activity	Reference to past experience with exhibit or science centre
	Simple reference to comparable experience in visitor's life
	Reference to comparable experience in their life as well as making comparisons and deductions based on observations of similarities and differences
8. Seeking and sharing information	Calling someone over to look at exhibit, or to ask them to explain an exhibit; asking a question of staff or family member without lengthy discussion or exploration of topic
	Reading signage; having conversations about exhibit and related science with staff or family member
	Sharing experience and information with others by explaining the exhibit to them, giving them details about gained information and observations; discussions and questions about exhibit with staff or family member/friend
9. Engaged and involved: testing variables, making comparisons, using information gained from activity	Engaging in inquisitive behavior, exploratory actions such as repeating the activity several times, reading signage, and asking questions; remaining on task for 2–3 min
	Concentration and motivation are obvious; doing the activity as a means to an end, or meeting a challenge; length of interaction significant, 3 to 5 min; outcome or result of activity important
	Experimenting, testing different variables, looking for different outcomes; engages in discussion with others (visitors or staff) about the various outcomes; experience—'flow'; involved in activity for long period of time, i.e., more than 5 min

Analysis of Visitors' Verbal Responses

In order to answer the second research question, we analyzed what students said during their engagement with the exhibit. We gathered all the utterances of the students from our observations and grouped them into themes, such as "talking about competition" and "frustration". We then counted the number of utterances in each theme and its percentage of the total utterances for each exhibit. (Note: Each utterance was only counted once and assigned to only *one* theme. This means, for instance, that a given utterance can be associated *either* with the theme “talking about competition” *or* the theme “frustration,” but it cannot be associated with both).

The content analysis of the verbal responses provided a useful counterpoint to the VEF analysis of the students’ behavior because it both corroborated and expanded upon the information provided by the VEF. Some of the themes that arose from our analysis of the verbal responses aligned with the VEF subcategories. In some places, the two aligned exactly, as in the “*connection to life*” theme and the *referring to past experience* VEF subcategory (after all, the observers could not know if students had made a connection between the exhibit and their own lives unless they said so aloud). In other cases, the verbal analysis provided themes that only partially reflected a VEF category. For example, both the verbal analysis and the VEF reflected an expression of positive emotions, but in the themes, these were only verbal and in the VEF, they were manifested in gestures as well as talking. In yet other cases, however, the verbal analysis provided information that the VEF could not, since looking at the specifics of how many students talk near each exhibit and what they talk about provided additional insight into the details underlying the engagement patterns made visible by the VEF.

Findings

The results of the study are presented here according to the three research questions. This section will therefore begin by identifying and categorizing the students’ observable behavior in all the nine exhibits, move on to an examination of the differences between the exhibits, and then conclude by looking closely at four selected exhibits to determine how their design elements influence the students’ engagement.

Question 1—What Kinds of Behaviors Are Observable in Visiting Students as They Engage with the Exhibits at the Science Museum? What Do These Behaviors Tell Us About the Level of the Students’ Engagement?

To answer this question, we counted the number of interactions engaged in by the 200 students that approached each exhibit, classifying them into the VEF categories (as presented in Fig. 2). This provided us with the general trends of the visiting students’ engagement with the exhibits. All of the students we observed exhibited the first level of engagement, the Initiation behavior (for a breakdown of how many engaged in each type of Initiation behavior, see Table 3). Chi-square test showed no significant difference between the nine exhibits in terms of the number of behaviors they elicited in this category ($\chi^2_{df=8} = 11.91, p \leq 0.1551$). This was not the case in the other two categories. In the Transition behavior, we can see that—in all nine the exhibits—there were considerably fewer behaviors than there were in the Initiation category. Moreover, unlike the Initiation category, a chi-square test indicates significant differences between the nine exhibits in this category ($\chi^2_{df=8} = 249.51, p < 0.0001$). The data on the Breakthrough behavior category showed another marked drop in number between the Transition and Breakthrough behaviors. Like the Transition category, it also showed a significant difference between all the nine exhibits ($\chi^2_{df=8} = 143.59, p < 0.0001$).

To conclude, as Fig. 2 shows, all of the exhibits elicited behaviors in all the three categories, and all showed a marked decline in number as the behaviors moved to a higher engagement level. Despite these similarities, however, Fig. 2 also shows that the three levels of student engagement are expressed to different degrees in the different exhibits, and that the ratios between the three engagement levels in each exhibit also differ. These differences are addressed in more detail by the next research question.

Question 2—Do the Different Exhibits We Observed Elicit Different Behaviors and Different Forms of Engagement?

The differences between the exhibits are already apparent from the broad categorization presented in Fig. 2, but to gain a finer, more in-depth perception of the nature of the students’ engagement and how it differed between the exhibits, we must delve into the subcategories of each learning behavior. Table 3 presents the number of interactions performed by students in the Initiation behavior subcategories (*watching others*, *negative emotions*, and *doing the activity*).

Examining the findings at this finer resolution revealed that not all of students who were counted in the Initiation behavior were, in fact, *doing the activity*. For example, in Fig. 2, in the Robots exhibit, 282 initiation behaviors were performed by 200 students, but only 123 students were actually *doing the activity*.

Because only students who were actually doing the activity could move on to higher levels of engagement, we focused only the students who were *doing the activity* (in the Initiation behavior) for additional analysis, referring to that number as our *N* (see Table 4). The distribution of *doing the activity* ranged from 123 to 171 students out of the 200 that were observed each exhibit. Table 4 shows the percentage of these students that engaged in behaviors from each of the subcategories in the Transition and Breakthrough categories.

Looking at the subcategories of the Transition behavior, we see that the most dominant subcategory (across all the exhibits) was *repeating the activity*. For example, in the exhibit Solar Train, more students engaged in *repeating the activity* (16.7%) than those in *asking others* and *expressing positive emotions* (9.5% each).

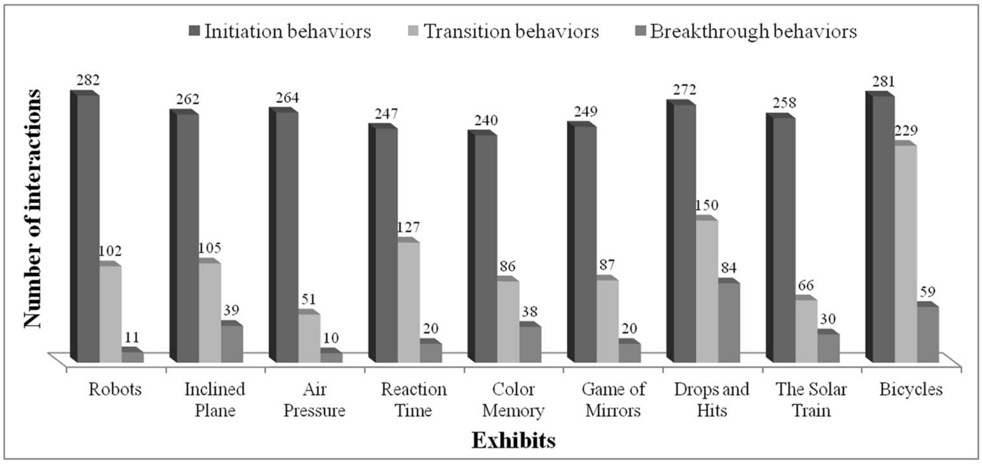

Fig. 2 The number of interactions that were performed during an observation of 200 students in each exhibit

However, unlike the Transition behavior category, in which we found a dominant subcategory, in the Breakthrough behavior, each exhibit was different, and in each exhibit, students showed a different distribution of learning behavior. In the Bicycles exhibit, for example, we observed that *referring to past experience* was more dominant, while in the Drops and Hits, *seeking and sharing information* was more prominent. These differences in the expression of learning behaviors can be a reflection of the exhibits' differing characteristics, with the different design of each potentially explaining the differences in student response.

Of all the exhibits, the Bicycles exhibit stood out as the only one in which *referring to past experience* was a prominent subcategory. Indeed, all of the exhibits except this one share a common trait—namely the low percentages of students who showed *referring to past experience* in the Breakthrough behavior. This difference could be due to the exhibit's particular design.

Exhibits' characteristics and design may play a big role in the behaviors that students express while engaging with them. In order to explore this claim further, in research question 3, we "zoomed in" on four of the nine exhibits to examine the relationship between their characteristics and the students' engagement with them more closely.

Question 3—What Are the Characteristics Associated with the Most "Successful" Exhibits? What Are the Characteristics Associated with the Least Successful Ones? What Insights Can We Glean from These Characteristics That Could Be Useful in Future Exhibit Design?

To answer this question, we took a closer look at the four exhibits that stood out as exceptional in the VEF analysis. The first two, Bicycles and Drops and Hits, stood out as particularly "good" because they showed the highest number of Transition and Breakthrough behaviors (see Fig. 2). The third, Air Pressure, stood out as particularly "bad" because it showed the lowest numbers in those categories. Finally, we also looked at the Robots exhibit, which had mixed data—

Table 3 Internal distribution of the Initiation behavior

	Exhibit	Initiation behavior			
		Watching others (number of students)	Negative emotions (number of students)	Doing the activity (number of students)	Total number of interactions $n = 200$
1	Robots	147	12	123	282
2	Inclined Plane	119	3	140	262
3	Air Pressure	104	2	158	264
4	Reaction Time	97	15	135	247
5	Color Memory	52	17	171	240
6	Game of Mirrors	78	3	168	249
7	Drops and Hits	135	4	133	272
8	The Solar Train	93	6	159	258
9	Bicycles	116	32	133	281

Table 4 Internal distribution of the subcategories

Exhibit		Initiation behavior	Transition behaviors			Breakthrough behaviors		
		Doing the activity (number of students)	Repeating the activity %	Asking others %	Positive emotion %	Referring to past experiences %	Seeking and sharing information %	Engaged and involved %
1	Robots	123	34.96	23.6	19.5	1.6	4	3.25
2	Inclined Plane	140	37.86	30.7	5	1.4	17.2	9.3
3	Air Pressure	158	25.32	3.2	1.3	0	4.4	1.9
4	Reaction Time	135	42.96	24.4	22.9	0	11.12	3.7
5	Color Memory	171	21.05	7.01	19.3	5.8	11.1	3.5
6	Game of Mirrors	168	26.2	17.3	8.3	0	10.12	1.8
7	Drops and Hits	135	53.3	43.7	11.8	1.5	32.6	27.4
8	The Solar Train	159	16.98	9.5	9.5	0	15.7	3.2
9	Bicycles	133	63.2	45.9	42.8	18.8	14.3	9.02

scoring highest in the Initiation behavior, but almost as low as the Air Pressure in the Breakthrough behavior.

The results for this question are based on a composite of three sources: 1. the detailed VEF analysis of the students' behavior in each exhibit; 2. the content analysis of what students said while engaging with the exhibit; and 3. additional insights from the interview with the senior museum guide (an expert regarding this particular museum), whose observations and impressions over time supported our own findings in various ways.

Bicycles

In this exhibit, there are two bicycles (red and blue) and a TV screen. On the screen, there are illustrated figures of riders on red and blue bicycles. When activating the exhibit, visitors pedal the real bike and see the results of their actions illustrated on the screen in the form of a bicycle race. In addition, at the bottom of the screen, each of the two users can see how fast they are riding and how many calories they have burnt.

This exhibit was marked as noteworthy by the VEF findings because of three elements: the high number of interactions it elicited in the Transition behavior category (229), the percentage of students who expressed *positive emotions* while engaging in it (42.8%), and the percentage of *references to past experience* (18.8%), which was far and away higher in this exhibit then in any others (Table 4). Overall, this exhibit shows a high number of interactions compared to the other exhibits, in all learning behaviors. A key finding is the exceptional progression from the Initiation behavior (281) to Transition behavior (229) in this exhibit. Unlike the other exhibits, in this one, most students maintained their involvement and moved to the next level of engagement.

The themes that emerged from the students' discussions in the Bicycles exhibit are presented in Fig. 3 and described in more detail in Appendix 2. Examining these themes can provide us with additional information about the strengths and weaknesses of this particular exhibit.

The Bicycles exhibit is popular. Students stand in line waiting for their turn, and there is not a moment that this exhibit is "empty" (as we saw in the observations). From the students' positive verbal responses (represented in the theme "positive emotions"), we learn that the reason that the students like this exhibit may be because it appears to be a "cool game." Of the 16 expressions of positive emotion, eight refer to the exhibit as a game. In contrast, the word "game" does not appear very often in the students' responses to the rest of the exhibits; this exhibit is exceptional in that way.

The students' perception of the exhibit as a "game" may be related to the fact that it incorporates a strong competitive element as well as a digital element. Analysis of the students' verbal responses showed that the second most popular theme—31 statements—referred to the competition element in the exhibit. As we can see in the examples for the theme in Appendix 2, students talk about winning and losing: "I won right?," "I am the blue and I am winning," "Who is winning now?," etc. The correlation between the exhibit's popularity and its strong competitive element was echoed in our interview with Sharon, where she noted that "An exhibit that students like usually has a competitive element in it – either in the form of two competitors or in the form of scoring points," adding that "if there is no such element, students seem to like the exhibit less."

The theme of "talking about competition" did not just include utterances from the students who were on the Bicycles but also from those who are waiting their turn. The verbal analysis showed that the waiting students often acted as "cheerleaders" for the competitors ("Go faster!" "You can

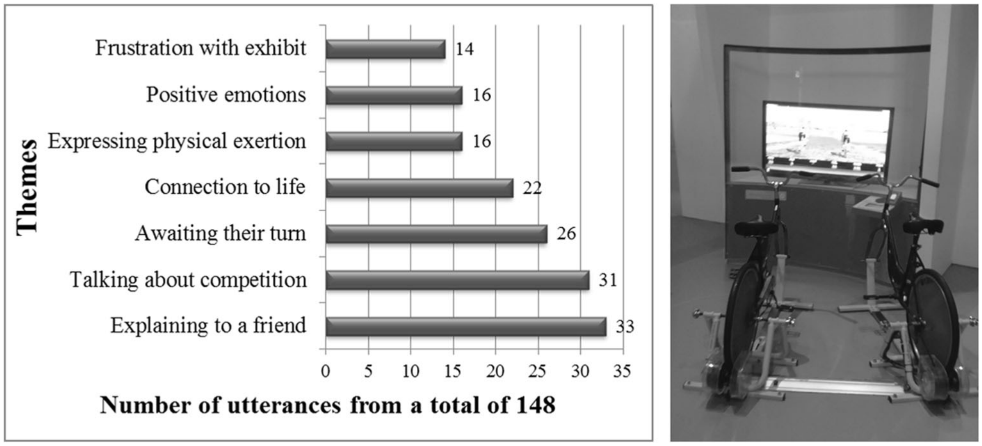

Fig. 3 Themes that emerged from verbal responses in the Bicycles exhibit

do this!"), and engaged in extensive discussions about what is happening in the bicycle race ("Is she on the blue bike? How can you tell if she is winning?").

This indication that the exhibit provides a strong sense of participation, not just for the two who operate it but for those who are gathered around them, is reiterated even more strongly in the fact that the most prominent theme in the students' verbal responses is "explaining to a friend" (see Fig. 3). This theme shows once again how extensively the students standing around this exhibit talk to one another: explaining how to operate the exhibit, giving advice to the competitors, cheering them on, and discussing the best ways to win. We can see this in examples like "You should go on the blue bike. It is faster you will see", and "Transfer to gear 7, it will be easier and faster."

Another reason that positive emotions are fairly high in this exhibit (as indicated by both the VEF and the verbal themes) can derive from the fact that this exhibit is very easy to activate and familiar to the students from their daily lives—you only need to pedal the bike. According to Sharon, based on her experience in this museum, easy activation and familiarity are very important. She claimed that exhibits should have "A clear goal defining what you need to do in order to succeed in the task ahead," that exhibits should not be "complicated to manipulate," and they should make use of "known signs" in the design. As Sharon pointed out, "students know immediately that a button needs to be pushed, a wheel spun and a joystick moved from side to side."

This simplicity and familiarity, and its connection to the exhibit's popularity, is reflected in verbal responses like:

> Hi look! Cool, real bikes! Do you want to race me? I have a bike just like this at home. If you want to go faster uphill you need to change gear.

Responses like this one show that the student was immediately able to recognize the goal of the exhibit and what he needs to do to activate it. The quote also reveals a connection between the exhibit's familiarity and ease of activation and its strong connection to the visitors' past experience (as indicated by the VEF). Riding bikes is an activity that connects clearly to the students' daily lives, allowing them (as the quote above indicates) to draw on their own experience for help in the exhibit's activation.

Analyzing the verbal responses of students can also help illuminate the exhibit characteristics underlying some of the behavioral trends identified by the VEF. For example, the VEF analysis showed that *negative emotions* were high in the Bicycles exhibit (32 interactions as shown in Table 3). A closer look at the verbal responses revealed that there were a lot of utterances that express frustration. The students are mainly frustrated because the exhibit does not work properly ("frustration with the exhibit" theme). It is also physically hard for them to achieve the goal of the exhibit, which is winning a bicycle race with real bikes. The students express physical exertion by noting: "I can't move my legs any more" and "This is so hard I have to quit." While, their frustration and negative emotions do seem to arise directly from the exhibit design, this example shows us that negative emotions are not always an indication that an exhibit is "bad." Moreover, it shows that looking closely at the context and content of students' responses is a crucial part of understanding an exhibit's impact.

Drops and Hits

In the "Drops and Hits," the visitors must throw a ball through a hall from one side of the exhibit to the other. In order to get the ball through, they must move a paddle by dropping a weight on it. The students need to pull the weight up by spinning a handle; when they believe it is at the right height, they must push a button that releases the weight down on the paddle (which in turn will bounce the ball).

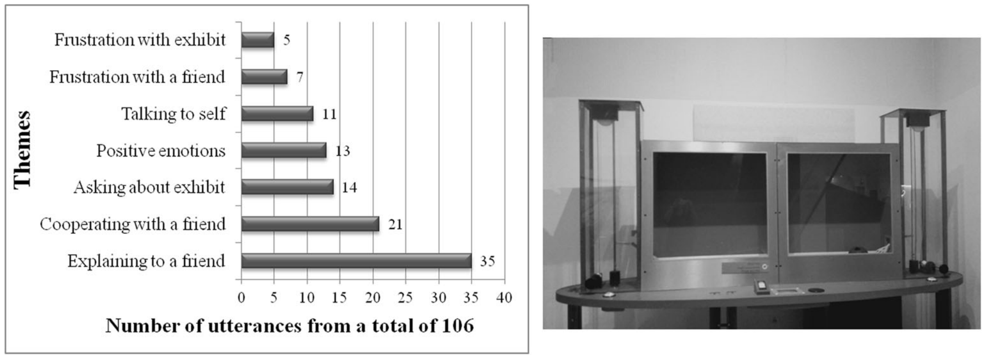

Fig. 4 Themes emerged from verbal responses in the Drops and Hits exhibit

This exhibit was singled out as particularly successful for a number of reasons. First, it had the highest number of students engaging in the Breakthrough behavior (84 as shown in Fig. 2). Furthermore, analysis of its subcategories showed that it had the highest percentage of students who were *engaged and involved* (27.4%) and *seeking and sharing information* (32.6%) (see Table 4).

The themes that emerged from the students' verbal responses to this exhibit appear in Fig. 4, with further elaboration and examples in Appendix 2.

Like the Bicycles exhibit, this one is also characterized by extensive social interaction between the students. Here too, the most prominent theme is "explaining to a friend," indicating that students visiting this exhibit spend time explaining to their friends how to activate it ("You need to get the weight higher. Don't push it until you are done") and explaining the scientific concept behind it ("You need to use the right amount of energy to make it go through"). Moreover, in this exhibit, the social interaction also extends to cooperation—in which two or more students work together to successfully activate the exhibit. The theme that gathers together the students' utterances during such cooperation, such as "I will be on that side and you will go there and press the button," is the second most prominent in the exhibit.

These findings from the verbal responses correspond to the VEF findings about the subcategories *asking others* and *sharing information*. The cooperation reflected in the verbal analysis is directly elicited by the exhibit's design, which relies on teamwork—there is no way to activate it alone. In her interview, Sharon claimed that "Exhibits that require teamwork are more enjoyable to the students," referring to exhibits in which "one needs to cooperate with someone else in order to succeed in the activity."

Like the Bicycles exhibit, this exhibit also contains an element of competition, though in this case, the competition element consists in the challenge of gaining the highest score. Moreover, like the Bicycles exhibit, the goal of this exhibit is very clear—the visitor needs to get the ball to the other side through the hole. In the case of this exhibit, however, understanding *how* to achieve the goal is more of a challenge. The students need to figure out what must be done with the weight in order to succeed and can try different locations (for the weight). Our observation revealed that students often work in more than a pair, discussing what to do, how to do it, and why to do it. We believe that this is the reason students tend to stay and manipulate the exhibit, resulting in higher engagement levels and discussion (*seeking and sharing information)*. This can be seen in the next example:

Ron, a 6th grade student, could not make the ball go through the hole, so he consulted with Dillon:

> Ron: You need to get the weight higher so it will have the power to get it through the hole.
> Dillon: You need to get it to the right height; you need to adjust the energy.
> Ron: It needs to get to the top and then you push the button.
> Dillon: I am not sure; I think it depends on how high the hole is.
> Ron: Let's try it both ways and see who is right.

They do and see that Dillon is right.

In this example, we see that the two students discuss what the proper height of the weight is. They explore their hypothesis while manipulating different positions in the exhibit. This kind of opportunity for discourse, as seen in the Bicycles exhibit as well, has the potential to keep the students engaged and involved longer with the exhibit.

Air Pressure

In this exhibit, the user must get a red ball to go as high as a yellow one by spinning a handle. There is an air regulator in the back, and adjusting the air pressure makes getting the ball to rise much easier. Unlike the two exhibits previously described, in this exhibit, we saw a dramatic drop in the numbers of interactions performed by students in the Transition behavior (51) and Breakthrough behavior (10). Moreover, most of the students who did proceed to transition behavior were

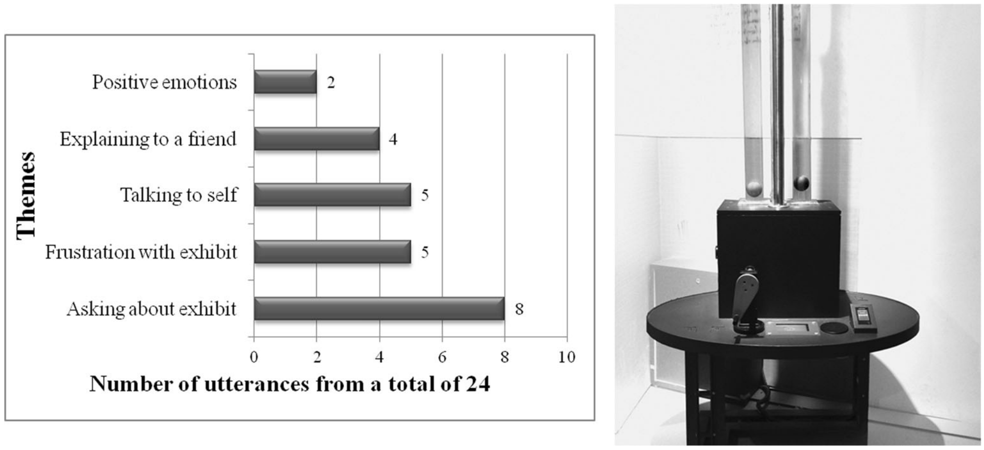

Fig. 5 Themes emerging from the verbal responses in the Air Pressure exhibit

merely *repeating the activity*. The themes that emerged from the students' verbal responses are presented in Fig. 5. Explanations and examples of the different themes appear in Appendix 2.

First and foremost, comparing this exhibit's verbal responses to the previous two reveals a surprisingly low number of utterances—just 24 utterances vs. the much higher number we counted in the previous two exhibits, each of which elicited over a hundred. The reader must keep in mind that these 24 utterances come from 200 students that were observed in the exhibit. This low number reflects the fact that the students tended to not talk while engaging with this exhibit, perhaps because—unlike the previous two—it is an individual exhibit (only one handle to spin). One student operates the exhibit, and even though there are other students watching (as indicated by the VEF), they have no impact on the activity and do not really talk to one another like they do in the other exhibits.

This exhibit is similar to the Drops and Hits exhibit in the fact that its goal is clear, but it is not necessarily clear how the goal should be achieved. Although it was clear that one needs to spin the handle in order to get the ball higher in the tube, the air regulator was not familiar to the students, and they did not know what to do with it. Most students tried to spin the handle as fast as they could with little success, not realizing that there was an air regulator on the side, and that lowering the air pressure makes the task much easier so the goal can be accomplished. Since most students did not use the regulator, the result was often that they spun the handle and almost nothing happened. The persistent ones tried again, but most students just left. The frustration from the exhibit can be seen in statements like "This is boring" and "Nothing happens, I think it is broken." The fact that only one can operate the exhibit at a time means that only individuals approach the exhibit, and that there is no opportunity for discourse to take place (like the conversation we noted in the two previous exhibits, where one student helps another figure out the challenge). Most of the talking that was done in this exhibit (from the verbal responses) consisted of asking how to operate the exhibit and talking to oneself.

Robots

In this exhibit, the students need to move the robotic arm in order to grab the cubes and stack them in a pile. There is a joystick that moves the arm and buttons that close the fingers.

As Fig. 2 shows, the Robots exhibit had the highest number of interactions in the Initiation behavior (282), suggesting that it was as initially attractive as the popular Bicycles exhibit, which elicited 281. On the other hand, however, the Robots elicited only 11 interactions in the Breakthrough behavior, which is only one more than the unsuccessful "Air Pressure" exhibit. We deemed this striking combination of successful and unsuccessful indications worth exploring, since it suggests that this exhibit had the qualities necessary to spark visitors' initial interest, but that something about it failed to keep them fully engaged. The themes that emerged from the students' verbal responses are presented in Fig. 6. Explanations and examples of the different themes appear in Appendix 2.

The Robots exhibit is a very popular exhibit, which is designed for two participants at a time (much like the Bicycles and Drops and Hits). All of the students in every visiting class *wanted* to activate that exhibit, forming a line behind it to await their turn. Unlike the Air Pressure exhibit, in which little was said at all, this exhibit generated a great deal of interest and discussion among the students, as manifested in the greater number of overall utterances, which is once again over a hundred, and in specific themes like "explaining to a friend," "asking about the exhibit," and "positive emotions" (similarly to the other exhibits—see examples in Appendix 2).

However, unlike the Bicycles, which also had a long line of students awaiting their turn, here the students who were waiting were not waiting "patiently," which led to arguments

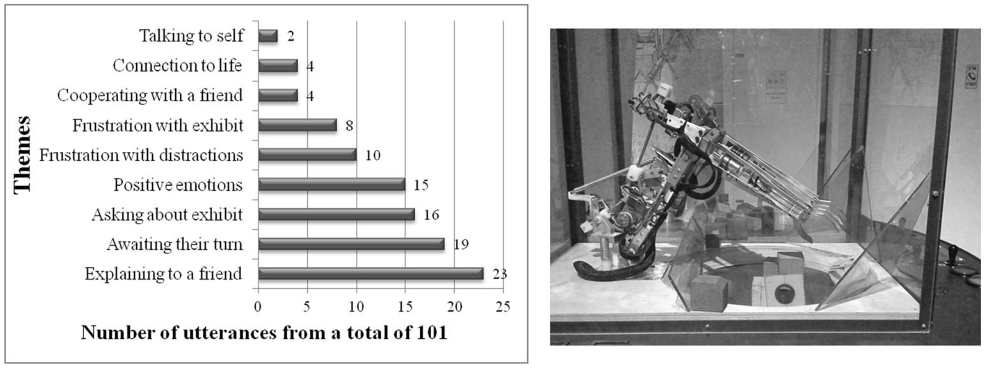

Fig. 6 Themes emerging from the verbal responses in the Robots exhibit

between the students and utterances like "Move, I'm next (pushing)." The different reactions of students waiting in line can be attributed to differences in the exhibit design. While the Bicycles exhibit encourages the students to cheer for their friends, giving them something to do and a way of participating while they wait, the Robots is an exhibit that demands concentration, so that other students talking around you might be annoying rather than encouraging. We can see that the students were frustrated with those distractions and said, "Stop talking I can't concentrate" and "Don't stand behind me, it is distracting." No such reactions were recorded in the Bicycles or Drops and Hits.

Indeed, if we look at the Robots exhibit in conjunction with the more successful Bicycle and Drops and Hits, it appears that the exhibit's ability to tolerate large groups is a key factor in determining its success (or lack thereof). We have already noted that, despite the fact that it could be activated by only two visitors at a time, the Bicycles exhibit was extremely tolerant of large groups, with waiting students cheering the participants on and shouting advice. This ability to congregate around the exhibit allowed the students to conduct extensive discourse among themselves and to benefit from one another's experience, insight, and encouragement. The other successful exhibit, Drops and Hits, is also built for two participants, but for 70% of the time, it was observed by us that there were more than two students activating it together, sometimes up to ten at a time. Like the Bicycles, this exhibit is also tolerant of the presence of a larger group, and here too, the presence of more students was a help rather than a hindrance.

Unlike these two successful exhibits, the Robots does not seem to be able to tolerate a large congregation of visitors. This intolerance seems to have had several consequences that separated this exhibit from the other two. First, due to the arguments between the students, the teacher who accompanied the class often had to intervene and send students away. This resulted in fewer opportunities for discourse between students. Second, the teacher did not let students activate the exhibit for as long as they wanted because of other students complaining that it is "their turn." Therefore, the students did not really have the chance to become *engaged and involved*, and this might be the reason for the low interactions in the Breakthrough behavior.

Discussion

This study outlines the engagement of school children with science museum exhibits based on their learning behavior and their verbal responses to the exhibits as they interact with them. Understanding the different ways students engage with museum exhibits and how these forms of engagement are related to design elements in the exhibits themselves can be extremely useful to museum educators and exhibit designers, who can use this information to design more engaging—and thus more successful—exhibits.

In a museum, engagement is indicated when the visitor pays attention to an exhibit by looking at it, reading accompanying signs, touching or manipulating the exhibit, or discussing the exhibit with another person (Boisvert and Slez 1995). Overall, the results of our study showed a substantial decline in expressed behavior from the low-level engagement of the Initiation behavior to the higher engagement levels (Transition and Breakthrough behavior). The smallest engagement was in the breakthrough behavior subcategories, one of which is being *engaged and involved*. One of the criteria of being *engaged and involved* is the time a student spends at the exhibit. The VEF model refers to 5 min as the minimum time necessary to reach the Breakthrough behavior. In that sense, this research reinforces previous studies that claim that it is not an easy task to keep visitors engaged with exhibit for more than 2 min (Gutwill 2008; NRC 2009).

This substantial decline in engagement has been documented extensively in the literature and has been given a variety of explanations. Allen (2004), for instance, suggests that without restrictions, visitors have complete freedom to follow their interests and impulses as they move through a public space packed with exhibits, all of which are vying for their attention. In addition, visitors have no way of knowing whether the reward for persisting will be worth the effort, and in an environment full of interesting alternatives, they are very likely to simply leave an exhibit and move on.

In addition to being *engaged and involved*, another Breakthrough behavior subcategory is *referring to past experience* while engaging with the exhibit. Our data suggest that very few references (if any) were made by the students comparing an experience at the museum to experiences in their daily life. One of the main goals of science museums is to make science more accessible to the public, and one way to do that is to design relevant and authentic exhibits, as stated by the NRC (2009). Informal environments should prompt and support participants to interpret their learning experiences in light of relevant prior knowledge, experiences, and interests. Though the design of some of the exhibits in our study does seem to take this goal into account (for example in the Robots or Game of Mirrors exhibits), it seems, based on the students' behavior, that this connection to their life is unclear.

Our study revealed several design elements that seem to contribute more strongly to students' engagement with exhibits in science museums. Firstly, we found that interaction is encouraged by exhibits that are "familiar" and therefore, more intuitively easy to activate. Second, exhibits that facilitate social interaction were found to increase engagement, especially if the exhibit is harder to activate. Finally, we found that both of the exhibits that showed the highest levels of engagement were exhibits that support large groups, while the two exhibits that showed the lowest levels of engagement were not.

The literature about exhibit design attributes a great deal of importance to the clarity of the exhibit. We too found that making exhibits out of familiar components that participants instinctively understand how to operate is an important element in encouraging visitors to engage. As can be seen in the data, exhibits that the visitors immediately know how to operate (like the Bicycles) encourage them to stay and engage further, while exhibits that rely heavily on unfamiliar components and are therefore less intuitive and more confusing (like Air Pressure) can cause visitors to become bored or frustrated and leave.

It makes sense that visitors would find it less intimidating to approach something familiar to them and be more likely to pursue this kind of interaction (Orion 1993). Furthermore, a familiar activation design reduces the cognitive load placed on visitors, freeing them to focus on those aspects of the environment that are rewarding to them and worthy of their attention (Allen 2004). Allen (2004) refers to the quality of "immediate apprehendability," which means that when people are introduced to a given stimulus for the first time, they will be able to understand its purpose, scope, and properties almost immediately and without conscious effort. Sandifer (2003) specifies "accessible" as one of the characteristics affecting the ability to attract and hold a visitor's attention. By "accessible" Sandifer (2003) simply means comfortably used by the visitor. In addition to making exhibits easy to activate, clarity and familiarity can also be encouraged by using what Allen (2004) calls "known signs." The exhibit should have control mechanisms that match visitors' expectations (e.g., dials should work either clockwise or anticlockwise, knobs should be pushed, and wheels should turn) (Allen 2015). A recent study performed by Gurel and Yasar (2016) found that the inability of some of the students to advance to the higher levels of knowledge arose from their failure to understand how to use the exhibit. On the other hand, exhibits that demonstrated situations they encounter in their everyday lives contributed to the levels of knowledge they performed.

Our second main finding refers to the impact of the possibility of social interaction during the exhibit's activation on the level of engagement it elicits. Many studies support the claim that visitors' social interaction in museums and other informal learning environments is important (Laursen 2012; Tal and Morag 2007; Tal et al. 2014). For example, it is increasingly recognized that social interaction and collaboration are critical to visitors' experience of museums (Falk and Dierking 1992, 2012; Heath et al. 2005). Studies have shown that the social context allows visitors to explore, experience, and discover the exhibits collaboratively and interactively, as visitors share their experiences with their companions and smaller groups are continuously formed and reformed around different exhibits (Laursen 2012; Schwan et al. 2014.

In our study, that interaction was elicited by exhibits designed as competitions between students (like the Bicycles), or as tasks that require collaboration and teamwork (like the Drops and Hits). The fact that these two highly social exhibits were also the two most successful in eliciting visitor engagement supports Meisner et al. (2007) that shared experiences are an effective means of creating engagement and participation with museum exhibits. Meisner et al. (2007) suggest that the social influences created by the visitors' actions both attract others to the exhibit and provide them with the resources to make sense of the exhibit's functionality. This suggestion reflects our own observations of the students' difficulty and frustration with the difficult to interpret the Air Pressure exhibit, which, because it was designed for individual rather than collaborative use, did not provide an opportunity for students to figure it out together. The importance of this opportunity is illustrated by the direct contrast between the Air Pressure and the collaborative exhibit Drops and Hits, in which frustrated or confused students were encouraged to overcome their initial difficulties with the exhibit by cooperating with or receiving advice from a friend.

A study conducted by Allen and Gutwill (2004) reported findings that were similar to ours regarding the potential importance of an exhibit's ability to accommodate multiple users. They too found that "good exhibits encourage simultaneous interactivity by multiple users," and that several of the exhibits they examined evoked increased large group learning when they were changed to accommodate several sets of hands or bodies (like our own Drops and Hits exhibit). Moreover, they also noted that the design of other exhibits could be problematic when it prevented the exhibit from being activated by multiple users (as in the case of our Robots and Air Pressure exhibits).

Studies have also shown that exhibits that demand some sort of social interaction foster more positive attitudes (Gutwill and Sindorf 2015). This claim may be reflected in our findings as well, since the competitive and socially interactive Bicycles exhibit elicited a great deal of positive emotion from the students who engaged in it.

Having noted the importance of the social element, both in our study and in others, we must also draw attention to Pinus (2000), who claims that "in the museum literature, the importance of the social element is fully recognized but not always translated into practice" (p. 21). She argues that—having noted the importance of the group dynamic—we must think about the visitor within the group structure and find specific ways of encouraging and supporting group interaction through the content of exhibitions.

As stated before, the benefits of understanding the impact of exhibits on science center visitors extend beyond the need to provide proof to stakeholders. Science centers seek feedback from visitors in order to improve the visitor experience and increase the impact of the interaction (Barriault and Pearson 2010). This study, which is based on a very large sample of students, can help them achieve this goal. Even though the definition of the "ideal" exhibit will differ from exhibition to exhibition and from visitor to visitor, for the practical purpose of designing exhibits, there is a need to gain general understanding of what sorts of things tend to make an exhibit "good" (Alt and Shaw 1984). In that sense, this research, which observed the engagement of a relatively large population of 1800 students, can contribute to our understanding of the impact that exhibits have on visitors. In addition, this research shows the importance of the analysis of verbal responses during the observations and highlights the need for naturalistic observations as research tool.

Acknowledgments This research was supported by the Israel Science Foundation, Research Grant Application no. 562/15

References

Adams M, Luke J, Moussouri T (2004) Interactivity: moving beyond terminology. Curator: The Museum Journal 47(2):155–170
Allen S (2004) Designs for learning: studying science museum exhibits that do more than entertain. Sci Educ 88(1):S17
Allen S (2015) Interactive exhibits. In: Encyclopedia of science education. The Netherlands, Springer, pp. 529–535
Allen S, Gutwill J (2004) Designing with multiple interactives: five common pitfalls. Curator: The Museum Journal 47(2):199–212
Alt MB, Shaw KM (1984) Characteristics of ideal museum exhibits. Br J Psychol 75(1):25–36
Archer L, Dawson E, Seakins A, DeWitt J, Godec S, Whitby C (2016) "I'm being a man here": urban boys' performances of masculinity and engagement with science during a science museum visit. Journal of the Learning Sciences 25(3):438–485
Bamberger, Y, Tal T (2007) Learning in a personal context: Levels of choice in a free choice learning environment in science and natural history museums. Science Education 91(1):75–95
Barriault C, Pearson D (2010) Assessing exhibits for learning in science centers: a practical tool. Visitor Studies 13(1):90–106
Bell P, National Research Council (U.S.) (2009) Learning science in informal environments: people, places, and pursuits. National Academies Press, Washington, D.C
Boisvert DL, Slez BJ (1995) The relationship between exhibit characteristics and learning-associated behaviors in a science museum discovery space. Sci Educ 79(5):503–518
Csikszentmihalyi M, Hermanson K (1995) Intrinsic motivation in museum: what makes visitors want to learn. In: Falk JH, Dierking LD (eds) Public institutions for personal learning: establishing a research agenda. American Association of Museums, Washington DC, pp. 67–77
Falk JH, Dierking LD (1992) The museum experience. Whalesback Books, Washington, D.C
Falk JH, Dierking LD (2000) Learning from museums: visitors experiences and the making of meaning. AltaMira Press, Walnut Creek, CA
Falk JH, Dierking LD (2012) Museum experience revisited. Left Coast Press, Walnut Creek, CA, USA
Guba EG, Lincoln YS (1994) Competing paradigms in qualitative research. Handbook of qualitative research 2(163–194):105
Gurel C, Yasar E (2016) Science museum exhibits' summative evaluation with knowledge hierarchy method. European Journal of Physics Education 7(1)
Gutwill J (2008) Challenging a common assumption of hands-on exhibits: how counterintuitive phenomena can undermine inquiry. Journal of Museum Education 33(2):187–198
Gutwill JP, Sindorf L (2015) Comparing the visitor experience at immersive and tabletop exhibits. Curator: The Museum Journal 58(4):401–422
Heath C, Lehn D, Osborne J (2005) Interaction and interactives: collaboration and participation with computer-based exhibits. Public Underst Sci 14(1):91–101
Hein GE (1998) Learning in the museum. Routledge, London
Hooper-Greenhill E, Phillips M, Woodham A (2009) Museums, schools and geographies of cultural value. Cultural Trends 18(2):149–183
Kirchberg V, Tröndle M (2012) Experiencing exhibitions: a review of studies on visitor experiences in museums. Curator 55:435–452
Laursen D (2012) Co-participation among school children around a computer-based exhibit. Soc Stud Sci 43(1):97–117
Meisner R, Lehn vom D, Heath C, Burch A, Gammon B, Reisman M (2007) Exhibiting performance: co-participation in science centres and museums. Int J Sci Educ 29(12):1531–1555
Orion N (1993) A model for the development and implementation of field trips as an integral part of the science curriculum. Sch Sci Math 93(6):325–331
Osborne J, Dillon J (2007) Research on learning in informal contexts: advancing the field? Int J Sci Educ 29(12):1441–1445
Pinus DA (2000) Look again! Planning an exhibition with social interaction in mind. Journal of Museum Education 25(1–2):21–24
Pattison SA, Ewing S, Frey AK (2012) Testing the impact of a computer guide on visitor learning behaviors at an interactive exhibit. Visitor Studies 15(2):171–185
Potvin P, Hasni A (2014) Analysis of the decline in interest towards school science and technology from grades 5 through 11. J Sci Educ Technol 23(6):784–802

Rennie LJ, Johnston DJ (2004) The nature of learning and its implications for research on learning from museums. Sci Educ 88:4–16
Sandifer C (1997) Time-based behaviors at an interactive science museum: exploring the differences between weekday/weekend and family/nonfamily visitors. Sci Educ 81(6):689–701
Sandifer C (2003) Technological novelty and open-endedness: two characteristics of interactive exhibits that contribute to the holding of visitor attention in a science museum. J Res Sci Teach 40:121–137
Schwan S, Grajal A, Lewalter D (2014) Understanding and engagement in places of science experience: science museums, science centers, zoos, and aquariums. Educ Psychol 49(2):70–85
Serrell B (1997) Paying attention: the duration and allocation of visitors' time in museum exhibitions. Curator: the Museum Journal 40(2): 108–125
Shaby N, Assaraf OBZ, Tishler CE (2016). The goals of science museums in the eyes of museum pedagogical staff. Learning Environments Research 1–24
Tal T, Morag O (2007) School visits to natural history museums: Teaching or enriching? Journal of Research in Science Teaching, 44(5):747–769
Tal T, Lavie AN, Morag O (2014) Exemplary practices in field trips to natural environments. Journal of research in science teaching 51(4): 430–461
Van Schijndel TJ, Franse RK, Raijmakers ME (2010) The exploratory behavior scale: assessing young visitors' hands-on behavior in science museums. Sci Educ 94(5):794–809
Yalowitz SS, Bronnenkant K (2009) Timing and tracking: unlocking visitor behavior. Visitor Studies 12:47–64