Journal of Museum Education

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/rjme20

"It Was Just Amazing!" Unstructured Interactions Following a Planetarium and Science Shows

Neta Shaby, Ran Peleg, Ian Coombs & Jackson Hemming

To cite this article: Neta Shaby, Ran Peleg, Ian Coombs & Jackson Hemming (12 Feb 2025): "It Was Just Amazing!" Unstructured Interactions Following a Planetarium and Science Shows, Journal of Museum Education, DOI: 10.1080/10598650.2025.2461846

To link to this article: https://doi.org/10.1080/10598650.2025.2461846

Published online: 12 Feb 2025.

JOURNAL OF MUSEUM EDUCATION
https://doi.org/10.1080/10598650.2025.2461846

Routledge
Taylor & Francis Group

OPEN ACCESS

"It Was Just Amazing!" Unstructured Interactions Following a Planetarium and Science Shows

Neta Shaby, Ran Peleg, Ian Coombs and Jackson Hemming

ABSTRACT
Visits to informal learning environments such as science centers can enhance curiosity and understanding of scientific concepts. These environments offer activities like science and planetarium shows to engage their audiences. One way to understand visitors' experiences in these environments is to investigate interactions. Previous research primarily focused on structured interactions such as guided tours, leaving the exploration of spontaneous, unstructured interactions understudied. In this research, museum practitioners audio-recorded unstructured interactions following science and planetarium shows during free-choice visits to a science center. Thematic analysis showed that although interaction time was short, it was positive and inquisitive in nature. Most questions were related to the content of the show and asked by children, with emotional reactions more prominent after the planetarium show. This exploratory pilot research adds to the body of knowledge on unstructured interactions between visitors and science center staff members, contributing to the understanding of effective science communication.

ARTICLE HISTORY
Received 10 September 2024
Revised 27 January 2025
Accepted 29 January 2025

KEYWORDS
Science centers; interactions; science shows; planetarium; qualitative research

Introduction

Informal learning environments such as science centers and museums play a pivotal role in fostering curiosity and understanding of scientific concepts among visitors of all ages.[1] In addition to the exhibitions, these venues offer activities such as science and planetarium shows that aim to engage audiences in immersive and educational experiences.[2] Previous studies investigated interactions between staff and visitors, highlighting their brevity and variability.[3] Structured interactions that are planned in advance, such as guided tours and educational programs, have been studied extensively revealing their positive impact on visitor satisfaction, knowledge acquisition, and inquiry behavior. However, the exploration of unstructured interactions, characterized by spontaneous conversations and engagements, remains relatively scarce in the literature.[4]

Science shows and planetarium shows serve as integral components of informal learning experiences, offering engaging narratives and immersive visualizations to audiences. Science shows, characterized by dramatic demonstrations and interactive elements, aim to communicate scientific concepts while fostering curiosity and engagement.[5] Similarly, planetarium shows combine entertainment and education, offering audiences a journey through celestial phenomena and astronomical concepts.[6] Despite the prevalence of these shows in informal learning settings, research has predominantly focused on measuring changes in knowledge and attitudes, overlooking the interactions before and after the shows. Understanding these interactions might include valuable information that can shed light on museum practitioners' instruction and inform their future practice.

This research aims to address these gaps by focusing on unstructured interactions that follow a science and a planetarium show within the context of free-choice visits to a science center. The research provides insights into visitor-staff engagement and a deeper understanding of its characteristics and implications for effective science communication. It also describes the method, a potential unique "easy to use" data collecting method for practitioners. In the following sections, we review the literature on interactions in informal environments followed by a review of the literature on science and planetarium shows.

Literature review

Structured and unstructured interactions in informal environments

In efforts to understand visitors' experiences in informal settings like science centers and museums, early research primarily used pre- and post-visit methodologies, such as exploring attitudes, prior knowledge, motivation and interest, before the visit and after the visit,[7] with most studies on science shows fitting this model. Some of the limitations of these approaches emerge from their misalignment with learning goals, ignoring visitors' own agency, inability to distinguish between factors emerging from the visit itself or from everyday life, and so on. Recognizing these limitations prompted research to focus on the relationship between learning outcomes and specific museum features and activities.[8] To explore these relationships, recent studies have shifted focus to the interactions occurring during the visit within these environments.[9]

Research on interactions in museums and science centers falls into three non-mutually-exclusive types: interactions between visitors, interactions between visitors and staff and interactions between visitors and exhibits.[10] In this study, we focus on interactions between visitors and staff. Scott Pattison and Lynn Dierking explored interactions in science center and further divided interactions between staff and visitors into two types.[11] *Structured* interactions are those that take place in predetermined settings such as museum tours, science shows, or educational programs. *Unstructured* interactions are those that are not pre-determined such as unscripted conversations between staff and visitors at an activity or exhibit. As such our study focuses on unstructured conversations that follow a science show or planetarium show (i.e. following structured interactions of the shows themselves).

Most research on interactions focus on structured interactions and show that visitors have positive feelings about engaging with staff, that the presence of staff can increase visitor satisfaction, the time spent at exhibits, and support knowledge acquisition and inquiry behavior.[12] Other studies on structured interactions demonstrate negative impacts such as staff interfering with visitors and staff using didactic strategies reminiscent of classroom instruction.[13]

Research on unstructured interactions is less common. Preethi Mony and Joe Heimlich examined how zoo docents (educational staff and volunteers) communicate conservation messages to visitors.[14] The study used observations of and interviews with docents and visitors to reveal that interactions were normally short (averaging just over a minute), with the length of interaction contingent on several variables including the day of the week, the location of the interaction, the group composition (with adult only groups having longer interactions) and the initiator of the interaction (with interactions started by staff lasting longer). Scott Pattison and Lynn Dierking studied unstructured staff-family interactions in a science and industry museum by inductively analyzing video recordings of the visits.[15] Whilst most interactions were initiated by staff, adult family members were essential in fostering and prolonging these interactions.

Neta Shaby, Orit Ben-Zvi Assaraf and Tali Tal investigated the interactions that took place during a fieldtrip of elementary school students to a science center by video-recording the visits.[16] Their study found that interactions between museum educators and students mainly consisted of technical explanations of how to operate the exhibits. This research, however, explored interactions that were initiated by the museum educators and not the students.

Science shows

Science shows aim to teach content knowledge and/or engage their audience with science by using dramatic techniques often while conducting scientific demonstrations.[17] At the heart of the science show are demonstrations that aim to illustrate an idea by means other than conventional visual-aid apparatus and can include an experiment or an analogy of a scientific phenomenon demonstrated by the use of physical props.[18] They are ubiquitous in virtually all science centers and science museums that use them to supplement their exhibitions and enrich the visitor experience while also catering to repeat visitors.[19] Many shows are no longer led by scientists, as they tend to incorporate many elements from drama and public speaking and thus need their presenters to master skills such as acting, storytelling, depiction of characters and the enactment of historical scenes.

Most research into science shows has focused on measuring changes in visitor knowledge and attitudes toward science. Most studies found an increase in knowledge following the show and favorable attitudes both towards the experience and science.[20] One study by Wendy Sadler aimed to identify which characteristics of science demonstrations had the greatest impact in the short and long term, by focusing on a show on the physics of sound.[21] The study triangulated short-term questionnaire data, short-term focus group data and long-term focus group data, to reveal that science show demonstrations that foster curiosity, are novel, counter-intuitive or involve a challenge, are remembered the best. A further study on a show about the physics of sound highlighted the importance of cultural differences of the audience.[22] The study found that urban students in South Africa significantly improved their knowledge scores in pre- and post-tests, whilst rural students though enjoying the show, found it difficult to understand and subsequently scored less well on the post-tests.

Studies on science shows have thus far used questionnaire data, interview data or a mixture thereof.[23] One study included an analysis of children's drawings in addition to questionnaire and interview data.[24] The current study introduces a new method of researching science shows.

Planetarium shows

The night sky has always fascinated humans and this has driven the creation of planetariums as a way to depict and understand the night sky.[25] Today's modern planetariums provide visitors with immersive visualizations through the use of digital ultra-high-definition projectors which make it possible to observe astronomical phenomena not only from a geocentric perspective (looking from the earth outwards) but also from an allocentric perspective (taking views from different starting points) such as from the moon looking towards earth, or from Uranus looking towards the Sun.[26]

Planetarium shows today serve two main purposes: to entertain and to educate.[27] From an entertainment point of view, planetarium shows often have narrative journeys leading visitors through stories about stars and space exploration using either pre-recorded audio tracks or live commentary to support the visual images projected.[28] From an educational perspective, planetariums main affordances are the acquaintance with celestial bodies, the facilitation of understanding of scales that are outside regular human experience and the development of a three-dimensional conceptualization of the motion of celestial objects.[29]

Research has mainly focused on planetarium shows within science centers or museums (rather than inflatable domes) and in the context of fieldtrips. Understanding the solar system, the moon and the reasons for its changing appearance in the sky is part of the formal curriculum in many countries, and teachers often organize fieldtrips to planetariums in support of these curricular aims.[30] It appears that such fieldtrips are most impactful when the visit to the planetarium is supported both before and after with discussions in the classroom.[31] Additionally, it was found that inviting children to participate in kinaesthetic activities during a planetarium show enhances their learning and understanding. For example, encouraging children to point and gesture along the trajectory of the sun across the sky in a planetarium show has been shown to lead to significant learning gains.[32]

Although scarce, research on free-choice visitors to planetarium shows indicates gains in understanding astronomy regardless of the visitor's motivation for visiting the planetarium, or previous interest in the subject.[33] Yet not all family-based free-choice visits to planetariums may be as impactful as science center intend, with visitors sometimes not picking up on important overarching themes presented in planetarium shows.[34] Most studies on planetarium shows focus on learning outcomes. Interactions within and after a planetarium show have received little research attention. Therefore, in this research, we ask the following research question: What characterizes the interactions between visitors and explainers after a science and a planetarium show?

The current study is unique in that it uses a research method novel to science and planetarium shows by focusing on unstructured interactions between museum staff and visitors. Additionally, we offer a new easy to use tool that can capture the interactions and can be used by museum practitioners. By shedding light on this overlooked aspect of visitor experiences, this study has the potential to enrich museum education research and practice, by providing both insights from the pilot research and using tool to capture the conversations.

Methods

This study was part of research-practice partnership project between university researchers and practitioners from a science center in the UK (note – practitioners/explainers in this science center refer to themselves as *inspirers*). In this qualitative investigation, inspirers collected data using audio recorders and analyzed the unstructured interactions after science and planetarium shows, aiming to uncover the themes that emerge from these interactions. This research emerged from the practitioners' own interest in their practice. They believed that capturing the conversations after the shows could benefit their practice and provide evidence of its impact. The suggested tool provides a more rigorous way to capture interactions and analyze them, compared to relying on memory alone.

Settings and participants

This study took place at the Winchester Science Centre in Winchester, UK. The science center is run by a not-for-profit charity "called Wonderseekers" which has been sparking children's curiosity in science, technology, engineering and mathematics since its founding in 1986. Each year the center hosts 130,000 visitors and an additional 45,000 primary school children who visit as part of school field trips. This research focused on unstructured interactions following two activities that took place in the center, specifically the "Flower Power" science show and the "Solar System Quest" planetarium show. The participants of this research were family visitors who attended either of the shows and approached the inspirers afterwards to engage in conversation.

Science show – Flower Power

This show took place at the "Science Theatre" space, which is a dedicated close theater area with a stage and chairs. The show can be attended at no extra fee. "Flower Power" explains the different mechanisms plants and flowers use to attract pollinators. For example, petal patterns that are only visible to insects were depicted through the use of ultraviolet light projected onto large artificial flowers. Another demonstration discussed how mild static electric charges on plants and insects encourage pollen to "stick" to visiting insects. This was explained using a demonstration of a Van de Graaf Generator. The show concluded with ballistic seed dispersal being illustrated through a device that used compressed air to fire socks into the air.

Planetarium show – Solar System Quest

Planetarium shows at the science center are offered at an additional fee and presented in a dedicated dome-shaped structure using digital projection. The live-event planetarium show lasted around 30 minutes, and the audio commentary was provided live by one of the inspirers. The inspirer was either standing on a stage directly in front of the audience or at the back of the dome behind the audience. The show focuses on celestial bodies in the solar system, including the introduction of the names and composition of each of the planets, and describing dwarf planets, including the demotion of Pluto from a planet to a dwarf planet. The show then looked beyond the solar system into the far reaches of space, introducing the constellations and some bright stars found in the night sky. After each of the shows, the inspirers stood at the exit door of the dome and visitors were encouraged to ask the inspirers questions.

Data collection and analysis

Data collection took place during two weekends in April. All visitors were informed at the entrance that research was being conducted in various areas of the center and encouraged to look for signs and ask staff members for more information. According to ethical approval received by the university's ethics committee, at the beginning of each show the inspirer informed the audience that any interaction at the end of the show will be audio recorded, however, if they wish not to be recorded, they should inform the inspirer who will stop the recording. This was also reiterated at the end of the show. No personal information was collected, which made the data anonymous. All inspirers recorded the conversations with visitors after the show, resulting in approximately 3 hours of audio recordings. After data reduction, which included eliminating corrupted files and poor audio quality, we had 1 hour, 11 minutes and 41 seconds of audio recordings to analyze. The audio recordings were transcribed using transcription software followed by a manual check by one of the researchers. The software recognized participants' voices in close proximity and attributed utterances to a speaker. One of the researchers then distinguished whether the speaker was an adult or child (this was based on voices only; we acknowledge that there might be some margin of error in researcher assumptions, but we believe this is kept to a minimum by interpreting the tone of voice, language and roles in the conversation). This process labelled participants in the transcription as adult 1, 2, 3 and child 1, 2, 3, and so on. If, however, a visitor asked a question and came back after a while, it would be nearly impossible to recognize them as the same person and they would transcribe them as new participants. Additionally, we do not have any information on the number of visitors attending each show: therefore, we analyzed the data according to interactions and not by visitors. Our unit of analysis (e.g. interaction) was a conversation that had a clear beginning and end. We excluded all general greetings from the analysis (e.g. "Thank you"). We analyzed the data using thematic analysis, following Virginia Braun and Victoria Clark's phases of thematic analysis. In the first phase, three researchers and four practitioners engaged in initial coding and brainstorming while reading the transcripts together and creating memos.[35] During that stage, a decision was made to create general themes emerging from the data, dividing the interactions into two types: one question/one answer interactions and a fuller dialogue. Also, it was decided to record the topics of the interactions (e.g. planets, moons, pigments, etc.). In the second stage, each science show was coded individually by a team of two practitioners and then reviewed by two researchers. Then, a list of codes was formed and grouped into themes. To ensure credibility, everyone involved in the analysis went through the process of "peer debriefing." For transferability purposes, we offer thick descriptions of the data.[36]

Table 1. Example of analysis – visitors-inspirer conversations.

Transcript	Types of visitors' utterances	Types of themes (questions and statements)
Adult 2 [00:00:40] [Name of child] has a question for you.	Encouragement by adult	
Child 3 [00:00:40] How many galaxies are there?	Question – Child	Related to content from the show
Inspirer [00:00:42] How many galaxies are there? So our current estimate, the best we can do is around 200 billion. [...] Do you see those that ... there might be ... a black [indistinct] were there was just nothing as we going around. And that's because our Milky Way kind of gets in the way. We can't.	Question answered by inspirer	
...	Unrelated conversation – not coded	
Child 3 [00:02:04] How many, are there any other like planets except for our planets in our solar system?.	Question – Child	Related to topic but not the show
Inspirer [00:02:13] So those are the only planets. The other ones, the exoplanets, they're basically planets. [...]. They're essentially the same thing we found.	Question answered by inspirer	
Child 3 [00:02:36] What color are they?	Question – Child	Related to topic but not the show
Inspirer [00:02:36] Well, there's lots of them. So we think there's one group of planets, exoplanets is called Super Earths and they like earth, they've got water and they're just super big, so they're a lot bigger than us. Another, there's other groups of planets that are and there's another group called Little Neptunes, which are like small little blue worlds that are like Neptune, but not as big.	Question answered by inspirer	
Adult 2 [00:02:57] Oh that's fun.	Statement – Adult	Emotional response

Findings

Overall, the nine Planetarium shows inspirers recorded interactions with a total time of 32 minutes and 50 seconds, averaging at 3 minutes and 20 seconds per interaction. Of the entire dataset, 73% of the conversation time (24 minutes and 7 s) with inspirers after a planetarium show included some science content. Overall, for the fifteen Flower Power shows we recorded interactions with a total time of 38 minutes and 51 seconds, an average of 2 minutes and 38 seconds for each interaction. Of the entire dataset, 77% of the conversation time (29 minutes and 55 seconds) with inspirers after the Flower Power show included science content.

We performed three general analyses on this reduced dataset for both shows: (1) First the types of visitors' utterances were coded for questions, statements or encouragements. (2) Then we searched for themes that emerged from the questions and statements. Encouragements were not coded because they did not contain scientific content. (3) Finally, we counted how many questions the inspirers were able to answer successfully.

The transcript in Table 1 illustrates the two types of analyses performed.

(1) Types of visitors' utterances

The number of questions, statements, and encouragement that visitors asked the inspirers are shown in Table 2. We differentiate between those originating from children and from adults.

Table 2 indicates that children asked more questions than adults for both shows. Statements were more prominent after the Planetarium show, although adults did not make

Table 2. Interactions with inspirers after science shows.

Type of interaction	Planetarium		Flower Power	
Question – Child	41	52	26	35
Question – Adult	11		9	
Statement – Child	7	19	8	8
Statement – Adult	12		0	
Total of Questions and Statements	**71**		**43**	
Encouragements – Adult	17		1	
Total of utterances	**88**		**44**	

any statements in our recorded dataset after the Flower Power show. In total, the Planetarium show elicited more questions and statements. Additionally, more encouragements from adults were recorded after that show.

(2) Themes that emerged from the questions and statements

Figure 1 illustrates the themes that emerged from the analysis of utterances from both shows.

While coding both the questions and the statements, we saw that visitors were mainly seeking additional information about the content of the show (19 utterances for the Flower Power and 47 utterances for the Planetarium for the theme "Related to the content from the show"). Some questions or statements were directly connected to the information presented in the show, for example: "How many galaxies are there?", "Why is it called the Milky Way?", "What if the specific flower can't pollinate at all what would happen to the flower?" and "Are there any different species of pollinators?." Some visitors were asking for clarification about content mentioned in the show, such as: "What's that constellation that's a saucepan called again?", "Is Pluto a planet again?", "How are plants negatively charged?" and "What's it called again, ballistic something?"

Some of the information seeking is related to the topic (planets or flowers), but does not necessarily appear in the show (17 utterances for the Flower Power and 9 utterances for the Planetarium for the theme "related to the topic but not the show"), such as: "Do

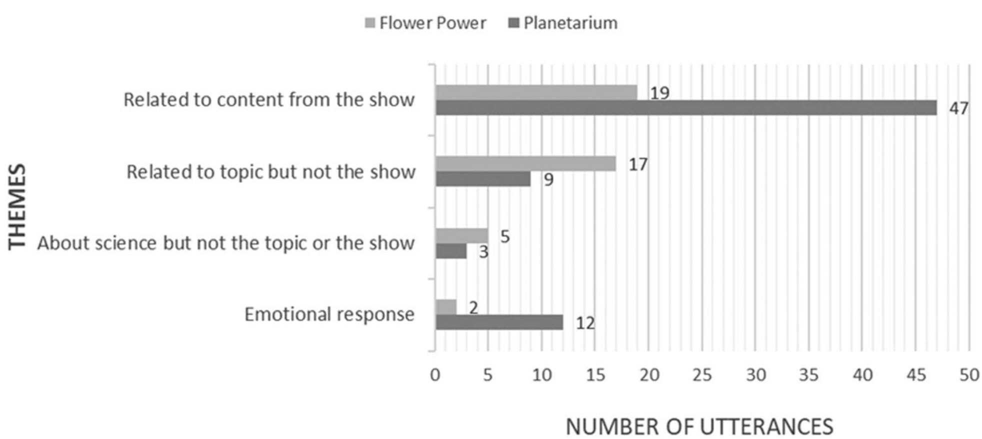

Figure 1. Number of themes from utterances with inspirers after the shows.

you think it's possible that the, ummm, that there's life on other planets?" and "Do you think any organism could live on another planet, like, for example, if like a caterpillar decided to live on another planet do you think it would survive?."

Some visitors asked general questions about science (8 utterances from both shows), for example: "How did the dinosaurs grow?"

Some of the visitors had emotional reactions to the show that they expressed while they were leaving: "It was just amazing, thank you very much", and some had emotional responses relating to the conversation they had with the inspirer: "Well, I see. I'm fascinated. Yeah. It's fascinating, isn't it?" This was more prominent in the Planetarium than the Flower Power show.

Common topics asked by visitors after the Planetarium show were about the celestial bodies in our solar system, specifically Pluto, dwarf planets, galaxies and stars, moons and constellations. The common topics asked by visitors after the Flower Power show were related to the science topic, Ladybirds, bees and pollinators, second, were questions about the props used to demonstrate scientific concepts, such as the Van de Graff Generator.

(3) Questions the inspirers were able to answer successfully

As mentioned, we also counted the number of questions that the inspirers were able to answer successfully. Of the 52 questions asked (by adults and children) after the Planetarium, 87% of them were answered by the inspirer. Some of the questions that were not answered posed difficulties, such as: "How far away is the Andromeda Galaxy?", "Which is the biggest of dwarf planet?", and "Why is Earth called Earth?." In the example below, we see a response of an inspirer to a difficult question they were asked and the way the inspirer found a way to answer it:

Child 2 [00:01:03]	I have got a question. What does NASA stand for?
Inspirer [00:01:10]	Oh dear. You know what? I'm going to look it up for you because I should know this, but I don't.
Child 2 [00:01:14]	[Indistinct].
Inspirer [00:01:15]	You know, it's a good question. I feel like I should know this. Let's see. What is NASA's stand for? Can I do a quick Google? National Aeronautics and Space Administration. There you go.

Of the 35 questions asked after the Flower Power show, 83% of them were answered by the inspirer. Most of the questions that were not answered were on why flowers are colorful, a topic that is not covered in the show, but seems to interest visitors. Usually, the inspirer indicated that this topic is complicated and suggested the questioner to find out more online.

To conclude, these findings indicate that the nature of the unstructured interactions tends to be exploratory; the interactions consisted mainly of questions rather than statements and stemmed mainly from children (and not adults). Questions are more aligned with the content of the show in the planetarium, but in the science show, questions relate to broader aspects of the topic (flowers) and science in general. Additionally, the science show elicited more dialogue (54%) than the planetarium (33%). Overall, inspirers were able to answer most of the questions asked by visitors. These findings will be discussed in the next section.

Discussion, recommendations, and limitations

This research adds to the body of knowledge on unstructured interactions between visitors and science center staff members, initiated by free-choice visitors after science and planetarium shows. This research also used a data collection method that is easy to use and can be duplicated by other practitioners in different settings. Our findings illustrate that although interaction time was relatively short, it was positive and inquisitive in nature. Additionally, most questions were related to the content of the show and asked by children, with emotional reactions more prominent after the planetarium.

The nature of interactions recorded in this research were generally positive, driven by visitors' own personal curiosity and interest, as found in previous research.[37] Additionally, the interactions were mostly based on providing factual knowledge, similar to what others have found.[38] This highlights the significance of the initiator of the unstructured interactions; most of the unstructured interactions were initiated by the visitors. This can elicit beneficial conversations and contribute to effective science communication, in contrast to interactions initiated by staff members.[39] The specific physical settings allow children to ask more questions, guided by previous knowledge and personal interest. This type of interaction is supported by the Contextual Model for Learning in museums, which highlights the importance of the personal context in the learning process.[40] The fact that children ask more questions than adults is interesting, maybe indicating inherent characteristics for children's interactions and situated interest in the topic that can be attributed more to children. Another explanation might be that science centers are usually more directed at children, thus, prompting more questions from them. It will be interesting to explore the same centre during adult-focused night events to compare adults' questions in the same settings.

Generally, visitors ask questions that are related to the shows' content. This suggests that the shows inspired further engagement. However, we see a difference between the shows, with the Flower Power show generating more questions about the broader topic of pollination and insects. This might be due to the relatability of this topic compared to space, and more everyday concrete experiences that children can refer to. This might be related to the perceived authenticity of this topic and the ability to view something more concrete, as was found by Tirsa de Kluis, Sanne Romp, and Anne Land-Zandstra.[41] The reason could be related to personal interest but also the physical space where it occurs. As the exit from the planetarium show is through a corridor, and the science show is in a larger space, visitors might feel rushed to leave the hall and not stay and be involved with further conversations. Additionally, sometimes while exiting the planetarium, the line to the next show is already forming, creating a less welcoming space for prolonged dialogue. Although visitors asked more questions after the Flower Power show, more emotions were expressed after the Planetarium show. This could be attributed to the fact that visitors pay an additional fee to attend the show, thus indicating a previous interest and potential fascination with space.

This research was driven by the practitioners' interest to inform their practice. An easy-to-use data collection method was integral to the research design, as it enabled the practitioners themselves to collect the data, and in the future use it again to explore additional areas. This pilot study sheds light on unstructured interactions between visitors and staff after shows and can inform the science center's future practice.

First, the types of questions and topics that visitors are interested in can help develop new shows. Second, the content of the questions can be used for training purposes. In a separate study, we investigated the process of conducting research with inspirers in a participatory manner. The findings of that research showed that having been part of the data collection and analysis fostered a feeling of excitement and self-efficacy amongst the inspirers.[42] The findings of that study together with the findings emerging in this study highlight the importance of front-line facilitators to be given the space (mental and physical), the time, and the support to develop their practice and knowledge base. This can help motivate inspirers about the significance of their responsibilities. Although inspirers were able to answer most of the questions, addressing the unanswered questions collectively can support all inspirers and promote the general knowledge transfer and the way it is communicated to visitors. Third, the science center might consider the physical space where the unstructured interactions take place to create a more welcoming setting that can elicit and promote dialogic conversations. Moreover, inspirers can dedicate time for questions in the show's space, to create a welcoming physical space and allocate time to this type of science communication.

Future research might address some of the limitations of the current research. As we did not have information on the number of visitors attending each show, the conclusions are limited as we do not know what percentages of the visitors actually engaged with the inspirers. Additionally, only visitors who were willing to ask questions were the sample of this research, making it hard to make inferences about the effective science communication of the shows.

Notes

1. Falk, Storksdieck, and Dierking, "Investigating Public Science Interest."
2. Austin and Sullivan, "How Are We Performing?"
3. Davidsson and Jakobsson, *Understanding Interactions at Science Centers*.
4. Pattison and Dierking, "Staff-Mediated Learning in Museums."
5. Austin and Sullivan, "How Are We Performing?"
6. Petersen, "The Birth and Evolution of the Planetarium."
7. Davidsson and Jakobsson, *Understanding Interactions at Science Centers*.
8. Anderson, "A Reflective Hermeneutic Approach to Research"; Davidsson and Jakobsson, *Understanding Interactions at Science Centers*.
9. Ash, Lombana, and Alcala, "Changing Practices, Changing Identities"; Davidsson and Jakobsson, *Understanding Interactions at Science Centers*; Pattison and Dierking, "Staff-Mediated Learning in Museums"; Authors, "."
10. Davidsson and Jakobsson, *Understanding Interactions at Science Centers*.
11. Pattison and Dierking, "Staff-Mediated Learning in Museums."
12. Ibid.
13. Ibid.
14. Mony and Heimlich, "Talking to Visitors about Conservation."
15. Pattison and Dierking, "Staff-Mediated Learning in Museums."
16. Shaby, Ben-Zvi Assaraf, and Tal, "An examination of the interactions between museum educators."
17. Austin and Sullivan, "How Are We Performing?"; Peleg and Baram-Tsabari, " Atom Surprise"; Walker, "Motivational Features of Science Shows."
18. Austin and Sullivan; Taylor, 1988 in Walker, "Motivational Features of Science Shows."
19. Sadler, "Evaluating the Short-Term and Long-Term Impact of an Interactive Science Show."

20. e.g. Bell, "A Low-Cost High-Impact Computer Science"; Musacchio, Lanza, and D'Addezio, "An Experience of Science Theatre to Introduce Earth Interior"; Price et al., "Understanding the Effectiveness of Demonstration Programs"; Schechter, Priedeman, and Goodman, "The Amazing Nano Brothers Juggling Show."
21. Sadler, "Evaluating the Short-Term and Long-Term Impact."
22. Fish et al., "A Cross-Cultural Comparison of High School Students' Responses."
23. Fish et al., "A Cross-Cultural Comparison of High School Students' Responses to a Science Centre Show on the Physics of Sound in South Africa."; Lecky et al., "Using Interactive Family Science"; Musacchio, Lanza, and D'Addezio, "An Experience of Science Theatre"; Price et al., "Understanding the Effectiveness of Demonstration Programs"; Sadler, "Evaluating the Short-Term and Long-Term Impact"; Schechter, Priedeman, and Goodman, "The Amazing Nano Brothers Juggling Show"; Walker, "Motivational Features of Science Shows."
24. Carpineti et al., "Theatre to Motivate the Study of Physics."
25. Petersen, "The Birth and Evolution of the Planetarium."
26. Chastenay, "From Geocentrism to Allocentrism."
27. Petersen, "The Birth and Evolution of the Planetarium"; Petersen and Petersen, "The Role of the Planetarium."
28. Lantz, "Planetarium of the Future"; Wyatt, "Planetarium Paradigm Shift."
29. Brazell and Espinoza, "Meta-Analysis of Planetarium Efficacy Research"; Plummer and Small, "Using a Planetarium Fieldtrip to Engage."
30. Chastenay, "From Geocentrism to Allocentrism"; Hobson, Trundle, and Sackes, "Using a Planetarium Software Program"; Johnson and Majewska, "Formal, Non-Formal, and Informal Learning"; Plummer, Kocareli, and Slagle, "Learning to Explain Astronomy Across Moving"; Plummer and Small, "Using a Planetarium Fieldtrip to Engage"; Seyma and Unsal, "Planetariums as a Source of Outdoor Learning Environment."
31. Plummer and Small, "Using a Planetarium Fieldtrip to Engage."
32. Plummer, "Early Elementary Students' Development of Astronomy"; Plummer, Kocareli, and Slagle, "Learning to Explain Astronomy Across Moving."
33. Trucks et al., "How Interested Are Planetarium Visitors?"
34. Dusenbery and Morrow, "Making the Connection between Formal and Informal Learning."
35. Braun and Clarke. "Using Thematic Analysis in Psychology."
36. Lincoln and Guba, "Naturalistic Inquiry."
37. Pattison and Dierking, "Staff-Mediated Learning in Museums."
38. Kamolpattana et al., "Thai Visitors' Expectations and Experiences of Explainer Interaction."
39. Pattison and Dierking, "Staff-Mediated Learning in Museums"; Authors, "."
40. Falk and Dierking, *Learning from Museums*.
41. Kluis, Romp and Land-Zandstra, "Science Museum Educators' Views."
42. Shaby, Peleg, and Coombs, "Participatory Research with Museum Practitioners."

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by RE QR2022/23 Participatory Research Allocation. Ethics and Research Governance Online approval number 79451.A1.

About the authors

Neta Shaby is a Lecturer in Science Education at the Southampton Education School. She holds a BSc in Life Science, MA and PhD in Science Education. Neta's research focuses on Informal

Science Learning Environments, mainly Science Museums and learning within the family. As a Postdoctoral Scholar at Oregon State University, she contributed to a longitudinal research project focused on enhancing the STEM learning ecosystem for middle-school youth and their families. During her fellowship at Ben Gurion University of the Negev, she explored family learning across settings and time, following families of varying socio-economic backgrounds in informal contexts such as home, the beach, the zoo, and outdoor picnics.

Ran Peleg is a Lecturer in Science Education at the Southampton Education School. His research explores the design of informal learning environments, including museums and educational games. Dr. Peleg holds a BA in Natural Sciences and an MEng in Chemical Engineering from the University of Cambridge. He earned his PhD in Science Education from the Technion, where he focused on learning science in informal settings, particularly museum theatre. Dr. Peleg was a Fellow of the Mandel Scholars in Education program for distinguished PhD students and received a postdoctoral fellowship from the University of Haifa to develop computerized instructional tools for blind students.

Ian Coombs is a Research Assistant at the Southampton Education School. He earned a BEd in Secondary Geography, a MA in Educational Leadership, a MSc in Web Science, and an interdisciplinary PhD in Web Science and Education. His doctoral research focused on how young social media adopters conceptualize and engage with the technology. Prior to completing his PhD, he spent 30 years working in English secondary education and holds National Professional Qualification for Headship.

Jackson Hemming is a Curiosity Officer at Winchester Science Centre an educational attraction run by the charity Wonderseekers. In his capacity as a Curiosity Officer, he oversees the development and delivery of science content to school groups visiting the Centre. ***Jackson Hemming*** holds a BA in Primary Education from the University of Winchester. He was a key participant in the "Impact Measuring Toolkit project", a research-practice partnership project between The University of Southampton and the Winchester Science Centre.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

ORCID

Neta Shaby http://orcid.org/0000-0002-3788-6613
Ran Peleg http://orcid.org/0000-0002-9184-6030
Ian Coombs http://orcid.org/0000-0001-6618-5843

Bibliography

Anderson, David. "A Reflective Hermeneutic Approach to Research Methods Investigating Visitor Learning." In *Putting Theory Into Practice*, edited by Doris Ash, Jrène Rahm, and Leah M. Melber, 15–25. Rotterdam: SensePublishers, 2012. doi:10.1007/978-94-6091-964-0_2.

Ash, Doris, Judith Lombana, and Lucia Alcala. "Changing Practices, Changing Identities as Museum Educators: From Didactic Telling to Scaffolding in the Zpd." In *Understanding Interactions at Science Centers and Museums*, edited by Eva Davidsson and Anders Jakobsson, 23–44. Rotterdam: SensePublishers, 2012. doi:10.1007/978-94-6091-725-7_3.

Austin, Shanii R. P., and Miriam Sullivan. "How Are We Performing? Evidence for the Value of Science Shows." *International Journal of Science Education, Part B* 9, no. 1 (2019): 1–12. doi:10.1080/21548455.2018.1532620.

Bell, T. “A Low-Cost High-Impact Computer Science Show for Family Audiences.” In *Proceedings 23rd Australasian Computer Science Conference. ACSC 2000 (Cat. No.PR00518)*, 10–16. Canberra, ACT, Australia: IEEE Comput. Soc, 1999. doi:10.1109/ACSC.2000.824374.

Braun, Virginia, and Victoria Clarke. “Using Thematic Analysis in Psychology.” *Qualitative Research in Psychology* 3, no. 2 (2006): 77–101. doi:10.1191/1478088706qp063oa.

Brazell, Bruce D., and Sue Espinoza. “Meta-Analysis of Planetarium Efficacy Research.” *Astronomy Education Review* 8, no. 1 (2009): 010108-1. doi:10.3847/AER2009033.

Carpineti, Marina, Michela Cavinato, Marco Giliberti, Nicola Ludwig, and Laura Perini. “Theatre to Motivate the Study of Physics.” *Journal of Science Communication* 10, no. 01 (2011): A01. doi:10.22323/2.10010201.

Chastenay, Pierre. “From Geocentrism to Allocentrism: Teaching the Phases of the Moon in a Digital Full-Dome Planetarium.” *Research in Science Education* 46, no. 1 (2016): 43–77. doi:10.1007/s11165-015-9460-3.

Davidsson, Eva, and Anders Jakobsson, eds. *Understanding Interactions at Science Centers and Museums: Approaching Sociocultural Perspectives*. Rotterdam: SensePublishers, 2012. doi:10.1007/978-94-6091-725-7.

Dusenbery, P. B., and C. A. Morrow. “Making the Connection Between Formal and Informal Learning.” *NASA Office of Space Science Education and Public Outreach Conference* 319 (2004): 275–277.

Falk, John H., and Lynn D. Dierking. *Learning from Museums*. 2nd ed. American Association for State and Local History Book Series. Lanham: Rowman & Littlefield, 2018.

Falk, John H., Martin Storksdieck, and Lynn D. Dierking. “Investigating Public Science Interest and Understanding: Evidence for the Importance of Free-Choice Learning.” *Public Understanding of Science* 16, no. 4 (2007): 455–469. doi:10.1177/0963662506064240.

Fish, Derek, Saalih Allie, Nancy Pelaez, and Trevor Anderson. “A Cross-Cultural Comparison of High School Students’ Responses to a Science Centre Show on the Physics of Sound in South Africa.” *Public Understanding of Science* 26, no. 7 (2017): 806–814. doi:10.1177/0963662516642725.

Hobson, Sally M., Kathy Cabe Trundle, and Mesut Sackes. “Using a Planetarium Software Program to Promote Conceptual Change with Young Children.” *Journal of Science Education and Technology* 19, no. 2 (2010): 165–176. doi:10.1007/s10956-009-9189-8.

Johnson, Martin, and Dominika Majewska. *Formal, Non-Formal, and Informal Learning: What Are They, and How Can We Research Them? Research Report*. Cambridge: Cambridge University Press & Assessment, 2022. https://eric.ed.gov/?id=ED626005.

Kamolpattana, Supara, Ganigar Chen, Pichai Sonchaeng, Clare Wilkinson, Neil Willey, and Karen Bultitude. “Thai Visitors’ Expectations and Experiences of Explainer Interaction within a Science Museum Context.” *Public Understanding of Science* 24, no. 1 (2015): 69–85. doi:10.1177/0963662514525560.

Kluis, Tirsa de, Sanne Romp, and Anne M. Land-Zandstra. “Science Museum Educators’ Views on Object-Based Learning: The Perceived Importance of Authenticity and Touch.” *Public Understanding of Science* 33, no. 3 (2024): 325–342. doi:10.1177/09636625231202617.

Lantz, Ed. “Planetarium of the Future: Planetarium of the Future.” *Curator: The Museum Journal* 54, no. 3 (2011): 293–312. doi:10.1111/j.2151-6952.2011.00093.x.

Lecky, Donna M., Meredith K. D. Hawking, Neville Q. Verlander, and Cliodna A. M. McNulty. “Using Interactive Family Science Shows to Improve Public Knowledge on Antibiotic Resistance: Does It Work?” Edited by Herminia De Lencastre. *PLoS One* 9, no. 8 (2014): e104556. doi:10.1371/journal.pone.0104556.

Lincoln, Yvonna Sessions, and Egon Guba. *Naturalistic Inquiry*. London: Sage Publications, 1985.

Mony, Preethi R. S., and Joe E. Heimlich. “Talking to Visitors about Conservation: Exploring Message Communication through Docent–Visitor Interactions at Zoos.” *Visitor Studies* 11, no. 2 (2008): 151–162. doi:10.1080/10645570802355513.

Musacchio, Gemma, Tiziana Lanza, and Giuliana D’Addezio. “An Experience of Science Theatre to Introduce Earth Interior and Natural Hazards to Children.” *Journal of Education and Learning* 4, no. 4 (2015): 80. doi:10.5539/jel.v4n4p80.

Pattison, Scott A., and Lynn D. Dierking. "Staff-Mediated Learning in Museums: A Social Interaction Perspective." *Visitor Studies* 16, no. 2 (2013): 117–143. doi:10.1080/10645578.2013.767731.

Peleg, Ran, and Ayelet Baram-Tsabari. "Atom Surprise: Using Theatre in Primary Science Education." *Journal of Science Education and Technology* 20 (2011): 508–524. doi:10.1007/s10956-011-9299-y.

Petersen, C. C. "The Birth and Evolution of the Planetarium." In *Information Handling in Astronomy – Historical Vistas*, edited by André Heck, 233–247. Dordrecht: Springer Netherlands, 2003. doi:10.1007/0-306-48080-8_13

Petersen, C. C., and Mark C. Petersen. "The Role of the Planetarium." In *Information Handling in Astronomy*, edited by André Heck, 250, 195–204. Astrophysics and Space Science Library. Dordrecht: Springer Netherlands, 2000. doi:10.1007/978-94-011-4345-5_15.

Plummer, Julia D. "Early Elementary Students' Development of Astronomy Concepts in the Planetarium." *Journal of Research in Science Teaching* 46, no. 2 (2009): 192–209. doi:10.1002/tea.20280.

Plummer, Julia D., Alicia Kocareli, and Cynthia Slagle. "Learning to Explain Astronomy Across Moving Frames of Reference: Exploring the Role of Classroom and Planetarium-Based Instructional Contexts." *International Journal of Science Education* 36, no. 7 (2014): 1083–1106. doi:10.1080/09500693.2013.843211.

Plummer, Julia D., and Kim J. Small. "Using a Planetarium Fieldtrip to Engage Young Children in Three-Dimensional Learning through Representations, Patterns, and Lunar Phenomena." *International Journal of Science Education, Part B* 8, no. 3 (2018): 193–212. doi:10.1080/21548455.2018.1438683.

Price, Allison, Emily R. Boeving, Marisa A. Shender, and Stephen R. Ross. "Understanding the Effectiveness of Demonstration Programs." *Journal of Museum Education* 40, no. 1 (2015): 46–54. doi:10.1080/10598650.2015.11510832.

Sadler, Wendy J. "Evaluating the Short-Term and Long-Term Impact of an Interactive Science Show." *Research for All* 5, no. 2 (2021): 399–419. doi:10.14324/RFA.05.2.14.

Schechter, Rachel, Molly Priedeman, and Irene Goodman. *The Amazing Nano Brothers Juggling Show Outcomes Evaluation*. Boston: Museum of Science, 2010. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.grginc.com/documents/GRGMOSReportFINAL10-15.pdf.

Seyma, Aksu, and Umdu Topsakal Unsal. "Planetariums as a Source of Outdoor Learning Environment." *Educational Research and Reviews* 12, no. 5 (2017): 283–287. doi:10.5897/ERR2016.2956.

Shaby, Neta, Orit Ben-Zvi Assaraf, and Tali Tal. "An Examination of the Interactions between Museum Educators and Students on a School Visit to Science Museum." *Journal of Research in Science Teaching* 56, no. 2 (2019): 211–239. doi:10.1002/tea.21476.

Shaby, Neta, Ran Peleg, and Ian Coombs. "Participatory Research with Museum Practitioners: A Reflection on the Process." *Research in Science Education* 54, (2024): 891–908. doi:10.1007/s11165-024-10167-4.

Trucks, Jesica, Shannon Schmoll, Kathleen Hinko, and Gloria Lopez. "How Interested Are Planetarium Visitors in Astronomy? Comparing Online and In-Person Audiences." *Journal of Museum Education* 47, no. 4 (2022): 510–520. doi:10.1080/10598650.2022.2087162.

Walker, Graham James. "Motivational Features of Science Shows." Unpublished doctoral thesis. Australian National University, 2012.

Wyatt, Ryan. "Planetarium Paradigm Shift," 2005.