Received: 4 December 2017 | Revised: 2 May 2018 | Accepted: 9 May 2018

DOI: 10.1002/tea.21476

RESEARCH ARTICLE

WILEY | JRST

An examination of the interactions between museum educators and students on a school visit to science museum

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Funding information
Israel Science Foundation, Grant/Award Number: 562/15

Abstract

Today, science is a major part of western culture. Discussions about the need for members of the public to access and understand scientific information are therefore well established, citing the importance of such information to responsible citizenship, democracy, socially accountable scientific research and public funding (National Research Council [2009] *Learning science in informal environments: People, places, and pursuits*. National Academies Press). In recent years there has been an increased interest in investigating not just what visitors to informal environments have learnt after a visit, but also how visitors interact and engage with exhibits during the visit (Davidsson & Jakobsson [2012] Understanding interactions at science centers and museums: Approaching sociocultural perspectives. Rotterdam: Sense Publishers). Within the field of school visits to science museums, however, interactions between students and museum educators (MEs) remain relatively unexplored. In our study of such school visits, we are mainly interested in the interactions that take place between three agents—the students, the museum educator and the physical setting of the exhibit. Using moment-to-moment fine grain analysis of multiple interactions allowed us to identify recurring patterns between students and the museum educators around exhibits, and to examine the MEs' mediational role during the interactions, and the practices they employ to engage students with exhibits. Our study revealed that most interactions between MEs and students consist of technical explanations of how to operate the exhibits. The interactions that do move past this stage often include two main practices, which the MEs use to promote students' engagement with the exhibits: physical instruction and engaging the students emotionally. Understanding what is actually happening in the learning process that occurs during students' interactions with exhibits can help museum educators and exhibit designers improve the experiences of students on school visits.

KEYWORDS
informal learning environment, interaction analysis, science museums

1 | INTRODUCTION

Over the years, awareness of the importance of integrating informal learning environments such as museums into the curriculum has been on the rise (National Research Council, 2009). Serious scientific concerns are ubiquitous in modern life (global warming, alternative fuels, and stem cell research), and in a democratic nation, an educated population is needed to inform public policy. The reality is that schools cannot act alone, and society must better understand and draw on the full range of science learning experiences to improve science education as a whole, a purpose for which designed informal learning environments can be used (National Research Council, 2009).

Although school is clearly an important setting for individuals to learn about and become interested in science, it is not the only setting where this can happen (Falk, Pattison, Meier, Bibas, & Livingston, 2018). Informal out of school activities, like science museums, provide enrichment in various areas and break the daily school routine. They allow hands-on experiences, develop students' social and motor skills, and increase their motivation to learn and develop individually (Lavie Alon & Tal, 2015). The exhibit space of a science museum is also an appealing educational alternative to a school science classroom: hands-on exhibits are novel, stimulating, evidence rich, multisensory, and fun conveying complex science ideas and phenomena in non-traditional and engaging ways (Adams & Gupta, 2017). The environment of the science museum provides myriad personal choices, without any teachers forcing learners to do something unappealing, without curricular constraints, and without any testing or accountability (Allen, 2004), such museums can therefore be important resources for science learning (DeWitt & Osborne, 2007), especially for school students.

Early research in science museums often focused on visitors' learning outcomes (Davidsson & Jakobsson, 2012). In recent years, however, there has been an increased interest in investigating not only what visitors have learnt after a visit, but also what the visitors actually do during their visit (Davidsson & Jakobsson, 2012). In pursuing this question, more researchers have turned their attention to the processes that occur during the visit, examining visitors' interactions with each other, with the staff and with the exhibits (Davidsson & Jakobsson, 2012). Looking at the variety of cognitive, social and emotional interactions between a visitor and an activity, object, experience, or role can help museum educators gain a better idea of how learning processes in science museums take place.

The study presented here is part of a larger study devoted to looking at these types of interactions in a science museum located in Israel's southern region. Specifically, it presents the findings from our analysis of interactions between the students and the museum educators around an exhibit. We used a qualitative-interpretivist approach to examine the interactions between visiting school students and the museum educator (ME) in order to shed light on the role played by the educator in the science museum experience.

Research on interactions during museum visits defines interaction analysis as a way to identify regularities in the ways in which participants utilize the resources of the complex social and material world of actors and objects within which they operate (Ash, Lombana, & Alcala, 2012). We therefore asked:

1. What types of recurring patterns can we discern in the interactions between students and the museum educator around exhibits?
2. What sort of role do the MEs play in mediating the students' interaction with the exhibit, and what sort of practices do they employ in doing so?

2 | LITERATURE REVIEW

Visiting science museums is a relatively short, but nevertheless highly complex experience (Falk & Dierking, 2000). As a learner-centred experience, the visitor's experience at the museum is not predetermined, especially because it is embedded in various personal and social contexts, as well as the physical context of the science museum itself (Falk & Dierking, 2000). Museum visits are multidimensional experiences, providing visitors with a combination of leisure, social gathering and multifaceted learning experience.

Recent studies specific to science museums have tended to focus primarily on free-choice visitors like families, leaving the area of research about interactions between students and museum educators relatively unexplored. Studies of school visits have focused on a variety of topics, including conceptual change as an outcome for the visit (Anderson, Lucas, Ginns, & Dierking, 2000; Holmes, 2011; Hong & Song, 2013; Whitesell, 2016), the social and the long-term effect of a class visit (Bamberger & Tal, 2008), students' views (Griffin, 2004), engagements of school students with different kinds of exhibits (Faria & Chagas, 2012; Laursen, 2013; Yoon & Wang, 2014) and the affective, motivational or emotional changes that follow a school visit (Holmes, 2011; Rennie, 1994; Stavrova & Urhahne, 2010). Few studies, however, have examined the interactions that take place between students and museum educators in a guided school visit in a science museum.

2.1 | Interactions in science museums

Research on interactions between students and teachers in classrooms is common, but is far scarcer in the context of informal learning settings (Ash & Lombana, 2012). School visits to science museums are generally conducted either by the students' teachers (Griffin & Symmington, 1997; Kisiel, 2003) or by the museum's educational staff (Cox-Petersen, Marsh, Kisiel, & Melber, 2003; Tal & Morag, 2007). Most studies of visits to science museums have focused predominantly on the visiting students and their teachers, with little acknowledgment of the museum educators and their role (Tran, 2007). Moreover, studies that observed interactions around exhibits have focused on interactions during family visits, rather than on students visiting with a group of peers (Ash, 2004). These studies aimed at identifying the interactions *within* the visiting family, rather than the visitors' interactions with the ME (Ash, Lombana, et al., 2012).

One clear point that arises from these various studies is that the type of instruction museums employ is diverse. Instruction may be more formal, when a guide leads a group of visitors around the museum floor, or more informal, when visitors engage in a free choice experience and the guide is there to help. Pattison and Dierking (2013) divided museum instruction into two types: structured and unstructured. In structured interactions like "museum tours, stage shows or classroom programs," they note that the length of the interaction and the relationship between visitors and staff are largely predetermined. In contrast, unstructured facilitation takes the more unpredictable form of unscripted conversations between staff and visitors during educational activities (Pattison & Dierking, 2013). They also note that the majority of research has been done on structured, rather than on unstructured interactions (Pattison et al., 2017). We wish to add to the body of knowledge regarding unstructured interactions between students and MEs.

Much like Ash and Lombana (2012), we view museums as rich learning contexts where we might observe naturalistic interactions, rather than the more formulaic, top–down teacher–student practices. We therefore conducted observations of science museum exhibits, and the naturalistic interactions between students and museum educators that take place around them.

Interactions in the museum are a major part of the visitor experience, whether they are interactions between the museum educator and the group (Bamberger & Tal, 2007; Rahm, 2004), social interactions within the group (Ash et al., 2007; Rahm, 2004), interactions with the exhibit (Allen, 2004), or interactions within a family (Ash, 2003; Ellenbogen, 2002; Zimmerman, Reeve, & Bell, 2010). For the purposes of this study, we adopted Jordan and Henderson's (1995) definition of an interaction, which states that an interaction is "human activities, such as talk, nonverbal interaction, and the use of artifacts and technologies, identifying routine practices and problems and the resources for their solution" (p. 39).

As this definition suggests, the components of interactions can be drawn from the sociocultural approach, at the foundation of which lie two essential notions. One notion is that learners interact with cultural mediational means such as artefacts or cultural tools—ways of knowing, communicating, and utilizing resources (Zimmerman et al., 2010) that are accessible to them, and that these influence their actions or thoughts. The second notion is that artefacts mediate the individual's relation to the world and that the ability to manage and handle such artefacts is acquired in a social setting, through guidance from other individuals. This notion emphasizes the role of dialogue and the co-construction of knowledge, in our case between students, and between the students and the ME. It presupposes that language is a negotiating medium for teaching and learning, and that learning awakens a variety of internal development processes that are able to operate only when learners are interacting with other people in their environment and cooperating with their peers (Zimmerman et al., 2010).

The mediation work of the ME corresponds to what Ash, Lombana, et al. (2012) call "scaffolding activity." They define this as an interaction in which: (a) several people engage in joint activity; (b) typically one member asks for or receives some form of question or explanation (oral or gestural); (c) the exchange occurs between members who are cross-age or cross-generational; and (d) support eventually diminishes or fades. Based on this definition, the interactions between MEs and museum visitors can be interpreted in the context of Vygotsky's (1978) notion of the Zone of Proximal Development (ZPD).

Vygotsky defines ZPD as "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (p. 86). He adds that "what is the ZPD today will be the actual developmental level tomorrow—that is, what a child can do with assistance today he will be able to do by himself tomorrow" (p. 87). The MEs' mediation is therefore an example of "working in the ZPD."

Rogoff (2003) emphasizes, in her framework of guided participation, the cultural aspect of Vygotsky's ZPD, suggesting that children are able to engage in complex thinking and transform cultural tools for their own purpose only through interactions with more skilled partners. Furthermore, interactions within the ZPD enable children to participate in activities, and to adapt cultural tools to those activities, in ways that they would not have been able to achieve successfully otherwise (Rogoff, 2003, pp. 50–51). Rogoff (2003) explains that mutual bridging of meaning is the process in which "partners of the community seek a common perspective or language through which to communicate their ideas in order to communicate their effort" (Rogoff, 2003, p. 185).

When looking at an interaction in a science museum, we cannot limit our view solely to cognitive interactions, since experiences in informal learning environments go far beyond the cognitive domain, touching upon the affective, appreciative, aesthetic, social, moral, and identity domains, all of which are interconnected (Anderson, 2012). Furthermore, in a physical setting, our central interest lies in understanding what kind of interactions different artefacts generate and support (Jordan & Henderson, 1995). In this study, these interactions between students and the physical setting also include another agent—the museum educator.

In interaction research, one must define the "unit of analysis" and extract it from the data for further examination. In other words, it is necessary to define and isolate the interactions that are to be analyzed in the data. For example, Zimmerman et al. (2010) defined the interactions that they analyzed as conversational turns, in which family members attempt to make sense of an artefact. Rahm (2004) analyzed the process of learning in a summer program based on the dialogues conducted between participants. Ash (2002, 2004) devoted several works to refining the borders of interactions in order to detect scientific discourse in family visits, defining them according to "significant events." In this study, we used an inductive data analysis approach (Erickson, 1998; Lincoln & Guba, 1985) to describe the interactions that will be our unit of analysis. Because our focus was on the role of the ME in facilitating the students' interactions with museum exhibits, our units of analysis were defined as encounters that included the ME, a student/students, and an exhibit that they are engaged in operating.

2.2 | Museum educators

While studies focusing specifically on science museum educators are less common, various researches has been conducted with guides and educators in other types of informal settings. Those studies investigated different issues associated with the work of museum staff. Some, for instance, explored instructional strategies, like Singh (2016), who investigated *gallery educators'* instruction of adult audiences and found that balancing between providing information and creating an open space for visitors' results in the educators sharing their own ideas about works of art. Oleniczak (2016) described an improvisational teaching skills program for *gallery teachers*, to help them communicate and connect with the audience of their institution in a more meaningful way. Other studies investigated professional training in informal settings. Carr (2016), for instance, described a training program for *museum staff* that includes interpretive techniques and philosophies. Evans-Palmer (2013) stated that teaching students in informal contexts such as museums presents certain challenges and employed a professional development session for *art museum docents* in order to build up their self-efficacy in their ability to keep young visitors interested and engaged during school visits. Other studies have reviewed education programs for facilitators, with an eye towards improving their training. Finally, some studies have assessed educators' ability to represent the educational goals of their institution. Mony and Heimlich (2008), for instance, studied *docents* in a zoo as they communicated environmental conservation messages to visitors. They found that docents view themselves as facilitators for learning, but that their limited awareness of the institution's messages inhibits their ability to communicate these messages to visitors.

Museum educators have a longstanding presence in museums and play a significant role in the institutions' educational agenda. However, research on school visits to science museums has predominantly explored visiting teachers' and students' perspectives, with little acknowledgment of the museum educators (Griffin, 2012; Pattison et al., 2017; Tran, 2007). Research on science teachers (in school) comprises an important factor in shaping the nature and quality of student learning in schools

(Tran & King, 2011). We suggest that conducting this sort of research on MEs can make a similar contribution to enhancing students' experiences in informal environments.

Unlike teachers, museum educators face the challenge of supporting visitors' engagements with the museum based on very little knowledge of the visitors or their previous experiences (Ash, Lombana, et al., 2012). In such situations, educators need to rely on their previous experiences and build from a body of case examples, from which they may combine a range of common conceptions, age-specific language, and the particular set of skills required to transform knowledge into content for mediation (Tran & King, 2011).

As noted above, our study conducted an analysis of *unstructured* interaction between the ME and the students, similar to that explored by Pattison and Dierking (2013) and Pattison et al. (2017). In their study, these researchers noted that they could not review previous studies of this type of instruction, since the majority of research that has been conducted to date has focused on highly structured interactions (in science museums and museums in general) (Pattison et al., 2017).

3 | METHOD

3.1 | Research setting and participants

This study aims to shed light on the role played by the museum educator in the science museum experience. It is part of a larger research project taking place in Carasso Science Park, a relatively new science museum in the city of Be'er-Sheva, located in Israel's southern region. The study is a cooperative venture between the science museum and Ben-Gurion University in Be'er Sheva. The research in the museum began in 2013, as soon as it opened, following visiting elementary school classes over a period of three years. The classes are from schools in Be'er Sheva that serve students from low-medium socio economic backgrounds. Since the museum is designed for groups in the fourth to ninth grade, the research follows groups of fourth to sixth graders (elementary school).

This part of the study focuses on interactions that take place in the exhibition halls, which are one of several types of activity that take place in the museum. Therefore, only activities that occurred in the exhibition halls were selected for analysis here, and the students engaged in those activities were in the fourth and fifth grade. We observed 15 such visits in exhibition halls, in which each group of visiting students consisted of 15–20 individuals. Observations were collected from October 2014 to March 2016 (excluding summer break).

In Israel, most visitors to science museums are school students, and the instruction during those school visits is conducted by the museum's educational staff. Our study followed the actions of three MEs (pseudonyms—Sharon, Yael, and Gal), who instructed the students we were observing during their guided school visits. The MEs in Carasso Science Park are all science teachers, who teach at schools as well as in the museum (part time). The three MEs (all women) have been teachers for 10–15 years and teach elementary (Gal) or middle school (Sharon and Yael) in the city of Be'er Sheva. All three MEs have been working in the museum since it opened.

Throughout the study, the researchers had no influence on the assignment of MEs to classes. The MEs that worked on the days of the data collection were randomly assigned to groups by the museum administration. It is worth noting that the primary goal of the larger research project was to conduct long-term observations of specific groups of visiting students, and that these groups (primarily due to their schools' preference) came to the museum on Mondays. On that day there were six MEs working, and the three of them that were assigned to the classes we were observing thus became the subjects of the research described here. As a result, our observations were not evenly distributed between MEs,

TABLE 1 Exhibition halls observed in the visits

Exhibition hall	Grade of students	Description
Mechanics and machines	Fourth grade	Demonstrates the mechanical principles and the energy of motion gained or stored by an object
Communication	Fourth grade	Shows the development of communication systems used by people—from the invention of radio and television, through the invention of the computer, the internet and mobile applications
Chip's World	Fifth grade	This exhibition follows the chip found in every electrical and electronic device—its construction, its components and the technologies that use it
Light and sight	Fifth grade	Reveals the physical principles of light and demonstrates why sight is important, how the eye is designed and the brain's connection to the eyes
Sound and hearing	Fifth grade	Examines sounds from vibrating objects, how the ear hears sounds and how technology has increased the ability of the hearing-impaired to discern words

but were based on assignments made by the museum administration. In Table 2, the last letter of the observation code represents the ME's name.

In this science museum, the classes are assigned to an ME for the entire visit. The ME remains with the students while they are in the exhibition halls, but there is no formal instruction around specific exhibits. This form of instruction is what Pattison and Dierking (2013) refer to as "unstructured facilitation." The MEs are expected to "make the rounds" of the students during their time in the exhibition hall.

3.2 | Data collection and research tool

Observations are a common method of data collection in the field of research in informal learning environments. Such studies explore visitors' engagements in science museums (Gutwill & Dancstep, 2017; Hayward & Hart, 2015; Mortensen, 2011), family sense making in science centers (Zimmerman, et al., 2010) and students' interactions with exhibits (Faria & Chagas, 2012). The data for this study were collected through naturalistic observations (Lincoln & Guba, 1985). Because we wished to present an authentic portrayal of the interactions as they happen naturally in the museum, the researchers remained passive participants throughout all observed visits (Patton, 1990) and were present to videotape but not participate or interact with other people. We videotaped all activities during the visit, using three video cameras: one followed the ME, and the other two followed students. The classes visiting the exhibition halls remained there for 20–35 min. The students were not allowed to wander into a different hall on their own, but had to remain with the rest of the class. The ME was in the hall with the students during the entire visit. Descriptions of the exhibition halls that were observed appear in Table 1.

3.3 | Data analysis

All observations were transcribed from the video by the first author, including all things appearing in the video (e.g., talk, activity, gestures). In order to define our unit of analysis, we had to

TABLE 2 Interactions observed in exhibition halls during school visit

Observation	Time overall	Time in interactions	Number of interactions	Average duration of interaction	Initiated by student
A1S	00:36:43	00:31:20	33	00:00:57	2
A2S	00:23:51	00:19:53	15	00:01:20	1
A3Y	00:33:55	00:25:44	35	00:00:44	8
A4Y	00:24:00	00:19:45	26	00:00:47	8
A4G	00:25:22	00:18:39	15	00:00:49	1
B1G	00:17:20	00:12:34	14	00:00:42	0
B2G	00:23:25	00:19:34	24	00:00:49	0
B3G	00:37:34	00:28:28	28	00:01:01	2
B4G	00:23:14	00:17:38	23	00:00:43	3
B5G	00:29:12	00:11:14	12	00:00:56	2
C1S	00:22:58	00:18:18	27	00:00:41	2
C2S	00:17:58	00:14:31	21	00:00:41	2
C3G	00:38:24	00:26:55	26	00:00:47	6
C4G	00:23:25	00:19:26	23	00:00:41	10
C5G	00:27:22	00:22:22	14	00:01:36	3
Total	**6:44:43**	**5:06:21**	**336**	**00:53**	**50**

determine “what makes an interaction” in the context of our study. Since engaging with exhibits is the main activity in interactive science museums (Allen, 2004; Falk & Dierking, 1992, 2000), and since this study focuses on activity around exhibits, the interactions analyzed needed to consist of the ME and the students engaging with exhibits. All interactions that did not include an exhibit or the ME were excluded.

In order to maintain credibility, two researchers (authors) read the transcripts twice on their own and decided “what makes an interaction.” Each researcher described how the interaction starts and how it ends—decisions that later manifested as phase 1 (initiation) and phase 4 (termination) of the interactions as described in the findings section—and what will not be analyzed as an interaction (for instance, all interactions not connected to an exhibit, like logistics and disciplinary actions). The researchers shared their definitions in order to create a single definition with which to work (there were no disagreements). Next, one of the researchers divided all of the transcripts into interaction units for analysis.

In order to answer our research questions, we first analyzed the interactions to get the full picture of what sorts of recurring patterns emerge from the interactions. Next, we performed a micro-analysis of the interactions in order to define the roles that the MEs play in mediating the students' interactions and the practices they employ in doing so. The stages of this analysis are described below.

3.3.1 | Identifying characteristic patterns in the interactions

To identify the components of each of the 336 interactions, three researchers created, between them, a personal flow chart for every interaction (each analyzing one third of the data). Each flow chart describes the chain of events in the given interaction, starting with the beginning of the interaction and following its progress until its termination. To ensure a trustworthy process, the researchers analyzed the data individually, creating flow charts for every interaction, and then combining all charts into one chart that describes all stages in all interactions. In order to ensure credibility, a process of peer debriefing took place, involving other researchers (besides the authors) from the field of informal science education (Lincoln & Guba, 1985). The researchers compared all three flow charts in order to create one that combines all 15 observations.

Misalignments were discussed and documented in order to create the final flow chart. Most of these arose from differences between the patterns of the interactions themselves in the different observations, rather than differences of opinion between researchers. Thus, for example, uncommon situations, such as the teacher talking to the student during the interaction with the ME, or students arguing with one another during the interaction, were discussed and ultimately excluded from the flow chart in order to generalize it. The flow chart created from the entire body of data encompassed all of the interactions that were included in the analysis. It consisted of four stages that, between them, describe the interactions: Stage 1—beginning of the interaction, Stage 2—explanation regarding the operation of the exhibit, Stage 3—operation of the exhibit, Stage 4—termination of the interaction. These four stages are further elaborated in the findings section.

3.3.2 | Discourse microanalysis of the interactions

After creating the flow chart that characterizes the interactions as a whole, we wished to look into the interactions themselves to see the role that the MEs play in the interactions, and the practices they use in performing it. During this stage of the analysis we looked at specific parts of the data that we had already analyzed, using findings obtained from the first part of the analysis to choose interactions worthy of further examination. For this purpose, we used the video recordings, which provide rich data for studying interactions (Jaber & Hammer, 2016). Unlike field notes, which tend to highlight "important" aspects and pass over "unimportant" ones, video records social events as they occur and with a level of detail that is unattainable for methods that rely on reconstruction. In that sense, video provides data that more accurately presents what "really" happened (Jordan & Henderson, 1995).

We adopted an inductive analysis approach, which is used when a minimally edited video corpus is investigated with broad questions in mind but without a strong orienting theory (Derry et al., 2010), and which is free from predetermined analytic categories (Jordan & Henderson, 1995). We used the flow chart of the interactions as a road map (Azevedo & Mann, 2017), which helped us choose specific interactions for analysis. We decided to focus on the interactions that moved beyond giving technical instructions for operating the exhibit (i.e., those that progressed past stage 2 in the flow chart and entered the more complex and diverse stage 3). This left us with 106 interactions to choose from (out of 336). These were analyzed by three researchers from the field of science education, with experience in museum instruction (the first author and two others).

The researchers looked for interactions (up to two minutes) that consist of a variety of instruction practices or strategies on the part of the ME, and examined them for recurring themes. Every researcher chose 10–15 interactions that demonstrate those themes best in their view. These interactions were then discussed by the authors in order to revise and refine interpretation, following Jaber and Hammer's (2016) suggestion, until the two themes presented in the findings section were agreed upon. The selected examples of these themes were then re-transcribed with extra care to note paralinguistic channels of communication (intonation, cut-offs, overlap, and pauses), body gestures, movements, gaze, and facial expressions (Jaber & Hammer, 2016; Jordan & Henderson, 1995), and then underwent discourse micro analysis.

Microanalysis is considered to be an "insightful" tool for studying interactions in science classrooms, which makes it possible to identify patterns of engagement, and indicators of physical and emotional entrainment expressed in interactions (Elmesky, 2015). In microanalysis the researchers look for use of body language as a pedagogical technique, including gaze, facial expressions, posture, and location (Tobin & Hayashi, 2015). During the process of micro analysis, we asked ourselves—what did the participants say and do, why did they say and do those things, and how did they use their body? Regarding the MEs' instruction, we looked at the practices employed by the MEs and the students' reaction to them. In order to ensure transferability, we have provided rich descriptions of the interaction itself and the context in which it occurred (Lincoln & Guba, 1985).

4 | FINDINGS

The findings presented here are based on observations of 15 visits in different exhibition halls throughout the science museum. In Table 2 below, the observations are coded in the left column. The first letter represents the school (A–C), the number is the chronological order of that school's visit to the museum (1–5), and the last letter represents the name of the ME that accompanied the group. We divided each observed visit into interactions and calculated how much of the observed time was devoted to interactions, as well as the average time of each interaction. As seen in Table 2, in 15 observations, 336 interactions were observed. Average time of interaction was 53 s, and only 50 interactions were initiated by a student (the rest by the ME). We had 6:44:43 h of videotaped observations in the exhibition halls. Of these, 5:06:21 consisted of interaction between students and the ME around an exhibit. The rest of the time was spent dealing with technical problems, discipline, etc.

4.1 | Recurring patterns in the interactions

As noted above, in the first stage of our data analysis we created a scheme of the interactions in order to characterize the various courses that interactions between an ME and students gathered around an exhibit may take.

We identified four stages:

Stage 1—beginning of the interaction.

Stage 2—explanation regarding the operation of the exhibit.

Stage 3—operation of the exhibit.

Stage 4—termination of the interaction.

Identifying the beginning and the termination of the interaction gave us a definition of "what is an interaction around an exhibit." We will therefore begin by elaborating on the first and fourth stages before moving on to the two middle stages in the flow chart.

Figure 1 illustrates the ways in which the interaction begins.

Table 3 describes the ways in which the interaction can begin.

As Table 3 shows, interactions begin in one of several ways. Only 50 interactions (of 336) were initiated by the students. Moreover, the ME often seems to begin an interaction by "inserting herself" into an ongoing interaction. This terminology is borrowed from Pattison and Dierking (2013), who also reported MEs approaching and initiating an interaction in this way. In our case, the MEs "circle" the exhibition hall throughout the visit, approaching students who are located around exhibits. The MEs do not sit or stand, waiting to be called; they do not observe the students and decide whether or

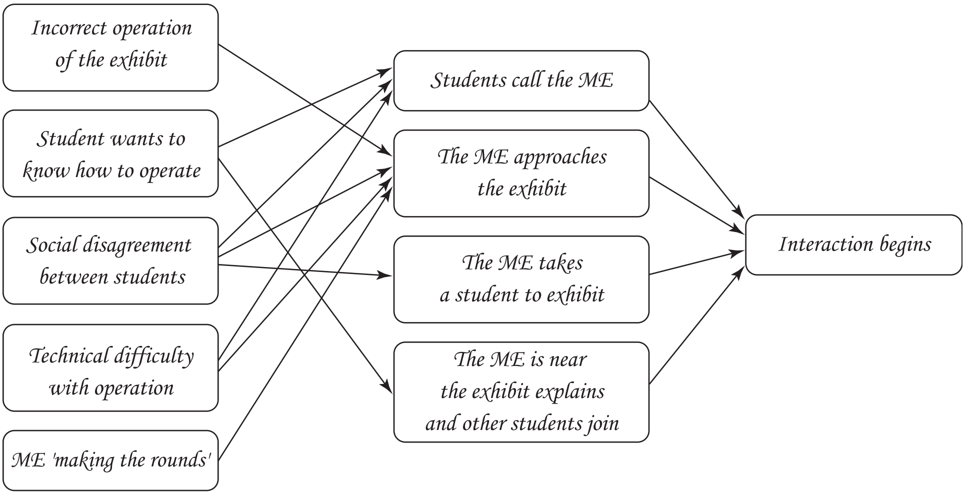

FIGURE 1 Stage 1—how the interaction begins

not to approach them; they just "make the rounds" and approach one exhibit after another in turn. This finding will be discussed further in the limitations section.

Figure 1 and Table 3 describe the elements that constitute stage 1: the *beginning* of an interaction. At the other end of the flow chart are the events that constitute stage 4: the interaction's *termination*. Interactions ended when: (1) the ME was called to another exhibit; (2) the students left the exhibit, giving the ME no reason to stay; (3) the students did not respond when the ME spoke to them, and then the ME left the exhibit (MEs usually did not persist if they were being ignored); (4) the ME saw that the students were operating the exhibit alone and left; (5) after explaining the scientific content of the exhibit, the ME left; (6) the ME moved on with her regular "rotation" through the exhibits. Just as MEs sometimes approached exhibits because they are "making the rounds," they also left them for the same reason.

At this point we would like to stress two things. First, there could be other beginnings and terminations than the ones described here. We only describe what we observed in the 15 observations conducted in this study. Second, termination of the interaction can occur at any of the intermediate stages that are further elaborated below. It is numbered as the fourth stage for convenience, but some interactions began and terminated after the second stage, never arriving at the third (as we will see below). After defining "what is an interaction" by noting how the interaction begins and terminates, we can now describe the actual mediation that occurs *during* the interaction—in stage 2 and 3. The second stage defined in our flow chart is the ME's explanation regarding the operation of the exhibit. All 336 (100%) of the interactions went through this stage (meaning there was no jumping from stage one to stage three). During this stage, the ME made sure that the students know how to operate the exhibit (sometimes even if they have operated it already), which suggests that this is the most important part in the ME's eyes—making sure that the students know how to operate the exhibit.

Figure 2 illustrates the ways in which the ME makes sure that the students know how to operate the exhibit. In some interactions the ME started explaining straight away, regardless of what the students are doing (they could be doing it already and the ME would still explain), or showed the students how they should operate/look at the exhibit physically (through a gesture like pointing or touching the students to direct them to the right position). In some interactions, the ME asked the students if they know how to operate the exhibit. If the students did not respond and paid no attention to the ME, she left (termination of the interaction) and did not persist. If the students said "No," the ME explained or asked them to operate the vocal instructions of the exhibit (most exhibits have vocal instructions). If

TABLE 3 How the interaction begins

How the interaction begins	Explanation	Example
Students call the ME	The students call the ME to the exhibit because they do not know how to operate the exhibit	Sharon, can you come tell us what to do here?
	The students call the ME to the exhibit because they have a disagreement with fellow students around the exhibit that they wish the ME to solve	Gal, there is only room for two players in the exhibit and Adam wants to play as well
	The students call the ME to the exhibit because they are having technical difficulties with the operation of the exhibit	This exhibit doesn't work! Can you fix it?
The ME approaches the exhibit	The students operate the exhibit incorrectly and the ME goes to correct them	No don't push with your legs. I will show you what to do
	The ME sees a social disagreement and goes to solve the problem	Shelly, wait for your turn, they will finish and then you can operate it
	The ME sees the students have technical difficulty with operating the exhibit	It doesn't work? Let me try to operate it for you
	The ME "makes the rounds"—arrives and physically inserts herself into the interaction	
The MEs take a student from one exhibit to another	When students have a disagreement around the exhibit, the ME takes one of the students (who seem to be the cause of the disagreement) and physically takes the student to another exhibit	Yael sees three students arguing over who will operate an exhibit and approaches: "This exhibit is for two. You two sit here and you come with me." Yael seats the two students that were near the seats and takes the one that was not. She touches him on the shoulder, signaling him to leave that exhibit and come with her
Other students join around the exhibit	Around a large exhibit, the ME explains to students and other students come along. They wait (or not) for the ME to terminate the first interaction and ask her what to do in the exhibit. By doing so, the first group of students usually leaves and the ME begins a second interaction near the same exhibit	Sharon explains how to operate the pulleys. Guy and Dan wait until she has finished explaining to Sarah and ask her: "Can you explain again so we can operate as well?"

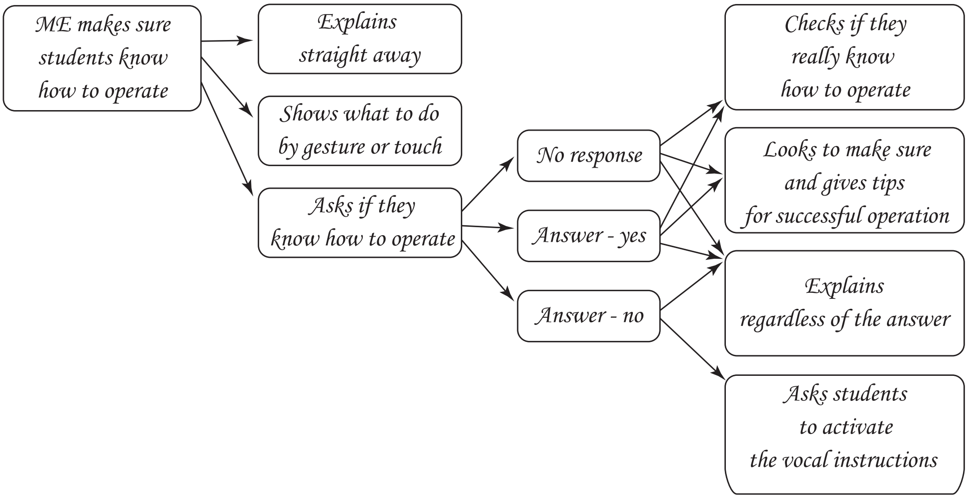

FIGURE 2 Stage 2—explanation regarding the operation of the exhibit

the students answered "Yes," the ME sometimes ignored the answer and explained anyway, or checked if they really know how to operate: "Tell me what you need to do here and how you do it." In some cases, if the students said that they know how to operate the exhibit, the ME watched them operating for a few seconds and gave them tips for better operation, for example: "If you press on the both buttons together you can release two messages at the same time and get to the end quicker."

Table 4 shows that 229 of the 336 interactions (68%) terminated during the second stage. Only 106 (32%) of the interactions moved on to the third stage before termination. The third stage is divided into four sub-stages (a, b, c, d), representing a cumulative progression over time (i.e., events in 3b only happen after events in 3a, etc.).

Figure 3 describes the flow of the sub-stages in stage 3.

Stage 3a includes one of three options: The students operate the exhibit **on their own**, the **ME operates** the exhibit for the students, or the **ME instructs** the students during the operation. Thirty of the interactions (9%) were terminated after stage 3a. The rest moved on to 3b (see Table 4).

In stage 3b, the students operate the exhibit and the ME makes comments regarding the operation or about the exhibit itself. This means, for instance, that the ME tells the students to **look at the phenomenon** presented in the exhibit—"Turn the wheel clockwise and observe what happens to the sticks." The ME often gives **feedback regarding the operation**—"Yes, this is how you build the tower" or "No, you need to turn the wheel the other way." In some cases, the feedback will be in the form of encouragement to the student activating—"Nice! You got it right." The ME asks **guiding questions** to promote students' understanding of how to operate the exhibit or of its ultimate goal, for example: "When you push the red it moves up, when you push the green it moves to the side, what happens when you push both the red and the green together? How does it help you to build the tower?" Forty-six interactions (14%) terminated at this stage (see Table 4). The rest progressed to stage 3c.

TABLE 4 Number of interactions terminated in the different stages

Number of interactions	Terminates after stage 2	Terminates after stage 3a	Terminates after stage 3b	Terminates after stage 3c	Terminates after stage 3d
336 (100%)	229 (68%)	30 (9%)	46 (14%)	12 (4%)	18 (5%)
		Total stage 3—106 interactions (32%)			

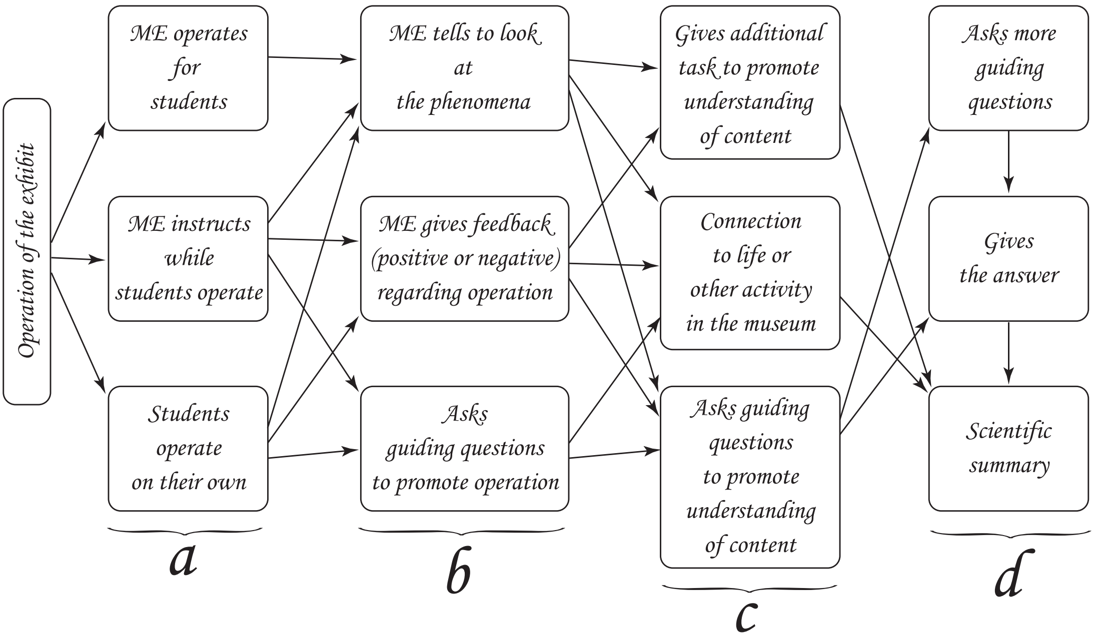

FIGURE 3 Stage 3—activating the exhibit

In stage 3c, the ME's explanations change from technical information about the operation to the scientific content of the exhibit. The ME **asks questions** or **gives "tasks"** to promote that understanding. For example, in the pulleys exhibit, Sharon asks the students: "You pulled 3 kilograms from the first station, now go to the second and third stations and pull the same 3 kg. Does it feel different?" The ME also **connects** the activity in the exhibit to a different activity that the students experienced in the museum ("It is like we saw in the lab, the oil breaks the light in a different way so we can see some objects and we can't see the others"), or **connects** it to something from the students' daily life ("We need to have reception, we get it from the tower closest to us. In real life our phones do it automatically"). Twelve interactions (4%) terminated after stage 3c and only 18 (5%) terminated after stage 3d (see Table 4).

In stage 3d, the ME asks more **guiding questions** to direct the students to the "right scientific" answer (in the ME's eyes), or **gives the answer** to the students when she sees that the students have not come up with it. Most MEs, at this stage, gave what we call a **"scientific summary,"** which means some sort of statement or content related explanation. The scientific summary can be short, like: "I move the log in the same direction, but the inner log moves back and forth because of the gear." Alternatively, it can be a more profound explanation, such as: "This is how the computer translates the photo. Where you have white dots it translates to 1 and if it is black to 0. This is the language of the computer," or "Our two eyes give us a sense of depth, 3D vision. When we look only with one eye, we get confused and don't know what is near and what is far from us."

After identifying the recurring elements emerging from the interactions and noting that most interactions terminated after stage 2 (which consisted primarily of ensuring that the students understood how to operate the exhibit), we decided to perform a micro analysis of the smaller number of interactions that had progressed into the *third* stage (particularly sub-stages b, c, and d). In examining these more extended interactions, we asked our second research question, namely what sort of role do the MEs play in mediating the students' interaction with the exhibit, and what sort of practices do they employ while doing so?

4.2 | The MEs' mediational roles and the practices they use during interactions

In the previous section, we described the recurring patterns that defined the course of the interactions between MEs and students on a school visit to a science museum. In this section we wish to demonstrate the mediational roles that the MEs play during the interactions and identify the practices that they employ in doing so. The use of video as a tool offers an opportunity to more closely examine the components that make up the interactions. In order to get a more detailed description, we performed a discourse microanalysis of the interactions. This form of analysis allowed us to note different instruction practices, physical gestures, types of engagement and more. In this analysis we pay attention to the talk itself, as well as paralinguistic channels of communication (like intonation, cut-offs, etc.), body gestures, movements, and facial expressions (Jaber & Hammer, 2016).

Our discourse microanalysis revealed two recurring strategies employed by the MEs in the interactions that successfully moved into stage 3: (a) physical instruction, and (b) engaging the students emotionally with the exhibit. Each of these themes is presented in detail below, with examples of how they were expressed during various interactions. This section also includes two interactions that are presented in full. These two interactions were singled out in the data analysis as the clearest examples of each theme, and providing them in full offers a more complex and comprehensive representation of how the MEs and students interacted, and of how these interactions were analyzed for recurring strategies.

4.2.1 | Engaging the students emotionally

One of the themes that emerged from our analysis was that the MEs use emotional engagement in their instruction in order to engage the students with the exhibits. Emotional engagement is a broad term referring to curiosity, interest and motivational factors, such as perceptions of value. Interest refers to the enjoyment that one feels when engaging in a task (Sinatra, Heddy, & Lombardi, 2015). Furthermore, emotional engagement draws on positive and negative feelings, orientations, and affect inherent in the learning process (Martin, Durksen, Williamson, Kiss, & Ginns, 2016). In our study we only note some of the factors that define emotional engagements, focusing specifically on observable (verbal and non-verbal) positive reactions.

The MEs we observed use emotional engagement as a practice repeatedly in their facilitation. Sometimes the ME looks for emotional "signs" in the students' behavior, and then magnifies these in order to create further excitement. This is the case, for example, in the "Morse code" exhibit, in which Sharon the ME explained to Dina how to spell "dad" in Morse code. The video shows that Dina is very excited saying: "This is so cool! Mari you have to come see it (calls to her friend)." Sharon sees Dina's reaction and encourages it: "Yes, Mari, come see, it's really cool. You can try it as well. Dina—do you want to teach her how to do it?" In another example, from the "technology development" exhibit, Yael the ME is seen standing near the exhibit answering questions on the operation. Another student (Raz) joins in and says: "Cool." Yael turns to him and asks him what about it he finds cool. Raz answers: "Those illustrations of a robot building cars." Yael "uses" that and says: "You are right! This is AWESOME! Do you want to see another awesome thing?" As these examples show, Yael and Sharon use the students' own emotional reaction to the exhibit to engage them further and keep them in the interaction.

In other cases, the ME tries to spark the excitement first. In one such example, Gal the ME approaches Yuval, who is manipulating the "game of mirrors" exhibit, where the user must compose a clown face using reflections: "OMG! This is so pretty, did you do it on your own?" Yuval smiles immediately and starts "bragging" about the way she did it. Gal uses her enthusiasm to ask her guiding questions about the operation and the function of the mirrors in the task ahead.

The following example demonstrates a longer interaction, transcribed in full from the video recording, in which the ME is trying to get the student emotionally involved in the exhibit. Here, the ME (Sharon) is standing with one fourth grade student (Mani) around the exhibit "House of the Future" in the "Communication" exhibition hall. This exhibit is a touch screen with information on different technological developments that might occur in the future. The visitor chooses an element in the house by touching the screen and the information appears on the screen in the form of text and images.

Observation A2S, time in video—00:02:13, total time of interaction—01:43 min.

#	Talk and actions	Result of talk and/or action and interpretation
1	Sharon takes Mani to the exhibit, Mani looks at the screen	Mani is standing near another exhibit, bothering the student who is operating it. Sharon sees that and approaches Mani, touches him on the shoulder and signals with her head to come with her. They stand in front of the exhibit, looking at the screen
2	Sharon: This shows us what will be in the house of the future, you can operate things from afar, even today you can operate with your Smartphone a washing machine, air conditioning	Sharon immediately explains the function of the exhibit. It is not specifically written on the screen; you need to operate it to get the idea. Sharon says it before they operate the exhibit. She is talking in a personal way—stating *you* can do this, not that it is something general *we* will have in the future
3	Mani: Seriously? ↑	Mani is very excited and has an emotional respons
4	Sharon: Yes ((Sharon presses on the screen and reads the text))	While the text appears on the screen Sharon moves her finger along with the text on the screen while reading out loud. She does not ask Mani to press the screen or read. The text is about an alarm clock that can operate the kettle for you in the kitchen 
5	Mani: So I am doing it ↑	Mani refers to the text Sharon has read, meaning that he wants to have this kind of alarm clock and use it. Again, he is very excited
6	Sharon: You can set the clock, it is not this clock ((points to the watch on her hand)), it's on your Smart-	Sharon sees that Mani is excited so she keeps on talking about the alarm clock. She makes the differentiation between a regular watch and the one the exhibit talks about (in Hebrew, "watch" and "clock" are the same word). When she talks again about the alarm clock, she repeats what she read from the screen before, in a different way

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#	Talk and actions	Result of talk and/or action and interpretation
	phone, you tell it— when you wake me up open the blinds, heat up the kettle, turn on the boiler	
7	Mani: = And is there an application yet?	Mani is interested in that alarm clock, cutting Sharon off by asking if there is a phone application for that function
8	Sharon: It is not an application, it is components ((Mani pushes the screen)) that you need to put in your house as well	Sharon answers the question in a vague way; it is not clear what those components are. This does not bother Mani, since he is already looking for another thing in the screen while she is explaining
9	Sharon pushes again and reads the text on the screen	The touch screen did not work when Mani pressed it so Sharon presses again, on the same thing Mani did. Again she does not ask him to read and follows with her finger on the screen
10	Sharon: Oh nice, when you brush your teeth you can see the appointments you have	Sharon responds in a dramatic way— "Oh nice" (from the intonation), it seems like she is copying Mani's enthusiasm in order to amplify his emotional response
11	Mani: WOW	
12	Sharon: It will be screened on the bathroom mirror ((Mani pushes the screen, Sharon reads))	Sharon elaborates on the function she read before, all resulting in surprise and amazement from Mani
13	Mani: WOW	
14	Sharon: You can see a movie with your coffee in the kitchen, when you move to another the room it will move with you	Sharon repeats what was written on the screen. When she talks about moving the coffee, she pretends to hold a mug in her hand and walk with it
15	Mani: Awesome ↑	
16	Sharon: You like it? ((Turns away and comes back))	Sharon smiles when she asks him if he likes it. It is more a rhetorical question because it is obvious that he does. She turns away to move on, but turns back again
17	Mani smiles	Mani smiles as response to her question whether he likes it

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#	Talk and actions	Result of talk and/or action and interpretation
18	Sharon: You have more things here ((points to the screen)) check them out.	Sharon turns back and gives Mani more suggestions to keep engaging with the exhibit. Then she goes and he stays

Transcript key: ↑ high tone; ↓ low tone; (()) description of non-verbal action; [] overlap talk; = cut-off.

In this example, the emotional engagement is very dominant. The ME triggers the excitement and the student becomes very excited. She then keeps it up, in order to keep him engaged with the exhibit, by offering "exciting" examples (line 2, 6, 10, 12), and using a dramatic voice (line 10) and comic gestures (line 14). When she sees that he is not very interested in a scientific explanation (line 8), she does not persist with it, moving on to show him something else instead.

4.2.2 | Physical instruction

The term "physical instruction" in this context means that the MEs use their body, or the students' body, as part of the instruction, engaging themselves and the students physically with the exhibit's environment. This differs from embodied cognition, which focuses primarily on the learner, rather than the actions of the mediator/instructor. As Lee (2015) describes, "cognition is embodied to the extent that knowing and learning are processes that take place through perception and action and that unfold in specific material, physical, and social settings." The term we propose here refers not to the learner's experience of "knowing and learning," but to a form of explanation employed by the ME both verbally *and* by means of the body (theirs and/or their students'). The form of these explanations is related directly to the physical environment of the museum, and therefore we have called it "physical instruction."

The example above contains several instances of physical instruction. For instance, the ME points to the text on the screen and moves her finger along while reading out loud (line 4). This keeps the student focused on what she reads. She also demonstrates on her watch and changes position—looking at the screen (to read) and looking at the student to see his responses (in contrast, the student only looks at the screen and hardly looks at the ME).

Another example of physical instruction is when the MEs position themselves at the same height as the students, in order to see what they see. Gal, for instance, did this in the "laser" exhibit, bending down to see why Adam did not understand how to move the laser. In another example, the same ME took a student's hand and placed it in the right place in the scanner ("binary code" exhibit): "Here, place your hand here (takes her hand)." In the "robot" exhibit, Sharon physically helped Nicole operate the exhibit by holding down a button for her: "Here, I am holding it for you. Tell me when you want me to let go." As these examples show, the MEs sometimes use their bodies as a form of explanation (since it is easier to show than to verbalize) and sometimes as a means of sharing the experience with the students.

The next full example shows several forms of physical instruction employed by an ME during a single interaction. The ME (Gal) is standing with two fifth grade students (Tammy and Sarah) around the exhibit "Reflections" in the "Light and Sight" exhibition hall. This 1.60 m exhibit is divided into three equal sections. The top and bottom sections have "wavy" mirrors that make you look distorted (your upper body and legs). In order to look at the middle section, you must bend down at a 90° angle so your head is level with that part of the exhibit. In that part of the exhibit there are parallel mirrors on the sides and a cube hanging in the middle of the space. When you look inside you are supposed to see infinite reflections of the cubes in the mirrors.

Observation C3G, time in video—00:05:28, total time of interaction—37 s.

#	Talk and actions	Result of talk and/or action and interpretation
1	Tammy: Wow cool ↑	Tammy approaches the exhibit alone and talks in an excited voice, seemingly not to anyone specific. Gal (the ME) apparently hears her, turns around and approaches her while talking to Tammy
2	Gal: Do you know what to do? What's inside?	Gal asks Tammy if she knows how the exhibit works, not waiting for an answer and asking Tammy to describe what she sees
3	Tammy: Cubes	Tammy says what she **sees**
4	Gal: Are there several cubes? ((Points))	Gal fine-tunes the question in order to make the differentiation between what there **is** and what we **see**. While she asks, she first points to the cube in the center and then moves her finger around to point to the mirrors on the sides. She implicitly shows Tammy how to look at the exhibit
5	Tammy: One cube. ((Looks again))	Tammy understands that Gal is asking to make the observation more specific and corrects the answer. She also bends down and looks in the way Gal has indicated
6	Gal: What happens to them when you look inside?	Gal asks another question to initiate sense making, referring to the cubes in plural form
7	Tammy: It becomes infinite ((Straightens up and looks at Gal))	Tammy refers to the cube (singular form) and answers the question correctly. Her reference to the one cube means that she recognizes the fact that there is one real object and the others are just reflections
8	Sarah joins them	
9	Gal: = Why? ((Smiles to Sarah and moves to the side))	Gal continues the sense making, asking for an explanation for the phenomenon seen in the exhibit Her attention is given to Sarah through gestures. She smiles to her and moves to the side so she can look as well
10	Tammy and Sarah bend down and look inside the exhibit	
11	Tammy: It looks like infinity [Like what we did in the experiment]	Tammy repeats the former answer (line 7) and does not really explain why it happens. She mentions an experiment the class did earlier in the lab with Gal, which demonstrates the same phenomenon. She stands up and looks at Gal, making room for Sarah to look (not deliberately)
12	Gal: [Look really] close, it is amazing ((Points))	After Tammy's reference to the experiment, we would expect Gal to continue the conversation in that direction, but she does not. She "delays" the continuity of the interaction in order for Sarah to "get in the loop." She points again towards the exhibit and gives Sarah a chance to look again. In Hebrew, Gal has changed her form of talking to plural instead of singular (meaning that she is now

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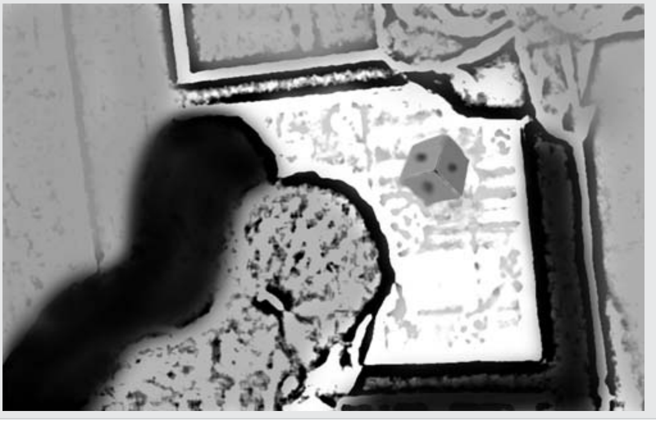
#	Talk and actions	Result of talk and/or action and interpretation
		talking to both of them not just Tammy) 
13	Sarah: WOW	This is the only verbal response Sarah makes in the entire interaction. It seems like she is recognizing Gal's efforts to include her and responding verbally
14	Gal: There is only one thing there but they made it ((makes a circle with her hands)) (XXX) a whole thing	Gal talks about the design of the exhibit, it is not possible to understand all she is saying in the video
15	Tammy: = It's like, you see dots, dots	Tammy cuts her off and refers to the dots on the cube
16	All three bend down to look inside for two seconds and then stand up	Gal is trying to see what Tammy is talking about and bends down with them 

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#	Talk and actions	Result of talk and/or action and interpretation
17	Gal: It is like the experiment with the candles ((Sarah starts walking away)) there are a few mirrors ((Tammy walks away too and Gal walks alongside them)) and the candles are duplicated by the mirrors ↓	Gal starts the explanation of the phenomenon and uses what Tammy said in line 11. Sarah loses interest and walks away. Tammy stays for a second and Gal continues to talk. Tammy starts walking away as well. Gal is trying to finish the sentence and walks alongside them, but her tone of voice goes down when she "gives up" and stops following them

This example shows how the ME uses physical gestures to communicate with the students. She shows them how to look at the exhibit correctly by pointing (lines 4 and 12) and moves so they can get a better look (line 9). The ME also participates in the students' physical experience and bends down with them to look inside the exhibit. Besides physical instruction, we can see that here too the ME uses the students' emotional engagement (in lines 1 and 13) and builds upon it (line 12).

As seen in both examples, the MEs use physical instruction and emotional engagement in their interactions with the students. These practices were dominant, but they are not the only practices employed by the ME. From our analysis of 106 interactions that proceeded to the third stage, we found other (less dominant) forms of instruction that are also worth noting. For instance, in the first example we see that Sharon chooses to read from the screen, rather than asking Mani to read (line 4). This is a strategy repeatedly used by the MEs. In addition, in the second example, Gal's sense making approach includes questions about the observable phenomenon (line 2, 4, 6) and an effort to explain it (line 9), which does not really succeed. Gal does not impose an explanation, and when she feels like the students do not want it, she lets go (very similar to Sharon's choice in the first full example). Finally, the MEs use the students' connection to previous experiments and repeat it in order to explain the phenomenon (line 11 in the second example) or refer to the students' own life experiences and how they connect to the experience of the exhibit (lines 2, 6, 8, and 10 in the first example).

To conclude, the first part of our analysis revealed several recurring characteristics in the interactions between the ME and students that take place around science museum exhibits. First, the average time of interaction is very short, 53 s. Second, the ME does not wait for the students to approach, but initiates interactions constantly, circling the exhibition hall, not resting for a minute. Third, almost 70% of the interactions terminate during stage 2, in which the ME makes sure that the students know how to operate the exhibit (taking on the mediational role of a "technician"). Finally, only 5% of the interactions included scientific explanations. The second part of the analysis, which focused on the interactions that *did* move past stage 2, showed that in these interactions the ME takes the role of promoting the students' engagement with the exhibits, using practices such as physical instruction and engaging the students emotionally.

5 | DISCUSSION

In designed informal learning environments, like science museums, visitors shape their experiences by interacting with the artefacts that are accessible to them in the environment (Davidsson & Jakobsson, 2012). This includes interactions with exhibits (mediation through artefacts), as well as encounters with staff members, other visitors, and the group with which you experience the visit (human mediation) (Davidsson & Jakobsson, 2012). To better help visitors grow and learn from their museum experiences, especially those involving unstructured instruction, we need to understand these experiences so that we can shape them (Hein, 1998).

This study was designed to shed light on a specific aspect of the science museum experience, namely the role played by the museum educator in unstructured instruction. We identified recurring patterns in the interactions between MEs and visiting students, and described the mediational role assumed by the MEs and the practices they use while engaging the students with exhibits. As mentioned, in this type of school visit, the ME is assigned to the class, joining the students throughout the visit. The exhibition halls enable many interactions to occur around the exhibits (social, cognitive, and affective). However, we found that most of these interactions were very short (Tran & King, 2011), ending after the ME had explained how to operate the exhibit. Most of the interactions, we found, did not result in any scientific explanation.

Today, there is a general expectation that visitors to science museums will, as part of their museum experience, learn about scientific concepts. Science museums have expanded in variety and exploded in popularity over the last few decades (Hein, 1998). As their numbers and popularity have grown, there has been a marked change in the role that they play in society. Today, all science museums place a strong, clear emphasis on education (Falk & Dierking, 1992; Friedman, 2010). And yet, our results showed that interactions consisting of scientific explanations were very rare.

5.1 | The museum educator as a "technician"

The role that the ME played in the interactions was, first and foremost, the role of a "technician." This may be due to the MEs' perception that visitors often do not know how to operate exhibits, manipulating them randomly by "just pushing buttons" (Allen, 2004; Faria & Chagas, 2012). Other researchers have shown that MEs believe that there is a right way to operate an exhibit, and that learning will not occur unless the visitor operates the exhibit correctly (Ash & Lombana, 2012). Furthermore, MEs tend to believe that visitors "mess up" the exhibits and should be taught the right way to use them (Ash & Lombana, 2012). This might lead to a "one size fits all" instruction strategy (Ash & Lombana, 2012), which in our study manifested as a focus on imparting "correct" operation procedures. It is worth noting in this context that the students also seem to perceive the ME's role in this way, only initiating an interaction in order to ask them how to operate the exhibit.

This generic strategy could be perceived as highly problematic from the perspective of Vygotsky's ZPD, which is based on the idea that education should be tailored to each student's specific needs (1978). Nevertheless, we suggest that the "one size fits all" approach could still be viewed as "working in the ZPD," based on Wells' (2000) suggestion that ZPD potentially applies to all participants, and not just to those that are less skillful or knowledgeable. Moreover, if we examine this form of "technical" instruction from Ash & Lombana (2012) perspective of mediation (see literature review), we definitely see that all aspects of a mediated interaction are reflected in the interactions we observed: several people engage in joint activity, one member at least (the student/s) receives an explanation (oral or gestural), the exchange is cross-age (ME-student), and the support eventually fades. Finally, as Granot (2005) points out, even when adults provide mediation, students have to choose to use it and be willing to grow with it (Granott, 2005). In that sense, the MEs provision of basic "technical support" can be seen as a means of offering the students a common ground of mediation that each student can draw upon of their own accord. On the other hand, Ash, Lombana, et al. (2012) further state that mediating learners' interactions involves diagnosing a current state and readiness to learn and then providing appropriate, flexible responses as scaffolding. In this study the MEs always followed the same strategy (of asking "do you know how to operate the exhibit?"). This tendency to follow structured pedagogy has also been observed in outdoor learning settings among environmental educators, who tend to follow the single instructional strategy of describing and explaining what is seen in the environment, rather than varied facilitation strategies that involve observation and exploration (Lavie Alon & Tal, 2017). This kind of instruction might result from the fact that shifting from being a didactic source of information to being a mediator, who listens, observes and then responds strategically, is no simple task for museum educators (Ash & Lombana, 2012; Tran & King, 2007). In addition, relying on the strategy of delivering content knowledge often has poor results (Ash & Lombana, 2012), which may cause MEs to try and avoid it based on past experience. Further study is required to really understand the reasons that MEs choose to limit themselves largely to such technical roles. This may be due, for instance, to a lack of appropriate professional development, or to insecurity regarding the actual science behind the exhibits.

These last two possibilities raise questions regarding the quality of mediation being offered here. Studies that employ a sociocultural perspective agree that the basic instruction of technical operation is a form of mediation (or scaffolding). But a more in-depth view of the theory reveals conflict between researchers—is explaining how to operate an exhibit in the same manner to all students really mediating? We claim that this might be looked at as a gradation in the *quality* of mediation. Our observations suggest that the MEs are trying to assume a mediator's role, but that they simply do not have the necessary skills to elevate it beyond the universal to a more situationally adapted form of mediation. The case of "noticing and responding" (Ash & Lombana, 2012) as a model for quality mediation remains elusive to the MEs in our study. In the interactions we observed, they did not attempt the strategy of looking at an interaction to evaluate its current state (noticing) and then performing a mediation that is custom made to the situation (responding).

5.2 | Facilitation strategies

So far we have seen that the majority of the interactions that take place between the ME and the students around exhibits consist of a technical explanation of the exhibit operation, and rarely include a scientific explanation of the phenomenon. To examine those interactions that did proceed further and move past the technical explanation, we used discourse microanalysis to identify the different roles that the MEs play in these interactions, and the practices they use when doing so. Other studies claim that MEs need to create opportunities for learners to engage with the objects and content for as long as they want by building understanding and inspiration to visit again, or to visit other related institutions (Tran & King, 2011). They claim that mediators must act as a responsive human presence trained to provide the support and information that visitors need to interact comfortably with the exhibits (Nyhof-Young, 1996). Our research revealed that MEs do indeed use some facilitation strategies, primarily physical instruction and engaging the students emotionally. We will elaborate on these practices further.

5.2.1 | Emotional engagement

A lot has been said about the role of emotional engagement in learning, especially in an informal context (Adams & Gupta, 2017; Bamberger & Tal, 2008; Eshach, 2007), most particularly regarding the significant role of the latter in forming positive attitudes toward science. Our observations showed first-hand that the MEs are sensitive to the students' emotional response to the learning environment, and that they use this to draw upon the students' own intrinsic motivation to learn (Tran & King, 2011).

The ME "detects" the students' enthusiasm, excitement, amazement, joy, etc. and nurtures it by being enthusiastic herself, expressing enjoyment and so forth. In addition, when students lack that excitement, the ME attempts to "generate" it. The ME thus harnesses the students' emotions (whether they originated in the student or in the ME) to keep them engaged in the exhibit, and perhaps make them more willing to hear a scientific explanation (though the ME does not persist in offering one).

Rogoff (2003) suggests that members of a community are characterized by the sharing of a common perspective. Thus, for instance, there is a common agreement in the scientific community that science is exciting and interesting. Earlier research on this museum's pedagogical staff suggests that MEs share that notion, and that conveying it to visitors is one of their primary goals (Shaby, Assaraf, & Tishler, 2016). This might explain the MEs' effort to elicit these sorts of emotions from students—towards exhibits and/or scientific phenomena in them.

This kind of instruction is important because studies show that "activity emotions" (like the ones we see here) are likely to generate motivational outcomes, such as situational interest and situational competence in science (Itzek-Greulich & Vollmer, 2016). Martin et al. (2016), for instance, demonstrated how emotional elements in the environment lead to emotional engagement during the visit, and how this is linked to emotional outcomes of self efficacy, values and aspirations in science. We therefore second their recommendation that emotional engagement should be taken into consideration when developing informal learning material (Martin et al., 2016).

5.2.2 | Physical instruction

Research done on ME instruction in museums has not (yet) described the kind of physical instruction we found in our study. We wish to state that the reason we find the MEs' actions noteworthy in this specific context is that-other than in the exhibition halls—we did *not* observe it in the other settings in the museum. In the lab activity, for instance, MEs did not touch the models on the students' tables while they were working in order to demonstrate what to do (as they did with the exhibits) nor did they move students around to improve their understanding of how to balance a model of a scale (again, as they did with the exhibits).

Other studies on informal settings have reported this sort of engagement in mediated interactions (not necessarily with formal educators). For example, Zimmerman and McClain (2016), who explored family learning in the outdoors, described the use of physical movements and body arrangements to support science learning, noting that this was a facilitation strategy previously unreported in the literature on informal science education. Their analysis showed how the adults physically adjusted the positions of children, re-arranging the young learner's bodily orientation and using other forms of physical touch and movement in order to guide their participation (Zimmerman & McClain, 2016). Another example drawn from the field of amateur astronomers refers to physical instruction as part of embodied cognition (Azevedo & Mann, 2017). In that study, the in-action practices of amateur astronomers were documented and investigated to show how physical instruction comes into play in celestial observation. The instructor in that case used pointing and finger movements to demonstrate, as well as moving learners' body parts—raising their head and positioning them in the right place. In our study we also observed the ME moving the students to the right place, touching them on the shoulder, pointing at different parts of the exhibit and demonstrating the operation through various other physical means.

Those studies and our own findings correspond to Vygotsky's (1978) notion of imitation. Vygotsky claims that a full understanding of the concept of ZPD must result in reevaluation of the role of imitation in learning (p. 88). Imitation is a form of mediation provided by adults to children. Here we see that the ME physically shows the students what to do, in a non-verbal way. In many cases the students imitated the ME's facilitation and "copied" what she had done. In a physical environment like a science museum, imitation seems to be a useful means of helping students understand exhibit operations.

In the spirit of these other studies, this line of instruction should be investigated further in science museums, especially due to the positive outcomes reported in those studies regarding the impact of this type of instruction and the physical nature of the environment itself. Other models, such as the contextual model (Falk & Dierking, 1992) and sociocultural perspectives emphasize the development of meaningful interactions mediated by physical context (Rowe & Kisiel, 2012). However, these refer mainly to the physical elements of the environment itself and not to physical elements in the instruction, although the museum setting promotes this kind of instruction.

If such instruction is pursued, it is worth noting that physical contact between teachers and students is a strategy that may require a particular sensitivity to the social norms and cultural context of the environment in which it is to be employed. In Israel, casual physical contact of the type we observed is considered entirely appropriate between students of that age and a teacher (or, in this case, a museum educator). However, since not all cultures are similar in their perception of appropriate contact, any adoption of these strategies would naturally need to be sensitive to MEs' and visitors' particular sensibilities.

6 | IMPLICATIONS AND CONTRIBUTION OF THE STUDY

As an institution, the museum that employs museum educators should carefully design their professional development, taking into account their educational role and expected practice. Consequently, this study works toward the goal of what Tran (2007) called "helping the helpers," by exploring what the educators do. A theoretical understanding of different practices in science museum interactions can help educators to improve the design of school visits to museums, making them more efficient (Eshach, 2007) and maximizing visiting students' experiences and gains (Tran, 2007).

Future research is still required to explore MEs' practices during interactions with students around exhibits. Based on our findings, however, we can make some tentative suggestions regarding ME instruction, professional development courses for museum staff and also guidelines for exhibit designers. First, educators should exploit the physical nature of the environment and make use of physical instruction. Exhibit designers should take this under consideration as well and provide space for this kind of instruction. Second, following Martin et al. (2016), we recommend that the role of emotional engagement should be considered and addressed when developing informal learning material. Furthermore, the ME should reinforce it during instruction and promote emotional engagement during the activity. These practices are derived from educational theories about learning with which MEs should be made familiar, so they can make use of them during facilitation.

In addition to these suggestions, however, we must also note the limitation of our study. Our study participants come from a "non-participant" background, as did the MEs that work in that museum. This factor may well have influenced the short duration of the MEs' interactions (less than a minute) with the students around the exhibit. In this study we did not conduct comparisons with other participants (students or educators) either in that museum or in other museums. Therefore, we can only assume what the reasons for the tendency towards short, technical instruction may be. We believe, for instance, that it might result from the MEs' low expectations of the students, leading them to instruct them in a way they feel they will understand. Alternatively, it may also be the result of the MEs' own lack of confidence in their knowledge of the scientific principles underlying the exhibits. The reason that we can only assume this is due to the fact that our data is based only on observations. We recommend further research that includes reflective interviews with MEs to gain understanding of the reasons that may underlie their choice of instruction strategies.

Another aspect in which our study is limited is the fact that we captured all sorts of interactions, engagements, facilitation, etc., but only emphasized the few that relate to our specific research questions. Other aspects (e.g., the content and efficacy of the scientific explanations that the MEs provided in the relatively few interactions that progressed that far) could also merit further exploration.

ACKNOWLEDGMENTS

We gratefully acknowledge Dana Vedder-Weiss for productive discussions and thoughtful comments during the analysis stages of this work, along with three other anonymous researchers.

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How to cite this article: Shaby N, Ben-Zvi Assaraf O, Tal T. An examination of the interactions between museum educators and students on a school visit to science museum. *J Res Sci Teach.* 2019;56:211–239. https://doi.org/10.1002/tea.21476