Provocative Questions: Supporting effective dialogue about societal issues informed by human biology in a changing world Exploratory Research

Report Written by Elizabeth Kunz Kollmann, Juli Goss, Catherine Lussenhop, Stephanie Iacovelli, and Christine Reich December 2012 Report #2012-10 Funded by the National Science Foundation



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Research and Evaluation Department Museum of Science Science Park Boston, MA 02114 (617) 589-0302 researcheval@mos.org © 2012

EXECUTIVE SUMMARY

In August 2010, the Museum of Science, Boston (MOS) received a pathways grant (DRL-1010830) from the National Science Foundation (NSF) to develop and prototype a series of unstaffed exhibit components designed to build visitors' capacities to engage in discussions of socio-scientific issues and improve visitors' socio-scientific argumentation skills. This report details the findings from an exploratory research study conducted by the Research and Evaluation Department at the Museum of Science, Boston about this exhibition, which came to be known as *Provocative Questions (PQ)*.

The *Provocative Questions* exhibition used a modified version of Toulmin's Argumentation Pattern (Toulmin, 1958), as adapted by Kolsto (2006), as an argument framework to describe socio-scientific arguments. This abbreviated framework focuses on the three core elements of an argument: claims, data, and warrants. The framework posits that a socio-scientific argument is composed of a claim with supporting data (scientific evidence and personal experiences) connected to each other through a warrant (social value). Exhibit components were designed to guide visitors through the process of recognizing the different elements of a socio-scientific argument as well as to allow them to construct their own argument around the question "Should sugary drinks be taxed?"

This investigation was guided by the following questions:

- 1. Will visitors engage in socio-scientific argumentation in an un-facilitated exhibit space, and are they aware that they are doing so?
- 2. How do the un-facilitated exhibits impact visitors' socio-scientific argumentation skills?

For the exploratory research study, visitors were cued to use the exhibits and observed. A subset of visitors was also video- and audio-taped. All visitors were interviewed afterward. To see the effects of the exhibition on visitors' argumentation skills, researchers compared results from this study to those from a front-end study (Kollmann, Reich, Bell, & Goss, 2010) conducted before the exhibition was completed.

Overall, findings showed that visitors used almost all of the components in the exhibition space, that they practiced a variety of socio-scientific argumentation skills, and that they were aware that they were doing so. Specifically, *Provocative Questions* visitors who took part in the study:

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- Demonstrated awareness of the three types of evidence;
- Discriminated between the three different types of evidence;
- Crafted arguments using supports;
- Recognized that the exhibition was about forming opinions; and
- Reported that they learned scientific evidence.

Not only did *Provocative Questions* provide visitors the opportunity to practice these skills, the exhibition improved visitors' socio-scientific argumentation skills. When comparing the arguments of visitors who used the exhibition to arguments of visitors who did not use the exhibition, the following findings emerged:

• Individual visitors who used the exhibition were more likely to give an "unsure" claim for their opinion about the taxation of sugary drinks.

These data suggest that interacting with the *Provocative Questions* exhibition made visitors more unsure about their claim for the socio-scientific question "Should sugary drinks be taxed?" It is possible that exposure to additional background information about scientific research, social values, and personal experiences caused visitors to further consider their position on the question. It is also possible that giving members of the public a venue in which to hear varied arguments and have their argument heard in return caused visitors to be more open to differing viewpoints about taxation of sugary drinks.

• Groups who used the exhibition were more likely to use social values and scientific evidence in their arguments about taxing sugary drinks. These data indicate that interacting with the *Provocative Questions* exhibition made it significantly more likely that groups would include social values and scientific evidence as supports within their arguments. It is possible that exposure to scientific evidence and values presented throughout the exhibition made visitors more cognizant of these kinds of evidence and therefore more likely to include these supports in their arguments.

• Groups who used the exhibition were more likely to use scientific evidence when asked their viewpoint about restricting antibacterial soaps and sanitizers. These data suggest that the *Provocative Questions* exhibition impacted not only visitors' abilities to construct arguments containing science about the socio-scientific question posed within the exhibition, but also their ability to include scientific evidence in arguments about other socio-scientific questions. This may be because content within the exhibition promoted science as a support that can be used as a part of socio-scientific arguments, or because visitors practiced this skill while using the exhibition.

These successes provide the opportunity for further research in order to understand the broader ability of *Provocative Questions* to generate argumentation and improve visitors' socio-scientific argumentation skills. As the exhibition shifts focus to another socio-scientific question, further research could allow for a greater understanding about the extent to which the topic or wording of the socio-scientific question posed in *Provocative Questions* impacts the frequency of inclusion of particular claims, data, or warrants in visitors' arguments. Additionally, further research regarding visitors' claims would be useful given that visitors who had experienced *Provocative Questions* were more likely to be unsure whether sugary drinks should be taxed than visitors who had not been to the exhibition. Some have theorized that promoting dialogue and listening about not only science, but also values and experiences makes people more open to different viewpoints (Ellenbogen, 2013; Johnson, Rochkind, & DuPont, 2011). A study could be unsure about their claim than non-*PQ* visitors. The opportunity for further investigation is essential in order to move *Provocative Questions* beyond proof-of-concept to field standard.

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I. INTRODUCTION

1. ABOUT THE PROJECT

In August 2010, the Museum of Science, Boston (MOS) received a pathways grant (DRL-1010830) from the National Science Foundation (NSF) to develop and prototype a series of unstaffed exhibit experiences designed to build visitors' capacities to engage in discussions of socio-scientific issues. The exhibition was aimed at improving visitors' abilities to recognize the components of socio-scientific arguments, evaluate them, and pose arguments of their own, particularly with regard to the numerous human-biology and health-related socio-scientific issues present in their lives today. This area, called *Provocative Questions (PQ)*, will be included as a part of the larger *Hall of Human Life* exhibition, which is scheduled to open at MOS in November 2013. It is anticipated that the socio-scientific questions posed within *Provocative Questions* will be changed approximately every six months. However, throughout the time data were collected as a part of the exploratory research study, the socio-scientific question posed within the exhibition was: "Should sugary drinks be taxed?" Possible future socio-scientific questions that may be used within the exhibition include the following:

- Should there be restrictions on the use of antibacterial soaps and sanitizers?
- Should parents have the ability to learn the genetic sequence of their future child and make decisions based upon that information?
- Should high schools delay their start time due to the sleep needs of teenage students?
- Should all boys and girls be required to get the vaccine for the Human Papillomavirus (HPV), which causes cervical cancer in women?



FIGURE 1. The Provocative Questions prototype exhibition.

1.1 Provocative Questions' goals

A review of existing literature about the inclusion of socio-scientific argumentation in formal (classroom) and informal (museum) science education settings was conducted at the beginning of this project to aid the *Provocative Questions* team in formulating public impacts for the exhibition. The goals of the *Provocative Questions* exhibition at the onset of the grant in 2010 were the following:

- 1. *Awareness, knowledge, and understanding.* Visitors will be aware of the different kinds of evidence that are frequently part of discussions of socio-scientific issues: scientific evidence, informal evidence based on personal experience, and societal/personal values.
- 2. Awareness, knowledge, and understanding. Visitors will understand that one's position with regards to a socio-scientific issue is influenced by one's worldview/values.
- 3. *Skills*. Visitors will practice socio-scientific argumentation skills, which include:
 - a. Discriminating between scientific evidence, personal experience/knowledge, and values,
 - b. Identifying the values underlying different viewpoints,
 - c. Reflecting critically about scientific claims, where visitors begin to ask about the who, how, and what behind the claims,
 - d. Recognizing potential counterarguments or rebuttals to a given argument,
 - e. Justifying one's position by connecting informal and scientific evidence with one's personal values and worldviews, and
 - f. Integrating scientific knowledge into arguments of socio-scientific issues.
- 4. *Other: Identity.* Visitors will come to see themselves as someone who can contribute to and participate in discussions of socio-scientific issues.

Due to learning based on formative evaluation findings and continued review of the literature, the PQ team modified the public impact goals throughout the development of the exhibition. The public impact goals at the completion of the grant in December 2012 were the following:

- 1. *Awareness, knowledge, and understanding.* Visitors will be aware of science research applicable to varied views on the provocative question.
- 2. *Awareness, knowledge, and understanding.* Visitors will be aware of the different kinds of evidence that are frequently part of discussions of socio-scientific issues: scientific evidence, informal evidence based on personal experience, and societal / personal values.
- 3. *Awareness, knowledge, and understanding*. Visitors will understand that one's social values can influence one's interpretation of scientific evidence as well as one's position with regard to a socio-scientific question.
- 4. *Awareness, knowledge, and understanding.* Visitors will be aware that social decisions impact individuals differently because of their varied biological and environmental circumstances.
- 5. Skills. Visitors will practice socio-scientific argumentation skills, which include:
 - a. Discriminating between scientific evidence, personal experience/knowledge, and values,
 - b. Exploring the values underlying different viewpoints,

- c. Reflecting critically about evidence from scientific research,
- d. Recognizing potential counterarguments to a given argument,
- e. Justifying one's position by using informal and scientific evidence with one's personal values and worldviews, and
- f. Integrating scientific knowledge into arguments of socio-scientific issues.
- 6. *Other: Identity.* Visitors will come to see themselves as someone who can contribute to and participate in discussions of socio-scientific issues.

The following two sections describe what the PQ team learned from the literature about the use of socio-scientific issues and argumentation in formal and informal science education settings (sections 1.2 and 1.3). After describing the background literature, there is a description of the PQargumentation framework (section 1.4). Finally, a description of the formative evaluation conducted for this project and how it impacted team decision making is included in section 1.5.

1.2 Literature about argumentation in museums

For years, museums and other informal science education institutions have created exhibits and programs to help members of the public practice argumentation skills related to science. Information below summarizes what these projects have learned about the abilities of visitors to create arguments in an informal education setting.

The most basic scientific argument skill is the ability to make claims about a science-related question and discuss these claims (Allen & Gutwill, 2009; Kolsto, 2006; Toulmin, 1958). A review of research and evaluation studies indicates that it is possible for visitors to display these argumentation skills during facilitated informal science programs. Facilitated activities used within museums such as *Play Decide* and *Mine Games* were successful at getting visitors to articulate their claims about socio-scientific issues surrounding mining, nanotechnology, and xenotransplantation (Duensing & Lorenzet, 2007; Pedretti, 2007). Some facilitated programs such as *Play Decide*, the NISE Net *Forums*, and the Dana Centre forums were also successful at encouraging groups of museum visitors who knew each other, as well as groups of visitors who did not know each other, to have discussions about controversial socio-scientific topics such as nanomedicine, genetic testing, and HIV/AIDS (Duensing & Lorenzet, 2007; Flagg & Knight-Williams, 2008; Kollmann, Reich, & Lindgren-Streicher, 2009; McCallie, Simonsson, Gammon, Nilsson, & Lehr, 2007; Reich, Bell, Kollmann, & Chin, 2007).

Some un-facilitated exhibits have also been successful at getting visitors to create claims or have discussions about science-related questions. Visitors to MOS *Science is an Activity* exhibitions (*Making Models* and *Investigate*) were observed to form claims about the scientific questions they have explored through interactive exhibits (Hein, Kelley, Bailey, & Bronnenkant, 1996; Karp & Leblang, 2004). Additionally, exhibits such as *In Future* at the Science Museum, London and *The Power of Children* at the Indianapolis Children's Museum were able to generate discussion among museum visitors about topics as diverse as racism, lifestyle, and health through the use of interactive exhibits, labels, and artifacts (Smukler & Chin, 2006; Wood & Cole, 2007).

While informal science education projects have been able to promote these basic argumentation skills, a review of the evaluation and research literature indicates that it is more difficult for visitors to take the next step and create arguments that acknowledge alternative claims. Evaluation of the *Investigate* exhibition showed that while visitors made claims about the science questions they explored, they did not often explore or discuss alternative claims (Hein et al., 1996). This was also seen in the Exploratorium's *GIVE* project. Allen and Gutwill (2009) found that it was possible to get visitors to choose and support a model to explain their science questions by using an inquiry game at museum exhibits, but that it was difficult for visitors to generate multiple explanations. They hypothesized that this was because in an exhibit where visitors are able to ask and answer multiple scientific questions, it is hard for people to focus on describing a single aspect of exhibit. Additionally, they felt that in a fun informal science setting groups may be unwilling to engage in the conflict that might arise if different members of a visiting group supported different explanations (Allen & Gutwill, 2009).

Literature shows that not only do visitors have problems acknowledging alternative explanations, they also have difficulty integrating scientific evidence into their arguments. The *Investigate* exhibition evaluation indicated that the claims visitors made about the science questions they explored often did not include scientific data explanations (Hein et al., 1996). Additionally, while participant discussions from the *Play Decide* and *Mine Games* projects showed that visitors were capable of integrating informal evidence such as personal experience and knowledge into their discussions and arguments, it was unlikely for arguments to contain scientific evidence even when it was provided by project materials (Duensing & Lorenzet, 2007; Pedretti, 2007).

Some of these problems with argumentation seem to lessen when visitors are asked to answer questions about socio-scientific issues. The Dana Centre purposefully chooses topics for its dialogue events in the realm of socio-scientific issues, and they have found that by doing this a broad range of people felt they had the knowledge necessary to form viewpoints (McCallie et al., 2007). Other projects such as *Play Decide* and *Mine Games* found that while visitors still find it difficult to integrate scientific evidence into their arguments, consideration of socio-scientific questions did result in the participants debating and reflecting on alternative arguments (Duensing & Lorenzet, 2007; Pedretti, 2007). Additionally, an examination of the NISE Net *Forums*, which asks visitors to have discussions about socio-scientific questions related to nanotechnology, showed that after participating in the program visitors felt more confident in their ability to express and support their viewpoints (Flagg & Knight-Williams, 2008).

1.3 Literature about socio-scientific argumentation in formal educational settings

While socio-scientific argumentation has not been studied widely within informal education settings, it has been studied within the realm of formal education. The information below describes findings from formal education research about the inclusion of socio-scientific issues in school settings, and how this research is applicable to the *Provocative Questions* exhibition.

In recent years, there has been a call for "science for all" which was justified by a need for a broader, more capable workforce and informed citizens. Rationales for this need are seen in multiple formal science education publications including *Taking Science to School*:

At no time in history has improving science education been more important than it is today. Major policy debates about such topics as cloning, the potential of alternative fuels, and the use of biometric information to fight terrorism require a scientifically informed citizenry as never before in the nation's history. (National Research Council, 2007, pg. 1)

A similar call is echoed by *Changing the Conversation* which focuses on engineering education:

A number of important public policy issues, from global warming to the marketing of genetically modified foods, involve scientific and technical issues. Decision making on these and other topics will involve trade-offs, as we attempt to simultaneously manage limited resources while sustaining quality of life. Public discourse and the democratic process could be enhanced if citizens understood more about how engineers are trained and what the practice of engineering entails. (National Academy of Engineering, 2008, pg. 19)

Research indicates that the inclusion of socio-scientific issues in the classroom may be able to promote both the democratic discussion and decision making described above because they differ from traditional classroom science discussions in critical ways:

- Socio-scientific issues require consideration of both scientific knowledge and personal beliefs, morals, and values (Sadler, 2004).
- Socio-scientific issues require students to confront and consider topics at the frontiers of science, where the field of science has not reached consensus (Kolsto, 2001).
- Socio-scientific issues are most similar to those that all citizens will face, including (but certainly not limited to) future scientists (Tytler, Duggan, & Gott, 2001).

Despite the affordances of these kinds of issues within the classroom, a review of literature reveals that the inclusion of socio-scientific issues is not widespread in the U.S. In fact, American science argumentation literature is almost devoid of references to socio-scientific issues. Instead, most of the literature stems from work conducted in Europe with only a few American researchers studying this topic.

Framed by this context, the *Provocative Questions* team drew upon research about the use of socio-scientific issues in formal education classrooms in order to determine how to present socio-scientific argumentation within an exhibition. For example, Sadler's (2004) comprehensive synthesis of the use of socio-scientific issues in education as well as other studies point to the following trends in students' existing capacities to engage in argumentation of socio-scientific issues:

• Students do not typically demonstrate the capacity to construct strong or high quality arguments in the absence of explicit instruction or scaffolding (Sadler, 2004).

- Students with greater conceptual understanding of related science content tend to construct stronger arguments (Sadler & Fowler, 2006; Sadler & Zeidler, 2005).
- Students do not draw upon science facts or classroom science when constructing arguments, but instead rely extensively on their prior experience (Kolsto, 2006).
- Students craft arguments utilizing "rationalistic, emotive, and intuitive forms of informal reasoning" (Sadler & Zeidler, 2005, pg. 112).

Additional studies have shown that despite these potential issues, students are able to engage in argumentation of socio-scientific issues in the classroom (Albe, 2007), and student argumentation can improve over time (Osborne, Erduran, & Simon, 2004). Not only does this suggest the effectiveness of using socio-scientific issues as an entry point for engaging students in argumentation, but students also describe classroom discussions of socio-scientific issues as engaging (Hanegan, Price, & Peterson, 2008).

As a result of the literature mentioned, the *Provocative Questions* team began the exhibition development process with a few guiding principles. First of all, the team recognized that MOS visitors would likely need supports and scaffolding to craft their arguments. The exhibition team also recognized that visitors would need exposure to science content related to the socioscientific question posed in the exhibition, and that they would likely need additional help integrating scientific evidence into their argument. In spite of these challenges, this literature also highlighted the opportunity provided by an exhibition experience as opposed to formal classroom. Because visitors would likely draw upon their prior knowledge and experiences when discussing an issue, the MOS team felt that visitors may have an easier time creating arguments about socio-scientific issues than scientific issues in the un-facilitated space of an exhibition.

1.4 The Provocative Questions argumentation framework

In order to promote democratic discussion and decision making, *Provocative Questions* used socio-scientific questions within the exhibition to increase visitors' understandings of socio-scientific argumentation. The *Provocative Questions* team referred to literature about argumentation in general and socio-scientific argumentation more specifically to determine a framework to model the creation and analysis of arguments made within the exhibition.

Multiple frameworks exist within the formal science education literature related to the assessment of student argumentation of socio-scientific issues in classrooms, with Toulmin's Argument Pattern (TAP) maintaining a dominant position (Toulmin, 1958). TAP purports that the statements that form an argument can be categorized as six interconnected, functional elements: claims, data, warrants, backings, qualifiers, and rebuttals. An argument's strength is based on the presence of and relationship between these functional elements. Alternative frameworks have been presented that are more specific to socio-scientific discussions. Corner and Hahn (2009) argue that a Bayesian framework (where an argument's strength is based on an individual's prior beliefs and the quality of new evidence) may be more appropriate for discussions of socio-scientific issues given there is little difference in how individuals assess the strength of scientific and non-scientific arguments. Levinson (2006) proposes a framework based on an epistemology of controversy, which focuses on three separate elements of an argument:

reasonable disagreement, communicative virtues, and modes of thought. Levinson's framework is unique in considering the value of an argument based on the nature of democratic (as opposed to scientific) discourse. This framework holds promise, but is currently untested.

Of the frameworks identified through the review of the literature, Kolsto's (2006) adaptation of the TAP framework demonstrates the greatest potential for assessing socio-scientific argumentation in informal learning environments. Kolsto focuses on the three core elements of an argument as defined by Toulmin: claims, data, and warrants. This abbreviated version is more suitable to informal learning environments where interactions and exchanges take place within shortened periods of time. Kolsto's adaptation also emphasizes the differences in the characteristics of socio-scientific (as opposed to pure scientific) argumentation. According to Kolsto, claims within the realm of socio-scientific argumentation are defined as the position one takes on the issue. For example, a claim might be as simple as "Yes, sugary drinks should be taxed." The data within socio-scientific arguments can refer to scientific and/or informal evidence, with the use of scientific evidence representing a stronger argument than informal evidence. Finally, the warrants within socio-scientific arguments are defined as the individual's worldviews, perspectives, or values that connect the data to the claims. Although Kolsto utilizes this framework to describe socio-scientific argumentation within formal education environments, the Provocative Questions team decided to use this framework as a tool for assessing the arguments made by visitors within the Provocative Questions exhibition.

A second key part of building argumentation skills is the ability to evaluate and understand arguments (Driver, Newton, & Osbourne, 2000; Kuhn, Iordanou, Pease, & Wirkala, 2008; Tippett, 2009). Therefore, *Provocative Questions* made use of the framework provided in an article by Marttunen (1994) which posits that a person is not truly skilled in argumentation until he or she is able to evaluate arguments by being able to identify the components of an argument, judge the relevance and sufficiency of the evidence and values used to support a position, and assess whether counterarguments have been taken into account.

1.5 Formative evaluation testing of Provocative Questions components

Adapting Kolsto's (2006) and Marttunen's (1994) frameworks, the *Provocative Questions* exhibit components were designed to guide visitors through the process of making and evaluating arguments about a particular socio-scientific question. To accomplish this, the grant proposed that the *Provocative Questions* exhibition would be composed of six separate, unfacilitated components, each of which, with the exception of "The Question," would focus on specific socio-scientific argumentation skill(s). As outlined in the grant proposal, "The Question" would introduce visitors to the current provocative question and the components of a socioscientific argument. During "Break it Down," visitors would discover how to discriminate between examples of personal experience,¹ scientific evidence, and social values statements (goal 5a). In "State Your Values," visitors would practice exploring the values underlying

¹ Within the exhibit components, the argument support of "informal evidence" was presented to the public as "personal experience" in order to be more understandable to visitors. Therefore, this support is described as "personal experience" throughout this section as well as the rest of the report.

different viewpoints (goal 5b). While using "What's the Evidence," visitors would reflect critically about evidence from science research (goal 5c). At "Build Your Case," visitors would get a chance to create justified arguments that included personal experience, social value, and scientific evidence supports (goals 5e and 5f). Finally, at "Join the Debate," visitors would be given a chance to look at and explore the arguments of other *Provocative Questions* exhibit visitors (goal 5d).

Since that time, the exhibit components have gone through numerous rounds of prototyping and formative evaluation, changing significantly from their first iterations. Some of these exhibit components were combined or removed, and new components were added (Figure 2). This section has been provided to describe the formative evaluation process of the *Provocative Questions* exhibition and how the team made decisions about changes to the exhibit components based upon this process.



FIGURE 2. Formative Evaluation Testing Timeline

Museum of Science, Boston

October 2009 – January 2010: Preliminary Story Testing

The formative evaluation process began with story testing. Story testing is used to determine if an early version of an activity is meeting its goals – to test for the "proof of concept" for the component. These prototypes are generally less expensive table-top designs facilitated by an educator.

Story testing began in October 2009 with "Break it Down" and "Build Your Case" tested as one visitor experience. During testing, visitors were presented with one of two different socio-scientific questions:

- Should sugary drinks be taxed?
- Should high schools delay their start times because of the sleep needs of teenagers?

For "Break it Down," visitors were prompted to sort provided support statements into one of the three categories: personal experience, social values, or scientific evidence. For "Build Your Case," visitors were given small slips of paper containing claims, social values, personal experiences, and scientific evidence. Visitors were then given a larger piece of paper with "slots"

that could hold one claim and up to three personal experience, social value, and scientific evidence statements each. Using these materials, they were asked to create a position about the provocative question (see Figure 3).

Results from formative testing indicated that visitors were sometimes confused about the difference between personal experiences and social values. They also sometimes built cases that did not include all three types of support statements or that included contradictory statements that did not support their case. As a result of



FIGURE 3. "Build Your Case" activity during story testing.

this testing, development of a "Break it Down" prototype began in order to test the activity as a standalone, computer interactive. "Build Your Case" underwent further story testing after combining it with another activity.

Following this story testing of the first two activities, in November 2009, the first tests of "State Your Values" and "What's the Evidence" began. For "State Your Values," visitors were provided with hypothetical viewpoints and asked to pick generic social values statements that represented the values within the viewpoints. They were also asked to think about their own point of view and pick their top three social values for the provided provocative question of "Should sugary drinks be taxed?" (see Figure 4). As a part of "What's the Evidence," visitors

looked at pieces of scientific evidence and tried to decide which questions were most important when evaluating the evidence: what the results were, who did the study, or how they conducted it (see Figure 5). In general, evaluation results showed that visitors did not have much difficulty participating in the "State Your Values" activity, though they had more trouble identifying other peoples' values than



FIGURE 4. "State Your Values" activity.

their own. In using the "What's the Evidence" activity, visitors were interested in "debunking" the science claims, but did not always know which of the three questions it would be best to ask of the science study presented.

Based on these findings, development began of a standalone prototype for "State Your Values." Changes were made to the "What's the Evidence" activity in an attempt to curb visitors' cynicism about the scientific evidence provided. A revised version of "What's the Evidence" was tested in January 2010 (see Figure 5). In this version, visitors read a piece of scientific evidence and rated it on three axes: how reliable the source of the study was, how good the study's methods were, and how relevant the science research was to the current socio-scientific issue. Each visitor rated two pairs of statements, within each pair, one piece of scientific evidence contained few details and one contained more details. Evaluation data showed that visitors rated the studies with more detailed claims as more reliable, and most groups thought the point of the activity was getting them to think more critically.



FIGURE 5. Version 1 (left) and 2 (right) of "What's the Evidence."

August 2010 – April 2011: Combining "Break It Down" and "State Your Values" into a new "Break It Down"

While the formative story testing was facilitated by members of the exhibit's content team, later formative evaluation testing focused on stand-alone components that were designed and built for visitors to use without staff facilitation. Labels, including graphics, were included with each component. This prototype testing stage was used to further refine components that had made it through the story testing process as well as test some activity ideas that were not evaluated during story testing. Additionally, sometimes during this phase, it was discovered that further story testing needed to be conducted as new ideas and concepts were introduced.



FIGURE 6. The "Break It Down" activity with two side-by-side kiosks.

In August 2010, the "Break It Down" activity moved to a stand-alone format of two kiosks with touchscreens (see Figure 6). Two kiosks were created and tested together at this point in order to

begin to understand how visitors might interact and have discussions with each other when the two kiosks were placed in different configurations. However, each kiosk was independent and could be used by an individual. On each touchscreen, visitors saw three "bins" (personal experience, scientific evidence, and social values) into which they could sort provided argument support statements for the question "Should sugary drinks be taxed?" Before they began, they watched three statements being automatically sorted. Then they were able to sort six statements on their own. They were then told if their sorting was correct. The activity was tested in three different configurations. First, the two kiosks were tested side-by-side. Second, the two kiosks were angled away from each other. Finally, one kiosk was tested alone. Evaluation findings indicated that most visitors had some difficulty with the touchscreens, finding them "sticky" and unresponsive. Just under half of the groups were observed talking with each other. Finally, more visitors thought that the activity was about sugary drinks and health rather than about argumentation. Since visitors were not getting the main message, not having conversations, and having trouble with the touchscreens, the team began to explore alternative directions for the activity.



FIGURE 7. "State Your Values" activity screen.

In September 2010, "State Your Values" was also prototyped as a touchscreen kiosk activity (see Figure 7). In this activity, visitors were shown videos of people speaking value statements. At the bottom of the screen were a series of general values. After hearing the video, visitors were asked to choose which of these statements best fit the value the person in the video seemed to be expressing. Group results were then shown so visitors could see how others interpreted the values. Similar to "Break

It Down," evaluation results indicated that fewer than half of the groups were observed talking to each other, some visitors had trouble with unresponsive touchscreens, and more people thought the activity was about health issues and government regulations of sugary drinks than about values. Based on these findings, it was decided that changes needed to be made to try to encourage more conversation and help visitors to recognize that, at its core, this activity was about argumentation.

The next time these activities were evaluated, in April 2011, "Break It Down" and "State Your Values" were combined and called "PQ 2/3" by the project team (see Figure 8). The activity was another screen- and button-based activity with two rounds organized as a game show that could be played by two visitors. Round 1 asked visitors to sort different statements about the question



FIGURE 8. Statement-sorting activity from PQ 2/3.

"Should sugary drinks be taxed?" into the personal experience, scientific evidence, or social values categories, while Round 2 had visitors look at different value statements and answer questions, "Who should pay?" or "Who should make the decision?" As with previous standalone prototypes, the evaluation found that visitors had some problems using the component, as some groups did not understand how to select a response during Round 1 or rotate through the circle of choices during Round 2. Despite these issues, it was found that most groups sorted the statements in Round 1 correctly, and many groups were observed having discussions. However, while visitors had some success understanding the purpose of the Round 1 activity, they did not seem to pick up on messages around values that were a part of Round 2 of the activity. Therefore, the team decided to focus the content on helping visitors learn how to discriminate between different kinds of supports that can be used as a part of socio-scientific arguments and to name the activity "Break It Down." The content about sorting values statements was removed from this component and later integrated into the Social Values panel.

November 2010 – December 2011: Combining "What's the Evidence" and "Build Your Case" into the new "What's Your Opinion"

As stated previously, "What's the Evidence" story testing indicated that the current activity could cause visitors to become increasingly cynical or skeptical of scientific evidence provided. In order to encourage critical thinking, without as much skepticism, "What's the Evidence" underwent further story testing. In November 2010, the name of the "What's the Evidence" activity was changed to "Science Relevance." Reflecting this new thinking about the activity, this version asked visitors to first pick their viewpoint about the provocative question "Should sugary drinks be taxed?" and then pick a science topic to explore related to the question. Topics included the following:

- Are sugary drinks connected to an increase in diabetes / obesity?
- What is the effect of taxing on changing a behavior?
- Are artificial sweeteners a healthy alternative?
- Are sugary drinks addictive?
- Are there certain groups of people who could be easily impacted by this decision?

After choosing the topic, visitors read four studies about it and ranked the relevance of the research to their chosen viewpoint. Visitors then chose a second topic to explore and did the same thing. After exploring each topic, visitors were asked to talk about how the science impacted their view. During prototyping, educators modified the activity and asked visitors to explore only one science topic, instead of two, in order to shorten the length of the activity. Evaluation findings indicated that when asked what the Museum was trying to have them learn from the activity, several visitors were able to articulate the component message "*Science can inform my viewpoint*." An equal number said that the activity was about "*Effects of sugary drinks*," which is another goal of the exhibition. Based on these findings, the team brainstormed ways to help visitors better recognize that this activity was about argumentation. However, the team also learned that splitting science studies into topics helped visitors understand the variety of science available for the provocative question. This multi-topic framework for science was included in future iterations of the exhibit component.



FIGURE 9. The "Debbie" avatar from PQ 4/5.

Because "Science Relevance" and "Build Your Case" had so many similarities, the PQ team decided to combine them into one activity with the internal title "PQ 4/5" and story test them in January 2011. As a part of this activity, visitors were given a choice of two avatars named Debbie (see Figure 9) and Sovann, who had different personal experiences related to the question "Should sugary drinks be taxed?" After visitors chose one of the avatars, they were then given three packets of scientific evidence. Visitors were asked to pick one piece of science research from the packet that they thought would be important to their avatar. They then looked at eight social values statements and once again picked an argument support that they thought would be important to their avatar. Finally, they were asked to pick a "Yes" or "No" card depending on whether they thought their avatar would support taxation of sugary drinks or not. As with previous prototyping, evaluation findings from this round of testing indicated that most groups thought the Museum was trying to have them learn about

health issues. Additionally, it was found that almost half of the participating groups had trouble discussing the topic from the avatar's perspective, choosing instead to participate in the activity from their own perspective. This finding prompted the team to revise the next version of the activity so that visitors would be asked to think about the question "Should sugary drinks be taxed?" from their own viewpoint instead of from an avatar's.

In February 2011, the next version of the "PQ 4/5" activity was story tested. In it, visitors started by reading an avatar's argument about the question "Should sugary drinks be taxed?" with the three types of argument supports (personal experience, social values, and scientific evidence) highlighted in different colors (see Figure 10). They then were given the opportunity to create their own arguments by choosing one personal experience, one social value, and one piece of scientific evidence to support their viewpoint. During the



FIGURE 10. "Debbie" in the updated PQ 4/5.

evaluation, when asked what the Museum was trying to have them learn, visitors addressed all three intended messages in their responses. In particular, 8 of 10 groups touched on the message "There are three different kinds of statements that can make up an argument." In addition, all visitors expressed some level of interest in the activity. Most visitors also engaged in lively discussions about their arguments. Based on this information, the team decided to proceed to stand-alone testing using this general format and adding discussion prompts to further promote discussion.



FIGURE 11. The Personal Experience screen in PQ 4/5 v.3 (paper version).

In July 2011, a new paper version of "PQ 4/5" was prototyped. At this point, even though a paper version of the activity was used, educators attempted to see how the activity would work as a stand-alone. Additionally, to attempt to generate discussion among visitor groups, the activity was partnered, with the two visitors sitting face-to-face with each other. Each visitor was given a board with large sheets of paper that flipped back in order to simulate a computerbased activity (see Figure 11). Visitors were prompted to "build a case" by selecting one personal experience statement, one scientific evidence statement, and one social values statement, as well as a final claim ("Yes," "No," or "I can't decide."). Throughout the

activity, visitors were provided with discussion prompts encouraging them to share what statements they chose and why, or asking them to guess their partner's final claim. Evaluation findings showed that almost all groups engaged in discussion during the activity. After this round, because visitors generally did not refer to them, the team decided to move the prompting questions from the 'choose an evidence' pages to individual pages throughout the activity and provide more explicit instructions about when to have discussions about each argument support.

In September 2011, the "PQ 4/5" activity was moved to a touchscreen format and prototyped yet again (see Figure 12). The activity closely mirrored the paper storyboard version: visitors sat down facing each other at paired touchscreens and followed onscreen prompts to pick the three kinds of evidence, choose a claim, and discuss these decisions with their partners. Evaluations found that almost all groups had a discussion at some point during the activity, and visitors mentioned almost all of the component messages in interviews.



FIGURE 12. Personal Experience screen in touchscreen version of PQ 4/5.

However, visitors encountered barriers in the technical aspects of the activity. In particular, they had difficulty understanding how to start the activity and progress from the introduction screen. Visitors also found it difficult to select their scientific evidence. In addition to these observations, this difficulty was also reflected in visitor interviews, with the majority of visitors saying that the activity was "a little difficult to figure out." To remedy these issues, the team added more instructions and reorganized the graphical layout of the activity. The activity's name also changed from "PQ 4/5" to "PQ Building."



FIGURE 13. Argument Building and Analysis activity.

In December 2011, the "PQ Building" touchscreen activity was prototyped again (see Figure 13). The main format of the activity remained the same, except that the graphics and display were updated and an "Analysis" portion was added to the end of the activity. The "Analysis" section allowed visitors to browse the selections of other visitors who had completed the activity. After building their own case, visitors could see how many other people chose each of the personal experience statements, scientific evidence studies. social values, or claims. For this reason, the name of the activity was changed from "PQ Building" to "Argument Building and Analysis." Again, evaluation results

indicated that most visitors were interested in the activity. Additionally, it was found that visitors still had some issues using the activity, especially when they were trying to select supports or claims to add to their cases. An additional issue was that visitors thought they could change their cases when looking at the review screen at the end and were confused when they could not. In order to clear up this confusion, the team considered adding a "Back" button so people could change their mind about the evidence they picked as well as further clarifying the instructions.

April 2012: Final Exhibit Component Focus Testing

In April 2012, the *Provocative Questions* exhibit components were installed as a group in the Human Body Connection space on the 2^{nd} floor of the Green Wing at the Museum of Science, Boston. Before installation, the team decided to rename "Argument Building and Analysis" as "What's Your Opinion." The space included two pairs of "What's Your Opinion" touchscreens, a new "Break It Down" activity, four panels (one Intro Panel and one panel each for Personal Experience, Scientific Evidence, and Social Values), and a Science Reading Area with a couch and three binders containing more information about the scientific studies included in the exhibition (see Figure 14).



FIGURE 14. The *Provocative Questions* exhibit space in the Human Body Connection.

Before data collection for the exploratory research study began, evaluators conducted "focus testing" on all of the exhibit components with the exception of "What's Your Opinion." Because "What's Your Opinion" had undergone the most extensive prototyping, while other components had changed in format or content since previous testing, this "focus testing" was conducted to inform the team of any immediate changes needed, as well as to inform the exploratory research study. Data collectors chose one component at a time to

observe, then observed un-cued visitors in the area, and finally approached them after they finished using the chosen component. For instance, if the data collector was observing the Social Values Panel, they might see a group enter the PQ area, read the Intro Panel, use Break It Down, and then read the Social Values Panel. The data collector would approach the group for an interview immediately after they left the Social Values Panel and ask questions only about that component, even though visitors used others. At times it was necessary to cue visitors, especially for components located further into the space, such as the Scientific Evidence panel, though uncued interactions were preferred. Each panel, as well as "Break It Down," was tested individually. See Figure 15 for pictures of the panels.

Results of this "focus testing" indicated that the exhibit components were largely functioning as intended and only minor changes were made before the exploratory research study began. During testing of the Introductory panel, 11 groups were observed, all un-cued. Most visitors identified the specific provocative questions included on the panel as the most interesting part of Introductory panel. For the Personal Experience panel, nine groups were observed, four un-cued and five cued. Groups enjoyed reading the personal experiences on the panel, but a couple of groups found the handwritten text hard to read. For the Scientific Evidence panel, 12 groups were observed and interviewed; three were un-cued, while the other nine were cued. When asked what they learned that they didn't know before, most groups pointed out specific studies on the panel. Most groups also thought the Museum was trying to teach them about the health effects of sugar. Lastly, for the Social Values panel, 14 groups, all un-cued, were observed. The panel had a screen with three different provocative questions that visitors could scroll through as well as sliders that visitors could use to define their values on three different spectrums. About half of the groups had discussions at the panel, where a question about water fluoridation was the most commonly explored. At least one visitor group mentioned all three intended component messages.



FIGURE 15. The four *PQ* panels.



FIGURE 16. Break It Down in the exhibit space.

The final "Break It Down" activity (see Figure 16) was in a quiz format, where visitors watched short video clips in which actors stated a scientific evidence, personal experience, or social value statement. Visitors were then given 10 seconds to select the correct evidence type. Thirteen visitor groups were observed using "Break It Down," none of which were cued, and 10 of which were interviewed. Nine of those 13 groups were observed having discussions with each other at the component. With regard to categorizing the statements correctly, visitors were best able to answer the personal experience statements. 62% and

74% of visitors answered the first and second personal experience questions correctly (respectively). The next easiest category for visitors was social values, with 67% and 41% of visitors answering the first and second social values questions correctly. Visitors had more trouble identifying science, with 38% of visitors answering the first scientific evidence statement correctly and only 13% doing so for the second. As a result, the second scientific evidence statement was removed because the way in which it was presented caused visitors confusion.

During the focus testing process, researcher noticed that few visitors were using "What's Your Opinion," and if they did, they often left before finishing the activity. A short evaluation was undertaken to better understand why visitors were not using "What's Your Opinion," or why they were leaving early if they did visit. Data collectors kept a count of what percentage of visitors to the PQ space used "What's Your Opinion," and of those who did, their average stay time. If the interaction with "What's Your Opinion" was steady and the visitor touched the screen at all, the data collector would ask the visitor a few short interview questions.

Results showed that about a third (20 out of 58) of the groups who entered the PQ space approached and appeared to notice "What's Your Opinion." Sixteen of those groups interacted with the component in some way, and eight of those groups were interviewed. Only four of the 16 groups who used "What's Your Opinion" had any discussions, and the average stay time was 2 minutes and 22 seconds. The greatest barrier to use was confusion about what to do at the activity. Half of the groups who interacted with "What's Your Opinion" were visitors who approached alone, and they were unable to use the partnered activity.

Additionally, four of the eight groups interviewed asked for clearer instructions. Because of the request for more instructions, a large graphic label and several intro screens were added to the activity. These screens oriented visitors to the activity and allowed them to practice selecting something to add to their case. An example of one of the screens is shown in Figure 17. After this round of testing, data collection for the exploratory research study began.



FIGURE 17. Example orientation screen at "What's Your Opinion."

July – August 2012: Further Exhibition Development Conducted After the Exploratory Research Study

During data collection for the research study, a new version of "What's Your Opinion" was underway. This version was designed to be accessible to a broad range of visitors, specifically visitors with disabilities. The activity was designed such that visitors would use swiping motions to move through each step as well as to explore their options within each type of evidence (see Figure 18). Audio labels could be toggled on and off and the sound came from an "audio dome" speaker above the visitor. To the best of the PQ team's knowledge, this accessible touchscreen was one of the first of its kind. Since the swiping motion is similar to that used on smartphones and tablets that were growing more and more popular, it was hoped that all visitors, not just those with disabilities, would find the swipe-based version easier to use. To learn more about how visitors used the new mode, as well as the rest of the exhibit, it was tested with visitors with a range of disabilities as well as general Museum visitors.



FIGURE 18. Social Values screen from "What's Your Opinion" (swipe-based version).

First, visitors with a range of disabilities were recruited online for exhibit accessibility testing. They came to the Museum in 1-2 hour slots between August 11th and 21st, 2012. Visitors were recruited from a pool of previous participants, as well as through word-of-mouth and disability-related websites and listservs. Some visitors came alone, some came with family or friends, and some came with personal care attendants. They were instructed to use the exhibits as they normally would, but they were also asked to "think aloud" during use to point out any barriers, confusion, or helpful features of the exhibits. Data collectors noted any barriers or accessibility issues and grouped them into one of five categories: navigation/wayfinding, reach/use, information/instructions, comfort/aesthetics, and inclusion/independence.

Testing of the new swipe interface resulted in similar levels of interest and learning for visitors with disabilities as found during the evaluation with general museum visitors using the nonswipe version. Some visitors with disabilities also said that they felt overwhelmed by the amount of information in the exhibit, a comment that general Museum visitors had previously made about the exhibit. Visitors with disabilities faced some different challenges from the general Museum audience. Two visitors who are blind both swiped in the "wrong" direction while using "What's Your Opinion," expecting the swipe setup to be similar to their iPhones. Although the swiping progressed through the options in a loop, these visitors felt it was "wrong" because it proceeded from option 1 back to option 9, then option 8 (rather than 1, 2, and 3). They also both also asked for more repetition of the audio instructions. Several visitors (some with limited arm mobility) also had trouble with the swipe motion and accidentally selected things on more than one occasion.

The new swipe mode was also tested with general Museum visitors on August 22nd and 23rd, 2012. Similar to what was seen during the accessibility testing, six of eight groups accidentally

selected something at some point during the activity. However, participants also tended to explore all or most of the possible selections for each type of evidence. They were also generally interested in the activity, especially in the visitor data. The exhibition team will incorporate feedback on the swipe mode of "What's Your Opinion" as the *Provocative Questions* exhibit is prepared for a final installation.

3. ABOUT THE EXPLORATORY RESEARCH STUDY

As a part of the *PQ* grant, the Museum of Science agreed not only to prototype the *Provocative Questions* exhibit components but also to conduct an exploratory research study looking to answer the following questions:

- Will visitors engage in socio-scientific argumentation in an un-facilitated exhibit space, and are they aware that they are doing so?
- How do the un-facilitated exhibits impact visitors' socio-scientific argumentation skills?

This study began with a hypothesis that visitors would engage in socio-scientific argumentation in an un-facilitated exhibit space and that through this process their socio-scientific argumentation skills would improve. This exploratory research study looked to refine this hypothesis helping MOS to better understand *which* skills and knowledge visitors are better able to achieve in an un-facilitated exhibit space.

During the exploratory study, researchers collected data to understand which of the goals were more and less likely to be achieved by exhibition visitors to begin to learn whether visitors will engage in socio-scientific argumentation in an un-facilitated space. Additionally, comparisons were made between *Provocative Questions* visitors and other visitors who took part in a previous front-end study (Kollmann, Reich, Bell, & Goss, 2010) to understand the impact of the exhibit components on visitors' abilities to create arguments. The argumentation framework used to make these comparisons was a modified version of Toulmin's Argumentation Pattern (Toulmin, 1958) as adapted by Kolsto (2006). This abbreviated framework focuses on the three core elements of an argument: claims, data, and warrants. The framework posits that a socio-scientific argument is composed of a claim with supporting data (scientific evidence and personal experiences) connected to each other through a warrant (social value). This framework was used to understand if visitors were able to craft arguments composed of a claim with data and warrants (Impact 5e) and integrate scientific evidence into their arguments (Impact 5f). As stated previously, the goals of the *Provocative Questions* exhibition are the following:

- 1. *Awareness, knowledge, and understanding*. Visitors will be aware of science research applicable to varied views on the provocative question.
- 2. *Awareness, knowledge, and understanding.* Visitors will be aware of the different kinds of evidence that are frequently part of discussions of socio-scientific issues: scientific evidence, informal evidence based on personal experience, and societal / personal values.
- 3. *Awareness, knowledge, and understanding.* Visitors will understand that one's social values can influence one's interpretation of scientific evidence as well as one's position with regard to a socio-scientific question.

- 4. *Awareness, knowledge, and understanding.* Visitors will be aware that social decisions impact individuals differently because of their varied biological and environmental circumstances.
- 5. Skills. Visitors will practice socio-scientific argumentation skills, which include:
 - a. Discriminating between scientific evidence, personal experience/knowledge, and values,
 - b. Exploring the values underlying different viewpoints,
 - c. Reflecting critically about evidence from scientific research,
 - d. Recognizing potential counterarguments to a given argument,
 - e. Justifying one's position by using informal and scientific evidence with one's personal values and worldviews, and
 - f. Integrating scientific knowledge into arguments of socio-scientific issues.
- 6. *Other: Identity.* Visitors will come to see themselves as someone who can contribute to and participate in discussions of socio-scientific issues.

The goals for each of the *Provocative Questions* exhibit components were determined by the PQ team and refined through the formative evaluation process. The intended impacts for each component can be seen in Table 1 below. An "X" in the table represents any goal that the team thought could be achieved by a component. An "X" (X with a box around it) represents any goal that the team thought and formative evaluation indicated a component was likely to achieve, and an "[]" (empty box) marks any goal that formative evaluation indicated a component might achieve which was not mentioned by the project team as a specific goal of that component. This table reflects all of the formative evaluation. All of the components listed below except the Science Reading area were prototyped at least once. It should be noted that "Break It Down" and "What's Your Opinion" were prototyped multiple times, and the findings from all prototyping sessions are reflected in Table 1.

	Goals										
Components	1	2	3	4	5a	5b	5c	5d	5e	5f	6
Introductory panel		X									
Personal Experience panel		\mathbf{X}		Х	X						
Social Value panel		\mathbf{X}	Х	Х	X	\mathbf{X}					
Scientific Evidence panel	\boxtimes	\boxtimes			Х		X				
Science Reading area	Х						х				
"Break It Down"		\mathbf{X}		Х	X						
"What's Your Opinion"	\mathbf{X}	\mathbf{X}	X	Х	Х	X	X	X	X	X	X

TABLE 1. Goals likely to be achieved by each of the *Provocative Questions* components.

Note. X=identified by PQ team only; X=identified by formative evaluation and by PQ team;

II. METHODS

To answer the exploratory research questions posed, a range of data collection methods were employed. Some methods were based on those used in the front-end study (Kollmann, Reich, Bell, & Goss, 2010), others were used in order to understand if visitors achieved the exhibition's intended impacts, and others were adopted in order to capture the complex conversations that the *Provocative Questions* exhibition intended to stimulate. The exploratory research study used the following methods:

- 1. Visitor tracking and observations,
- 2. Exhibition exit interview,
- 3. Exhibition exit survey, and
- 4. Video- and audio-taping.

Data collection began on June 10, 2012, and finished on August 8, 2012. Data were collected in two-hour sessions during both mornings and afternoons. Until June 21, 2012, data collection occurred only on weekends, but after that, data were also collected on weekdays due to higher Museum visitation during the summer months. Video- and audio-taping began on July 9, 2012, and continued until August 4, 2012.

The target audience for the study was visitor groups of 2-5 people, where all group members were 13 years of age or older. To be able to conduct comparisons with the front-end study,² 88 groups were observed as they used PQ and interviewed and surveyed afterwards. Of those 88 groups, 30 groups were also video- and audio-taped (see Table 2). Because this study was meant to provide a "proof of concept" for the *Provocative Questions* exhibition, but not a summative evaluation of a finished exhibit, all visitors were cued to take part in the study. Researchers used a constant random sampling method to cue study participants. In this case, researchers cued the first visitor group fitting the above criteria to take part in the study. After completing the observation, interview, and survey, researchers cued the next eligible group that they saw.

	Number of Groups	Number of Individual
Evaluation Instrument		Visitors
Visitor tracking and observation	88	204
Exhibition exit interview	88 (same groups as above)	204 (same as above)
Exhibition exit survey	88	88
Video- and audio-taping	30	65

TABLE 2 Number of	f Groups and	Individuale	Darticinating in	Each Data	Collection	Method
TADLE 2. NUMBER C	n Groups and	individuals	Farticipating in	Each Dala	Conection	method

² Findings from the front-end evaluation and information about the sample were reported in Kollmann, E. K., Reich, C., Bell, L., & Goss, J. (2010). Using provocative questions to address societal health issues. *Museums & Social Issues*, 5(2), 175-190.

1. DATA COLLECTION INSTRUMENTS

The sections below describe the information collected as a part of each of the different data collection instruments. Full copies of the data collection instruments can be found in Appendices A - C.

1.1 Visitor tracking and observations

Visitors who were cued to use the *Provocative Questions* exhibition were observed during their interactions. Since the exhibition was placed near another exhibition space in the *Human Body Connection* area, data collectors informed participating visitors which exhibit components were part of the *Provocative Questions* exhibit before their interaction began. They were then instructed to use the exhibition as they normally would: they could visit whichever components of the exhibition they liked, in any order, for as long or short a time as they wanted.

The observation sheet tracked several behaviors. In addition to recording which exhibit components visitors used, the sheet also allowed for tracking specific behaviors at certain exhibit components. For example, during the "Break It Down" activity, visitors watched five videotaped statements and were asked to categorize each one as personal experience, social values, or scientific evidence. The players' answers were displayed onscreen after each question, so data collectors recorded which statements each visitor viewed as well as their answer to each of the questions. In addition, at "What's Your Opinion," data collectors observed how many steps of the activity groups completed, and at which points (if any) the group discussed the activity. Additional information was also collected about visitors' experiences at some of the other exhibit components. All 88 groups were observed, for a total of 210 visitors. A copy of the Visitor Tracking and Observation sheet can be found in Appendix A.

1.2 Exhibition exit interviews

When visitors finished using the *Provocative Questions* exhibition, they were asked to participate in a short interview. As a part of this interview, visitors were first asked some learning questions:

- What would you say the Museum is trying to have you learn about in these exhibits?
- What, if anything, did you learn from these exhibits that you didn't know before?

Next, visitors were asked to name the types of statements that can be used to support a viewpoint about a socio-scientific question. After this, if the visitor group had not used "Break It Down," they were asked to complete a sorting activity similar to the one presented in the exhibition. Six statements, different from the statements in the "Break It Down" exhibit component, were presented to the visitor on an iPad application that allowed for sorting. Visitors were asked to touch and drag notecards with the six statements on them into sections of the screen marked "Personal Experience," "Scientific Evidence," and "Social Value." The positions of the "notecards" on the iPad were randomly mixed up by the data collector after every use.

The next set of questions was drawn from the interview used during the front-end study. Here, visitors were asked to provide their opinion and any supporting statements about the question, "Should sugary drinks be taxed?" They were also asked to make a counterargument against their own viewpoint by arguing from the position of one of two avatars. The counterargument questions were not asked in the front-end study. Finally, they were asked to share their opinion and provide supports for a different provocative question, "Should there be restrictions on the use of antibacterial soaps and sanitizers?"

All 88 groups were interviewed, for a total of 204 visitors. The small discrepancy between the number of visitors interviewed and the number of visitors observed is due to a few instances of individual group members leaving the exhibit space before the exit interview. A copy of the Exhibition Exit Interview can be found in Appendix B.

1.3 Exhibition exit survey

At the end of the exit interview, one group member was asked to fill out a short survey containing eight statements. The statements were structured around the *Provocative Questions* "Awareness, knowledge, and understanding" goals listed in the previous section. Visitors were asked to rate their agreements with the statements on a scale of 1 to 7, with 1 being "Strongly Disagree" and 7 being "Strongly Agree." Some groups chose to read the survey and answer questions together. Besides filling out the Likert scale survey questions, group members who filled out the survey also reported their age, gender, race/ethnicity, and zip code. Groups who filled out the survey after videotaping began (after July 9, 2012) also answered a few extra questions in order to help researchers understand which Museum of Science audience clusters the groups fit in based on their motivations for visiting the Museum of Science. A copy of the Exhibition Exit Survey can be found in Appendix C.

1.4 Video- and audio-taping

A portion of those visitors observed and interviewed were also video- and audio-taped. Prior to the start of their interaction with the exhibition, visitor groups were asked if they would be willing to be video- and audio-taped while they used it. If they agreed, each group member signed a consent form and was given a lavaliere microphone to clip onto their clothing. They were then directed to use the *Provocative Questions* exhibition as they normally would and completed the Exhibition Exit Interview and Exhibition Exit Survey after they finished. Video- and audio-taped groups were offered two Exhibit Hall or Omnitheater passes in return for their participation. A total of 30 groups were videotaped, amounting to 65 individual visitors.

2. SAMPLE INFORMATION

As stated in the beginning of the Methods section, visitors were considered eligible for the exploratory research study if they were a part of a visitor group of 2-5 people where all group members were over the age of 13. Groups were recruited near the *Provocative Questions*

exhibition using a continuous random sampling method, where data collectors approached each eligible visitor group in the order they entered the space. Data collectors asked these groups if they would be interested in viewing the exhibition and answering questions about it afterward. If they said yes, they were told which components were a part of the exhibition, and then allowed to use the space as they saw fit. During the video- and audio-taping phase, eligible groups were approached and asked the same thing, and then asked if they would be willing to have their interaction with the exhibition video- and audio-taped. At this point, they were also offered two Exhibit Hall or Omni Passes in exchange for the extra time involved in video- and audio-taping. If they did not want to be videotaped, they were offered the opportunity to use the exhibition and participate in the study without being recorded, and were interviewed afterward as usual. To prevent approaching the same group more than once, participating visitors were given stickers after completing their participation.

Since *Provocative Questions* was intended to stimulate conversation about socio-scientific issues, individual visitors were not eligible. Groups larger than five people were also not eligible, due to the available number of lavaliere microphones for videotaping. Researchers also thought that groups larger than five people would have trouble effectively using "What's Your Opinion." The table below shows the distribution of the sizes of groups that used the *Provocative Questions* exhibition. Two-person groups were by far the majority, and only a few groups had more than three people (Table 3).

Group Size	Number of Groups	Percent of Groups
2 people	66	75.0%
3 people	13	14.8%
4 people	6	6.8%
5 people	3	3.4%
Total	88	100%

TABLE 3. Sizes of Groups Included in the Study Sample.

Group size is just one factor that can affect the dynamics of conversation; groups containing people of different ages or sexes might also have different types of conversations. The sample of *Provocative Questions* visitors from the exploratory research study contained visitors with a broad range of ages, with the oldest visitor being a 78-year-old and the youngest being a 9-year-old. The median visitor age was 25 years old (Table 4).

Visitor Description	
Minimum Age of Visitors	9
Maximum Age of Visitors	78
Mean Age of Visitors	31
Median Age of Visitors	25
	Number of Visitors
Under 18	32
18-24	67
25-29	29
30-34	13
35-44	22
45-54	17
55-64	16
65-74	7
75-84	1
85 or older	0

In terms of gender, the overall sample contained 116 females (56.9%) and 88 males (43.1%). The sample contained more female adults than male adults as well as more female children than male children. Most visitors in the sample were adults (84.3% of total), and most of those adults were adult females (54.7% of adults, 94 of 172). Table 5 summarizes the sexes of visitors who participated in the *Provocative Questions* exploratory study. To see if the sex distribution was similar to that of general Museum visitors, the sex distribution data were compared to the overall sex distribution data from the Visitor Experience Monitoring Project survey for Fiscal Year 2012 (Cahill, 2012). It was found that there were no statistical differences between the overall sex distributions of these two groups.

Sex	Number of Visitors	Percent of Total
Male Visitors	88	43.1%
Male Adults	78	38.2%
Male Children	10	4.9%
Female Visitors	116	56.9%
Female Adults	94	46.1%
Female Children	22	10.8%

TABLE 5. Sexes of Provocative Questions Visitors who Participated in the Exploratory Research Study Split by Adults and Children (N=204).

Group composition was another factor that could impact group dynamics. A group of adults might have different types of conversations than a group made up of adults and children. Researchers recorded if each group using the exhibit was made up of only adults, only children, or both adults and children. Table 6 shows the number and percentage of adult only, adult and

child, and child only groups who used the *Provocative Questions* exhibit as members of the study sample.

 TABLE 6. Group Composition of Provocative Questions Visitors who Participated in the Exploratory Research Study, Split by Adults and Children (N=88).

Group Composition	Number of Groups	Percent of Groups
Adults only	65	73.8%
Adults and children	22	25.0%
Children only	1	1.1%

3. DATA ANALYSIS

The data collected were analyzed using both qualitative and quantitative techniques. Quantitative data were analyzed using descriptive statistics (counts, percentages, and averages). Qualitative data were coded inductively as well as using pre-defined codes. Questions about visitor learning and component messages were coded against exhibit messages and inductively. The two questions coded this way were the following:

- What would you say the Museum is trying to have you learn about in these exhibits?
- What, if anything, did you learn from these exhibits that you didn't know before?

In order to code the responses to these questions, researchers first coded visitor responses against activity messages. Next, they looked across the remaining responses for common themes that became the codes for that data. The visitor learning questions were coded by one person, and then a random sample of 10% of the data was coded by a different person and checked for inter-coder reliability. This process was repeated and the codes were refined until inter-coder reliability was greater than 75%. The visitor learning questions were then coded by two separate researchers.

Questions about visitor arguments were coded using existing code books developed during analysis of the front-end data. These code books defined codes for a visitor's claim, data (scientific evidence and personal experiences), and warrants (values). The questions that used these code books included those that asked visitors to articulate their arguments about the socioscientific questions "Should sugary drinks be taxed?" and "Should there be restrictions on the use of anti-bacterial soaps and sanitizers?" The questions used to understand visitors' arguments about these questions were the following:

- What is your opinion about this topic?
- Can you explain to me why you feel this way?
- What information, data, or evidence do you have to support your point of view?

These code books were also used to code visitors' responses to questions that asked them to articulate evidence for a counterargument about taxation of sugary drinks. Those questions were the following:
- Andrea is a mother of two small children. She tries to make sure that her kids have a healthy diet. She is for taxing sugary drinks.
 - Why might Andrea think that sugary drinks should be taxed?
 - What values might Andrea hold that led her to this viewpoint?
 - What science evidence could Andrea use to support her point of view?
- Jeff is a teenager trying to complete high school and hold down a part-time job. He is against taxing sugary drinks.
 - Why might Jeff think that sugary drinks should not be taxed?
 - What values might Jeff hold that led him to this viewpoint?
 - What science evidence could Jeff use to support his point of view?

For all of these questions, researchers used a consensus coding method (Jenson, 2011), where they discussed each piece of data together and then came to a common understanding of which code fit the data best. More information about the argument coding rubrics can be found in Appendix E.

Chi-Square test statistics were conducted on data about visitors' arguments about the socioscientific questions "Should sugary drinks be taxed?" and "Should there be restrictions on the use of anti-bacterial soaps and sanitizers?" to understand if exhibition visitors were more likely to include values, scientific evidence, and personal experience in their arguments than non-users who were a part of the front-end study. Results were considered significant if p-values were less than or equal to 0.05. It should also be noted that individual visitors who did not give a discernible claim or groups where no one gave a discernible claim was found within their answers to the argumentation questions were removed from the dataset when analyzing the argument data.

The recorded videos were analyzed using the qualitative analysis software NVivo. Videos were coded primarily against the exhibition goals, and evaluators made note of any additional themes that emerged. In order to generate these codes, researchers watched multiple videos together in order to create a code book. After agreeing on evidence for each of the codes, one researcher coded the rest of the videos on her own. Videos were used to give researchers a better understanding of visitor conversation in general, as well as to provide supporting evidence for findings emerging from other data sources. Narratives relating to video data are presented throughout this report.

III. RESULTS AND DISCUSSION

This section of the report describes findings from the *Provocative Questions* exploratory research study. Findings are organized based on the two exploratory research questions, which were the following:

- 1. Will visitors engage in socio-scientific argumentation in an un-facilitated exhibit space, and are they aware that they are doing so?
- 2. How do the un-facilitated exhibits impact visitors' socio-scientific argumentation skills?

Other findings from the research will follow these two sections. Throughout the Results and Discussion section, the experiences of videotaped visitors are highlighted in order to illuminate exploratory research findings.

1. WILL VISITORS ENGAGE IN SOCIO-SCIENTIFIC ARGUMENTATION IN AN UN-FACILITATED EXHIBIT SPACE, AND ARE THEY AWARE THAT THEY ARE DOING SO?

In order to learn how the use of *Provocative Questions* impacted visitors' engagement in socioscientific argumentation, as well as determine visitors' awareness of their use of these skills, researchers collected observation data of visitors' usage of the exhibition. In addition, researchers interviewed visitors who had just visited the exhibition and asked questions related to their achievement of the exhibition goals. The sections below provide findings regarding visitors' practice of socio-scientific argumentation skills as well as visitors' learning. These data indicate that visitors were not only practicing socio-scientific argumentation, but were also aware of this fact. Findings include the following:

- 1.1 While using *Provocative Questions*, visitors practiced socio-scientific argumentation skills by thoroughly using almost all of the exhibits.
- 1.2 While using *Provocative Questions*, visitors practiced the socio-scientific argumentation skills of discriminating between types of argument supports and exploring the reasoning behind different viewpoints.
- 1.3 Visitors learned about socio-scientific argumentation through their experience with *Provocative Questions*.
- 1.4 Visitors learned about science research through their experience with *Provocative Questions*.

1.1 While using Provocative Questions, visitors practiced socio-scientific argumentation skills by thoroughly using almost all of the exhibits.

In order to determine the extent to which visitors were able to practice socio-scientific argumentation skills, researchers collected data regarding visitors' exhibition usage. Analysis of these data show that visitors used almost all the components in the space, especially "Break It Down," the Social Values panel, and "What's Your Opinion." Visitors not only interacted with multiple components, but often used them completely.³ This provides evidence that visitors achieved all the argumentation skills goals (Goals 5a-f: "Visitors will practice socio-scientific argumentation skills").

Table 7 identifies the number and percentage of groups visiting each exhibit component. While very few groups visited the Science Reading Area (4.5%, 4 of 88 groups), the remaining exhibit components were used by at least half of all observed groups. The three exhibit components which were most visited include "Break It Down" (84.1%, 74 of 88 groups), the Social Values panel (85.2%, 75 of 88 groups), and "What's Your Opinion" (94.3%, 83 of 88 groups).

Science Reading Area	Introductory Panel	Scientific Evidence Panel	Personal Experience Panel	Break it Down	Social Values Panel	What's Your Opinion
4	44	60	68	74	75	83
(4.5%)	(50.0%)	(68.2%)	(77.3%)	(84.1%)	(85.2%)	(94.3%)

Not only were "Break It Down," the Social Values panel, and "What's Your Opinion" visited by the majority of groups, but many visitors also completed the entire interaction that was a part of these exhibit components. Of the groups who visited the Social Values panel, nearly half completed the activity (49.3%, 37 of 75), and over half of the groups who visited "What's Your Opinion" used the component completely (65.1%, 54 of 83) (Table 8). Data collectors observed individual visitors using "Break It Down" in order to record their answers. From these observations, researchers concluded that over two-thirds of individual visitors (67.8%, 103 of 152) used this exhibit component to completion while in the space (Table 9).

³ Visitor groups were counted as completing the Social Values panel if they looked at all three sample questions and moved at least one slider per question. Visitor groups were counted as completing "What's Your Opinion" if they looked at the visitor data and got to the final screen. Individual visitors were counted as completing "Break It Down" if they answered all five available statements.

TABLE 8. Number and Percentage of Visitor Groups Completing the Social Values Panel and "What's Your Opinion".

Number of Groups completing Social Values Panel (n=75)	Percent of Groups completing Social Values Panel	Number of Groups completing "What's Your Opinion" (n=83)	Percent of Groups completing "What's your Opinion"
37	49.3%	54	65.1%

TABLE 9. Number and Percent of Individual Visitors Completing "Break it Down" (n=152).

Number of Visitors Completing	Percent of Visitors Completing	
"Break it Down"	"Break it Down"	
103	67.8%	

These findings indicate that visitors who were a part of the *Provocative Questions* study thoroughly used the exhibition, visiting most of the exhibit components and using them completely. This provides evidence that visitors were provided the opportunity to practice all of the argumentation skills that were a part of the exhibition, and that they were engaging in socio-scientific argumentation in an un-facilitated exhibition space.

Video Story 1:

Group 71 used all the components in the space and exhibited all skill goals.

Kyle and Brian, both 28 years old, visited all of the exhibit components except for the Science Reading Area. The pair started at the Introductory panel, reading through the examples of provocative questions, and quickly moved on to the Social Values panel. They engaged with all three questions at the values panel, mostly exploring their values, but also integrating some outside scientific evidence, such as the potential ramifications of people being able to assess their own need for anti-depressants. In regards to one question, "Should parents receive prenatal genetic information about their future children?" Brian said, "I don't feel informed enough on this issue." Brian also introduced the idea that different people may be affected differently by the government adding fluoride to the water supply. His example compared children with adults, as he said that children with "ignorant parents" may not be able to make informed decisions. Brian and Kyle had little conversation at the other panels and eventually moved to "What's Your Opinion."

At "What's Your Opinion," Brian and Kyle did not share their reasoning for why a tax on sugary drinks would personally affect them, but discussed many of the science articles. They reflected critically about the findings of some of the studies, mentioning the difference between causal and correlative interpretation of data. When they were explaining their reasoning behind choosing their scientific evidence, Brian again brought up the idea of individuals being impacted differently by a sugary drink tax, stating that "it seems like an individual decision, but it's affecting people who don't necessarily have the logical capacity to decide what is best for them long-term." He also explained that "when everybody's obesity and heart disease and hypertension risks are in the system... that increases health care costs for everybody." When Kyle asked how his ideas connected with a sugary drink tax, Brian said, "I don't think people can make good long-term decisions unless given a good short-term financial incentive." Brian also provided an example of how financial incentives can work by sharing a personal experience: when gas was \$5 per gallon, he chose to carpool instead of drive.

Continuing their "What's Your Opinion" interaction, they preceded to the values statements, where they both chose "We should be wary of what manufacturers put in food." They discussed manufacturers putting chemicals into food just to profit. Here, Brian stated, "I care about this more than I care about the obesity problem." And Kyle added, "Maybe if we were wary of what they put in food and drinks then maybe this problem wouldn't be as prevalent as it is." When it was time to choose whether sugary drinks should be taxed or not, both Brian and Kyle chose "I can't decide." They continued the conversation here when Brian stated that he believed subsidizing healthy food would be a better solution to the obesity problem. When talking about this, Brian went back to look at a scientific evidence article which found that taxing tobacco resulted in an increase in eating and obesity. He refers to this article to support his case that people will find something to abuse, so healthy food should be more accessible and affordable.

Lastly, Kyle and Brian visited "Break It Down," where they differentiated between types of evidence. Both visitors in this group were critical of what was considered scientific evidence during the activity because the speaker did not reference any studies.

1.2 While using Provocative Questions, visitors practiced the socio-scientific argumentation skills of discriminating between types of argument supports and exploring the reasoning behind different viewpoints.

Through the exploratory research study, researchers sought to determine which socio-scientific argumentation skills visitors were more and less likely to practice. The previous section provides evidence that visitors had the opportunity to practice all of the argumentation skills that were included in the exhibition goals because they used most of the exhibit components in the space. Further examination of data collected through observations, interviews, and video recordings provides evidence that visitors were generally able to discriminate between the different kinds of socio-scientific argument supports (goal 5a) as well as explore the reasoning behind different viewpoints (goals 5b and 5d).

Researchers' observations of visitors' usage of "Break It Down" indicate that visitors were generally able to correctly discriminate between the different kinds of socio-scientific argument supports (personal experience, social values, and scientific evidence). Figure 18 shows visitor responses to the statements provided through the "Break It Down" activity.⁴ Although most statements in "Break It Down" were correctly identified by the majority of visitors (64.6% or more), the scientific evidence statement was most difficult for visitors to correctly identify. Fewer than half of the observed visitors (36.8%, 46 of 125) correctly identified this statement, and in fact, more visitors actually identified this statement as personal experience (46.4%, 58 of 125). It is possible that the scientific evidence statement was most difficult for visitors to identify because it did not include words or phrases that visitors associated with something considered scientific evidence. As mentioned in the section on exhibition development, the Provocative Questions team attempted to craft statements in a colloquial style, similar to a statement that you might hear from a friend. However, visitors' comments while using the component suggest they might have benefitted from more technical language. For example, after incorrectly identifying this statement, one visitor said "I didn't know she was a researcher" while another said "She's not citing anything." Another possible reason for this difficulty could be that it appeared as the first statement of the activity. Nevertheless, these data indicate that while using the Provocative Questions exhibition visitors were generally able to discriminate between different types of socio-scientific argument supports.

⁴ Because "Break It Down" consisted of three stations, observations were recorded for up to three visitors per group.



FIGURE 18. Visitors' Identification of Support Type while using "Break It Down."⁵

Visitors who did not use "Break It Down" were asked to complete a card sort activity during the interview, similar to the activity that was a part of the exhibition, in which they identified six statements as personal experience, scientific evidence, or social values. Similar to "Break It Down," visitors were generally able to successfully sort these statements into the correct category. However, as shown in Figure 19, more visitors were able to correctly categorize the statements that were part of the card sort activity, with at least 86.7% (13 of 15) correctly identifying all of the types of evidence used to support an argument. Because the sorting activity contained different statements than "Break It Down," it is possible that the statements within the card sort activity, particularly the two scientific evidence statements, were written in such a way that they were more in line with visitors' expectations. It is also possible that visitors had an easier time with the card sort because statements were written down and could be processed as a group instead of one-by-one. Still, these findings indicate that while and after using the *Provocative Questions* exhibition a majority of visitors were able to correctly discriminate

⁵ The statements used in the interview as presented in Figure 18 were:

[•] Statement 1: Absolutely. All sugar does is add calories; it doesn't even satisfy our appetites. (Scientific Evidence)

[•] Statement 2: Absolutely. I have a friend who has diabetes, and she's pretty sure she got it from the drinks. (Personal Experience)

[•] Statement 3: I wouldn't want them to be taxed; I don't think that I should be charged for other peoples' stupidity. (Social Value)

[•] Statement 4: I think we should tax sugary drinks, because it would protect peoples' health, and it would be good for us in the long run. (Social Value)

[•] Statement 5: I do. I'm a teacher, and I see far too many overweight children each year. (Personal Experience)

between personal experience, social value, and scientific evidence statements, which are often used as supports for socio-scientific arguments.



FIGURE 19. Visitors' Identification of Support Type during the Exhibition Exit Interview Card Sort Activity (n=15).⁶

Another socio-scientific argumentation skill visitors seemed likely to practice was that of exploring the reasoning behind others' viewpoints. During interviews, visitors were presented with a fictional character who had a viewpoint opposite that of the visitor and were then asked why the character might feel that way. For example, if the visitor was against taxing (as identified through a previous interview question), he/she was introduced to Andrea, who thought sugary drinks should be taxed. This visitor was then asked about the values and science that Andrea might use to support her point of view. Results of this exercise show that the majority of visitor groups were able to articulate a value or scientific evidence applicable to a claim that is the opposite of their own. In other words, they were able to articulate supports for

• Statement 2: I drink a six pack of soda every day and I'm healthy. (Personal Experience)

• Statement 4: Companies that make these things should pay for the problems they cause. (Social Value)

Note. The correct answer to the statement is presented in parentheses after each statement number.

⁶ The statements used in the interview as presented in Figure 19 were:

[•] Statement 1: My friend drinks soda to keep awake for late night studying. (Personal Experience)

[•] Statement 3: The government should stay out of personal decisions like what we choose to drink. (Social Value)

[•] Statement 5: Studies have shown a direct relationship between drinking sugary drinks and obesity. (Scientific Evidence)

[•] Statement 6: Health costs related to obesity total more than a hundred billion dollars every year. (Scientific Evidence)

counterarguments, indicating that the exhibition helped them to understand the reasoning behind viewpoints other than their own (see Table 10).

When making a counterargument case against taxing, over three-fourths of visitor groups (78.4%, 29 of 37) included a value while over half (56.8%, 21 of 37) included science in their counterarguments (see Table 10). For example, while making a case against taxing, one visitor offered the value "He can drink in moderation and shouldn't be punished for others not doing so. He's not thinking about the greater community." Another visitor group suggested that this fictional character who was against taxing could use science, saying "cigarettes were taxed, obesity went up. Taxing sugary drinks might have a negative effect on the population." It is interesting to note that this quote mentions the scientific evidence from one of the research studies provided in "What's Your Opinion."

For those making a counterargument case in support of taxing, over two-thirds (70.8%, 34 of 48) of visitor groups included a value while almost all (93.8%, 45 of 48) included science in their counterarguments (see Table 10). For example, when asked for a social value that the character who supports taxing might hold, one visitor offered "the social value that community is responsible for the individual." When asked about science, visitors frequently mentioned the health implications of sugary drinks. For example, one visitor said "having soda leads to weight gain and diabetes," while another group mentioned "a lot of sugary drinks contribute to childhood obesity."

Counterargument	Used Valu	ue to Support	Used Science to Support		
	Counte	erargument	Counterargument		
	Number of	Percent of	Number of	Percent of	
	Groups	Groups	Groups	Groups	
Against Taxing (n=37)	29	78.4%	21	56.8%	
For Taxing (n=48)	34	70.8%	45	93.8%	

TABLE 10. Number and Percent of Interviewed Visitor Groups Able to Correctly Articulate Social Values and Scientific Evidence to Support Counterarguments.

The analysis of visitors' conversations as captured through the videos as well as their responses to four Likert scale questions provides further evidence of visitors' achievements of the exhibition's skill goals. Specifically, these data provide further evidence that the PQ exhibition gave visitors the opportunity to explore the reasoning behind different viewpoints.

Of the visitor groups recorded in the exhibition, 26 of 29 (89.6%) displayed the skill "exploring values underlying different viewpoints." This occurred frequently at the Social Values panel as well as "What's Your Opinion." In addition, almost half of the recorded groups (44.8%, 13 of 29) displayed evidence that they were recognizing potential counterarguments. For example, sometimes this occurred as visitors used "What's Your Opinion" when different members of a visitor group discovered that they had different viewpoints or when they encountered different viewpoints provided by previous visitors.

Finally, the exhibition exit survey indicated that *Provocative Questions* provided visitors with the opportunity to explore others' viewpoints. During the survey, visitors were asked to rate their agreement with a series of statements on a 7-point scale where 1 was "Strongly Disagree" and 7 was "Strongly Agree." Table 11 displays visitors' responses to statements related to exploring the reasoning behind different viewpoints. These data indicate that the vast majority of survey respondents "Agreed" or "Strongly Agreed" with the statement "A person's values can influence whether or not they believe a piece of scientific evidence" (91.1%, 80 of 88) as well as the statement "A person's values can influence whether they are for or against taxing sugary drinks" (94.3%, 83 of 88). It is possible that visitors responded with high agreement to these two statements because they already believed that values impact people's belief in science and their claim even before they used the exhibition. However, it may also be that this finding was observed because the exhibition provided visitors with the opportunity to see and understand the different values that various visitors hold about the socio-scientific question "Should sugary drinks be taxed?"

TABLE 11. Visitors' Responses to Exhibition Exit Survey Likert Scale Rating Questions (N=88).

	Mean	Standard Deviation	Number of Respondents Choosing 6 or 7	Percent of Respondents Choosing 6 or 7	
A person's values can influence whether or not they believe a piece of scientific evidence	6.34	.969	80	91.1%	
A person's values can influence whether they are for or against taxing sugary drinks.	6.53	.710	83	94.3%	

Note. Visitors were asked to rate their agreement with statements on a 7-point scale where 1 is "Strongly Disagree" and 7 is "Strongly Agree."

These data indicate that through the *Provocative Questions* exhibition visitors practiced the socio-scientific argumentation skills of discriminating between types of argument supports including personal experience, social values, and scientific evidence. Visitors correctly categorized statements into these three categories, yet may have had some difficulty correctly sorting scientific evidence because of the way it was presented in the exhibition. It is also possible that in normal conversations visitors have a harder time distinguishing science from personal experiences or values. In addition to discriminating between the types of supports, this study found that visitors explored the reasoning behind others' viewpoints while using the exhibition. It is unclear whether visitors came to the exhibition with this skill or learned it through *Provocative Questions*. Nevertheless, the data provide evidence that the exhibition provided visitors with an opportunity for further practice of this skill.

1.3 Visitors learned about socio-scientific argumentation through their experience with Provocative Questions.

In order to better understand what visitors learned through the exhibition, two questions were posed on the exhibition exit interview. Researchers asked visitors what the exhibition was about as well as if they had learned anything new in the exhibition. Looking across these data, 74% of visitor groups (65 of 88) responded either that the exhibition was about or that they had learned about elements of socio-scientific argumentation. This was the most common theme seen across these two questions. Further information about the individual responses to these two questions can be found in Appendix F.

The types of responses about socio-scientific argumentation most often referenced the formation of opinions (52%, 46 of 88 groups). For example, visitors commented on how people form opinions or learning about other visitors' opinions.

- [F1, 24]: "Forming opinions." [M1, 24]: "Different ways we form our opinion."
- [M1, 22]: "[I learned that] most people think what I think. We're conscious of health and stuff. So we know a lot about that."
- [M1, 27]: "Not a lot of people share the same ideas as me."
- [F1, 25]: "Formation of opinions." [M1, 25]: "Being able to make decisions for yourself."

Other types of responses about socio-scientific argumentation discussed how to use the three types of argument supports (39%, 46 of 88 groups). Many groups mentioned the three supports by name, citing personal experience, social values, and scientific evidence.

- [M1, 20]: "How opinions are generated between personal experience, social values, and scientific evidence." [M2, 58]: "Focus on, these are the three key parts of an argument." [M1, 20]: "The taxation question is just an example."
- [M1, 78]: "To see, social values, experience, science. That was interesting to learn."
- [F1, 23]: "It made me think more about my personal experience, how it influences my opinion more than I thought."
- [F1, 29]: "What goes into deciding." [M1, 30]: "How people are basing their opinions."

Not only did visitors mention the three types of argument supports as something they learned, they were also able to recall the names of all three types after using *Provocative Questions*. When asked to name the different kinds of statements described within the exhibition that can be used to support a viewpoint about taxation of sugary drinks, over three-quarters of groups were able to correctly name scientific evidence (77.3%, 68 of 88) and personal experience (76.1%, 67 of 88). Additionally, about two-thirds of groups were able to name social values (65.9%, 58 of 88). Looking across these responses, nearly two-thirds of visitor groups (62.5%, 55 of 88) were able to identify all three types of supports correctly in their answers (see Table 12).

TABLE 12. Visitor Groups' Responses to the Open-Ended Exhibition Exit Interview Question: "In the exhibits, different kinds of statements were described that can be used to support a viewpoint about taxation of sugary drinks. Can you please tell me what they were?" (N=88).

Group Identifies	Number of Groups	Percent of Groups	
Personal Experience	67	76.1%	
Scientific Evidence	68	77.3%	
Social Values	58	65.9%	
All 3 Types of Evidence	55	62.5%	

These data signify that visitors learned about socio-scientific argumentation through their experience with *Provocative Questions*. This is categorized by visitors' responses about the formation of opinions as well as the three types of argument supports. Whether in closed or open-ended responses, visitors often articulated the three argument supports by name. These data indicate that not only were visitors practicing socio-scientific argument while using *Provocative Questions* as described in the previous findings sections, but that they were also aware that they were doing so, thereby achieving goal 2 of the exhibition.

Video Story 2:

Group 66 learns about forming opinions and socio-scientific argumentation.

Alexis, 15 years old, and Jim, 66 years old, visited the Social Values panel, the Personal Experience panel, the Scientific Evidence panel," and "What's Your Opinion." As they were exploring their values at the Social Values panel, Jim said he considered himself to be a big believer of individual freedoms. He also admitted that this experience was not just about his opinion, telling Alexis that her opinion did not have to be the same as his. A child from another group interrupted their experience at the Social Values panel by pushing the button that switched the questions. This led Jim and Alexis to move on to the Personal Experience panel, where they thought about whether sugary drinks should be taxed. Alexis said that a tax would not affect her, but immediately brought up her brother who she thought that it would affect. Jim agreed that her brother drinks a lot of sugary drinks and would be affected by a tax.

They continued to the Scientific Evidence panel. Here, Jim brought up his experience smoking a pipe, referring to the health consequences of tobacco use. As they discussed their viewpoints at "What's Your Opinion," it was obvious that Alexis and Jim had differing opinions on the topic of taxing sugary drinks. Alexis said that the tax would not affect her since she never drinks sugary drinks, while Jim admitted that he did drink them sometimes and would be affected. When prompted to choose a science article to support their case, Alexis chose the study relating weight gain to consumption of sugary drinks whereas Jim chose the study about the importance of glucose for cognitive function. Immediately after Jim shared which scientific evidence he chose, Alexis brought up a counterargument, saying, "but you can get glucose in a lot of other places that's not sugary drinks." Jim considered this and agreed that his scientific evidence seemed weaker than the study that Alexis chose. At the end of the activity, Alexis said "I like [my final case]. It's solid."

1.4 Visitors learned about science research through their experience with Provocative Questions.

Awareness of science research applicable to varied views on the socio-scientific question was goal 1 of the *Provocative Questions* exhibition. In addition to learning about socio-scientific argumentation, there is evidence that visitors also learned about science research. In response to the two interview questions related to learning, 47% of visitor groups (41 of 88) responded either that the exhibition was about science research or that they had learned about it through using the exhibit. This was the second most common theme found across the two open-ended learning questions on the interview. Further information about the individual responses to these two questions can be found in Appendix F.

The types of visitor responses about science research were most often that science is applicable to varied views on the socio-scientific question or that varied science is available (28%, 25 of 88 groups). In describing what they learned about science research, visitors often mentioned one of the research studies included in "What's your Opinion." For example, one visitor said "when people increase tax on cigarettes, there was an increase in obesity" while a visitor from another group said he learned about the "correlation between tax of tobacco and how people react to it." Other examples include:

- [M1, 56]: "The tobacco thing, people ate more after tobacco taxes."
- [M1, 20]: "I didn't know the tax on tobacco lead to the increase in eating and obesity."
- [F1, 19]: "More about sugary drinks...Something about not causing cancer, like with artificial sugars, in an Italian population."
- [F1, 23]: "People increase in eating things after they quit tobacco use."

Other types of responses about science research were focused on the socio-scientific topic presented in the exhibition. In this instance, 26% of visitor groups (23 of 88) mentioned that the Museum was trying to have them learn about the health impacts of sugary drinks. Some examples of visitor responses include the following:

- [F3, 18]: "Think about health effects of these drinks."
- [M1, 22]: "Be aware of what ingredients are in sugary drinks."
- [M1, 11]: "Sugary drinks aren't good for you."
- [M1, 33]: "The possible health ramifications of obesity caused by sugary drinks."

These data suggest that for some visitors the *Provocative Questions* exhibition provided an opportunity to learn not only about socio-scientific argumentation, but also about science research. The *PQ* team struggled with the balance of these two objectives throughout the exhibition development process. However, this evidence indicates that visitors understood that the purpose of the exhibition overall was to help them practice their socio-scientific argumentation skills while a side benefit was that they also got to learn about new science research.

Video Story 3:

Group 47 talked about the scientific evidence provided as well as their own science knowledge.

Greg, 31 years old, and Amy, 33 years old, spent about 45 minutes in the exhibit area, visiting everything except for the "Science Reading Area." Throughout their experience, Greg and Amy emphasized science content, including discussing the articles provided in the exhibit, bringing in outside science information, and reflecting critically on scientific findings. They started their visit at the Introductory panel, where they talked about each of the examples of provocative guestions and constantly referred to outside science information. For example, when referring to the question about prenatal genetic testing, they talked about a friend who tested the viability of frozen embryos and connected this work to the question. At the Social Values panel, Greg and Amy incorporated personal experience (being required to use fluoride mouthwash in elementary school) and science content (carrier screenings that sequence the parents' DNA before embryos are even created) into their discussions. They moved on to the Scientific Evidence panel, where they reflected on an article about sugary drinks curbing appetite. Amy asked how soda related to appetite, which prompted Greg to explain the scientific processes surrounding hunger and sugary drinks. This study connecting sugar to appetite reminded Greg of a diet that he had tried. He referenced this diet in his conversation with Amy, further explaining the science behind appetite. They continued to discuss the science of this diet as they walked over to "What's Your Opinion."

The majority of Greg and Amy's conversations at "What's Your Opinion" involved critical reflections about the articles provided as scientific evidence. They spent about five minutes talking about many of the science articles provided, where they reflected upon methodology and findings. These discussions included general comments such as "The pieces of evidence here are not very good" and specific comments such as "I wish I could have seen how much the price increased in this study" and "Fifteen people? Is that statistically significant?" Amy also brought up some unhealthy aspects of soda aside from sugar content, saying "soda still has carbonic acid that is not doing great things for your teeth." Amy and Greg spent just as much, if not more, time exploring the analysis portion of the activity as they did building their cases. They were trying to understand other visitors, empathizing with their views, and trying to explain how visitors built their arguments. They discussed what visitors could have been thinking to put a specific piece of scientific evidence with a specific value statement and they also tried to explain the general trends that they were seeing in the visitor data.

2. HOW DO THE UN-FACILITATED EXHIBITS IMPACT VISITORS' SOCIO-SCIENTIFIC ARGUMENTATION SKILLS?

In order to learn how the use of *Provocative Questions* impacted visitors' socio-scientific argumentation skills, researchers compared arguments made by visitors who visited the exhibition between June and August 2012 to those who did not visit the exhibition, but participated in a front-end study conducted in October 2009 and July 2010.⁷ In order to capture

⁷ Findings from the front-end evaluation were reported in Kollmann, E. K., Reich, C., Bell, L., & Goss, J. (2010). Using provocative questions to address societal health issues. *Museums & Social Issues*, 5(2), 175-190.

visitors' arguments, researchers asked these visitors to take part in a structured interview that was used to understand the claims, data (scientific evidence and personal experiences), and warrants (social values) that were a part of their arguments for two socio-scientific questions: one of which was the *PQ* socio-scientific issue at the time of exploratory testing ("Should sugary drinks be taxed?"), and one of which was not ("Should there be restrictions on the use of antibacterial soaps and sanitizers?"). The answers to these questions were analyzed based on the *Provocative Questions* argumentation framework which is a modified version of Toulmin's Argumentation Pattern (Toulmin, 1958) as adapted by Kolsto (2006). This abbreviated framework focuses on the three core elements of an argument: claims, data, and warrants. The framework posits that a socio-scientific argument is composed of a claim with supporting data (scientific evidence and personal experiences) connected to each other through a warrant (social value). More information about the argument coding rubrics can be found in Appendix E.

The sections below are split based on findings about how the exhibits impacted visitors' socioscientific argumentation skills. Those findings include the following:

- 2.1 Visitors, who used the PQ exhibition, were more likely to say they were unsure of their position about taxation of sugary drinks than visitors who had not used the exhibition.
- 2.2 Groups, who used the PQ exhibition, were more likely to include scientific evidence and social values in their arguments about taxation of sugary drinks than groups who had not used the exhibition.
- 2.3 Groups, who used the PQ exhibition, were more likely to include scientific evidence in their arguments about restrictions on the use of anti-bacterial soaps and sanitizers than groups who had not used the exhibition.

2.1 Visitors, who used the PQ exhibition, were more likely to say they were unsure of their position about taxation of sugary drinks than visitors who had not used the exhibition.

Visitors, who took part in either the front-end or exhibition exit interviews, were asked a series of questions in order to understand their opinion about the question "Should sugary drinks be taxed?", why they felt this way, and what information, data, or evidence they had to support this point of view. Researchers looked at the responses to all of these questions to learn visitors' claims, scientific evidence and personal experience data, and social value warrants. Claims were coded as "Yes, sugary drinks should be taxed," "No, sugary drinks should not be taxed," or "I'm not sure if sugary drinks should be taxed." After coding these responses, it was found that, across both the front-end and exhibition exit interviews, visitors most commonly reported that they were against taxation of sugary drinks (front-end interview: 58.3%, 49 of 84; exhibition exit interview: 50.8%, 97 of 191). For example, when asked their opinion of the topic, visitors'⁸ responses indicating that they held a claim that sugary drinks should not be taxed included statements such as the following:

• "I don't think so."

⁸ All the group responses reported in this section came from the exhibition exit interviews although their content is representative of front-end responses as well.

- "No."
- "Against."

The second most common claim that visitors, who both visited and did not visit the PQ exhibition, gave was that sugary drinks should be taxed. Just over one-third of the visitors, who participated in the interviews, reported that they thought sugary drinks should be taxed (front-end interview: 38.1%, 32 of 84; exhibition exit interview: 34.6%, 66 of 191). When asked their opinion of the topic, the kinds of statements visitors used that indicated that they held a claim that sugary drinks should be taxed included the following:

- "For."
- "Yes, tax them."
- "I think so."

Finally, across the two visitor groups, participants were least likely to say that they were unsure whether sugary drinks should be taxed (front-end interview: 3.6%, 3 of 84; exhibition exit interview: 14.7%, 28 of 191). When asked their opinion about the topic, comments that visitors used that indicated that visitors were unsure about whether sugary drinks should be taxed included the following:

- "Neutral. I can see both sides."
- "I cannot decide."
- "Kind of indifferent."

Even though it was most common for visitors to be against taxation of sugary drinks and least common for visitors to be unsure whether sugary drinks should be taxed, Chi-square tests still indicate that there was a significant difference in the distribution of claims among interview respondents who did and did not use the exhibition (n=275, X^2 =7.194, df=2, p=.027). Looking more closely at these data, it was found that there were fewer front-end respondents who had an unsure claim than expected (see Table 19).

TABLE 19. Front-End and Exhibition Exit Interview Respondents' Claims for the Socio-Scientific Question "Should sugary drinks be taxed?"⁹

	Fron	t-End	Exhibition Exit Interviews	
	Number of	Percent of	Number of	Percent of
Claim	Respondents	Respondents	Respondents	Respondents
Yes, sugary drinks should be taxed.	32	38.1%	66	34.6%
No, sugary drinks should not be taxed.	49	58.3%	97	50.8%
I'm not sure.	3	3.6%	28	14.7%
Total	84	100.0%	191	100.0%

⁹ Visitors whose claims could not be determined through their interview responses were removed from these samples.

These data suggest that interacting with the *Provocative Questions* exhibition made visitors more unsure about their claim for the socio-scientific question "Should sugary drinks be taxed?" Some research posits that promoting dialogue and listening not just about science but also about values and experiences makes people more open to other viewpoints (Ellenbogen, 2013; Johnson, Rochkind, & DuPont, 2011). It is possible that this is also what is happening in the *Provocative Questions* exhibition – that exposure to additional background information about science research, social values, and personal experiences previously unknown to *PQ* visitors made them less sure about whether sugary drinks should be taxed. It is also possible that giving members of the public a venue in which to hear varied arguments and have their argument heard in return caused *PQ* visitors to be more open to differing viewpoints about taxation of sugary drinks. Finally, it is possible that forces outside the exhibition caused *PQ* visitors to be more unsure about whether sugary drinks should be taxed. In the time between when the front-end and exploratory research studies were conducted, taxation of sugary drinks was a topic in the news. It is possible that exposure to this topic through the media caused *PQ* visitors to be more unsure about the taxation of sugary drinks, not exposure to the exhibition itself.

Video Story 4:

One visitor in Group 29 becomes unsure of his opinion after visiting the exhibition.

At the beginning of their visit, Mike, age 23, spent time exploring values at the Social Values panel by himself while Alex, age 23, was using the Introductory panel. Eventually, Mike and Alex switched components, but Mike did not stay at with the Introductory panel for very long and came back to join his friend at the Social Values panel. While there, they discussed the question "Should parents receive pre-natal genetic information about their future children?" During this interaction, Mike tended to quickly state his opinion for each part of the question, possibly because he had already used this component, while Alex was visibly reading and thinking about the topic without verbalizing his opinion. After completing this question, the group moved on to discuss the question "Should anti-depressants be available upon request?" where Mike continued to immediately state his opinion. While exploring this question, Alex quickly became annoyed with Mike and said "I'm doing this, not you—go away!" They both laughed at this remark and then Mike moved on to the Personal Experience panel, while Alex continued to explore his values at the Social Values panel, taking his time to reflect and consider the different sides of the provocative questions.

After the two visitors had seen "Break It Down" and the Scientific Evidence panel, which they visited separately, they met again at "What's Your Opinion." When looking at the first screen, which asked the question "Should sugary drinks be taxed?" Mike expressed that he and Alex should have the same opinion because of their shared experience, stating, "We're on the same page...we don't want it to be taxed but we also know they are unhealthy." When prompted to choose whether taxation on sugary drinks would affect them or not, they discussed their personal experience, referencing their high consumption of Gatorade, which supported Mike's prior comment. While talking about their experiences, Mike also pointed out that someone's age might affect their viewpoint on the topic. He gave an example of a six-year-old who may not have the life experience they do and could not make decisions like this on their own. When prompted to discuss the scientific evidence and values statements that they chose, they told each other the titles of their choices but did not elaborate on why they selected them. Mike indicated that it was obvious to him that sugary drinks should not be taxed and expected his friend to share that viewpoint with him. However, Alex chose "I can't decide." This response prompted Mike to say "Why can't you decide now? Seeing all this evidence I added to my case. You should have said yes because you already went through all of yours too." Alex replied, "Yeah, but I still—I don't know." Although Mike's viewpoint seemed to strengthen after using "What's Your Opinion," Alex became more unsure of his viewpoint. Alex exhibited behaviors that indicated he was reflecting on the information throughout the exhibition and paying attention to both sides of the argument.

2.2 Groups, who used the PQ exhibition, were more likely to include scientific evidence and social values in their arguments about taxation of sugary drinks than groups who had not used the exhibition.

The PQ exhibition also impacted visitors' socio-scientific arguments in terms of the kinds of supports that they used as a part of their arguments. The responses of groups, who participated in both the front-end and exhibition exit interview, were coded to understand whether they included social values, personal experiences, and scientific evidence as a part of their arguments for the

socio-scientific question "Should sugary drinks be taxed?" Looking across the responses, it was found that groups¹⁰, from the front-end and exhibition exit interviews, most commonly included social values as supports within their arguments (front-end interview: 76.8%, 53 of 69; exhibition exit interview: 88.6%, 78 of 88). Examples of social values¹¹ used as a part of group arguments include the following:

- "Healthy people shouldn't be punished."
- "I think people should be able to choose, but I don't think we should pay for unhealthy people."
- "I don't think the government should decide what we put in our bodies right, wrong, or not. It's my choice if I want to."

Groups, who both used and did not use the PQ exhibition, also commonly used personal experiences as a support for their arguments about taxation of sugary drinks (front-end interview: 76.8%, 53 of 69; exhibition exit interview: 84.1%, 74 of 88). Examples of personal experiences used as a part of group arguments include the following:

- "We, on a daily basis, consume a lot of sugary drinks. Sugary drinks are something people use on a daily basis."
- "If I have a bottle it won't kill me. One won't kill me. If you tax me, I'd still buy it."
- "Thirty years ago, there wasn't such a thing as bottled water. It's marketing, it's personal. Things have a pattern - Extra-large fries, etc. We live in a profit-driven economy, and now there's a social backlash now to make everything smaller. We work with a drum and bugle corps out of Boston and during camp, we control what they do, eat, etc. and the difference is amazing... I've worked with United Way, Big Brother Big Sister, etc. and kids would bring food from home and you can tell what they're eating."

Across the front-end and exhibit exit interviews, groups least commonly included scientific evidence as a support within their arguments (front-end interview: 44.9%, 31 of 69; exhibition exit interview: 64.8%, 57 of 88). Examples of scientific evidence included within group arguments include the following:

- "Because we can see there is an obesity and cardiovascular epidemic due to the sugary drinks most importantly. Carbohydrates become fat."
- "I get that when you taxed cigarettes, fewer people smoked. I see that."
- "It's proven that sugary drinks are higher in calories. It doesn't hydrate you, it just increases appetite. It doesn't help at all."

¹⁰ In analyzing these data, evaluators considered entire groups as opposed to individuals within groups as it was felt that individuals were unlikely to repeat a support given by another group member. Therefore, it was felt that looking at group responses as opposed to individual responses would give us a truer understanding of argument support usage.

¹¹ All the group responses reported in this section came from the exhibition exit interviews although their content is representative of front-end responses as well.

Both those groups who did and did not use the PQ exhibition were highly likely to include social values and personal experiences as supports within their arguments and less likely to include scientific evidence as supports. However, Chi-square tests indicate that there were statistically significant increases in the likelihood that groups who used PQ would include the certain supports as a part of their arguments. These tests indicate that groups, who used the *Provocative Questions* exhibition, were significantly more likely to include social values (n=157, X²=3.914, df=1, p=.048) and scientific evidence (n=157, X²=6.183, df=1, p=.013) in their arguments than groups who had not used the exhibition (see Table 20).

	Front-E	nd (n=69)	Exhibition Exit Interviews (n=88)		
	Number of	Percent of	Number of	Percent of	
	Groups using	Groups using	Groups using	Groups using	
Support	Support	Support	Support	Support	
Social Values*	53	76.8%	78	88.6%	
Personal Experience	53	76.8%	74	84.1%	
Scientific Evidence*	31	44.9%	57	64.8%	

TABLE 20. Supports Used by Front-End and Exhibition Exit Interview Groups as a Part of the	ir
Arguments for the Socio-Scientific Question "Should sugary drinks be taxed?" ¹²	

* p ≤ .05

These data indicate that interacting with the *Provocative Questions* exhibition made it significantly more likely that groups would include social values and scientific evidence as supports within their arguments. In the case of scientific evidence, it was found that during the front-end study less than half of the study groups included science as a part of their arguments, but nearly two-thirds of groups, who used the PQ exhibition, included science in their arguments. However, there was not a significant change in the likelihood that groups would include personal experiences as a support within their arguments. The reason for these findings may be that exposure to scientific evidence and values, presented throughout the exhibition, made visitors more cognizant of these kinds of evidence and therefore more likely to include these supports in their arguments. It is not surprising that exhibition visitors were not more likely to include personal experience supports in their arguments given that the public were likely most familiar with personal experiences as argument supports even without the exhibition. These findings may also be a result of the fact that the exhibition provided visitors with frameworks for thinking about different kinds of scientific evidence and societal values but did not provide a framework for thinking about different kinds of personal experiences. Despite the reason for these findings, they still indicate that exposure to *Provocative Questions* exhibition can increase the likelihood that members of the public will be able to use social values and scientific evidence as supports, at least when involved in discussions about the socio-scientific argument posed within the exhibition.

¹² Groups for which no individual group members' claims could not be determined through their interview responses were removed from these samples.

Video Story 5:

Group 51 uses both science and values extensively during the visit.

Shannon, 16 years old, and her father, Troy, 44 years old, visited the Social Values panel and Personal Experience panel together without much discussion. Shannon wanted to move on to "What's Your Opinion," but her father was still engaged at the Personal Experience panel. She decided to ask Seth, another child in the area who was 14 years old, if he wanted to do the "What's Your Opinion" activity with her, and he was happy to participate. Scientific evidence, social values, and personal experience were used extensively throughout the children's conversation at this component. They talked about how taxation of sugary drinks would personally affect both of them, where Shannon stated "to some extent it would affect everything." She gave an example of an increase in sugary drink prices leading to an increase in the prices of non-sugary beverages. Troy joined them at this point and looked on with his daughter, listening to the conversations. During Seth and Shannon's discussion of the scientific evidence, the children referenced the "no taxation without representation" era. They connected the colonial time period and general taxation with the taxation of sugary drinks. At this point Seth said, "Truth is, if you say 'no taxes' then you're an idiot."

Further integration of values and science occurred after Shannon and Seth chose their value statements. Both children selected "We should be wary of what manufacturers are putting in food" to represent their value. This led to a conversation about the ingredients in food, specifically the use of corn products in food. Seth referenced a movie that he saw in science class about the food industry's use of corn products. Shannon related his statement to the ingredients of energy drinks, where she stated that one ingredient of these drinks is cow intestines. Troy laughed at this and asked her where she had heard such a thing. Seth connected Shannon's thoughts about energy drinks to the food industry's inhumane treatment of animals. Further exploration of values occurred when the children started looking at the visitor data at the end of the activity. Seth read a value statement different from his own, "A person should be able to choose what they want to eat or drink whatever the health consequences," and had a discussion with himself trying to understand why someone would hold this value. Shannon and Troy decided to try "Break It Down" and Seth followed them there. As they were discriminating the evidence types, Seth became frustrated when the statement classified as science did not include a reference to research and left the exhibit.

2.3 Groups, who used the PQ exhibition, were more likely to include scientific evidence in their arguments about restrictions on the use of anti-bacterial soaps and sanitizers than groups who had not used the exhibition.

Visitors, who used the PQ exhibition, were asked not only about their arguments for the socioscientific question used within the exhibition, "Should sugary drinks be taxed?", but also for a second question, "Should there be restrictions on the use of anti-bacterial soaps and sanitizers?" Questions were asked about a second socio-scientific issue to understand whether exposure to the exhibition had any impact on visitors' socio-scientific argumentation skills beyond the question posed within the exhibition. In order to understand if there was any impact, visitors, who participated in the exhibition exit interview, were compared to visitors asked about their argument for this same question as a part of the front-end interviews.¹³

Looking across the responses, it was found that groups, who did and did not use the PQ exhibition, most commonly included personal experiences as a support for their arguments about restrictions on anti-bacterial soaps and sanitizers (front-end interview: 83.3%, 50 of 60; exhibition exit interview: 86.2%, 75 of 87). In both of these cases, over three-quarters of participants included personal experience as a support. Examples of personal experiences¹⁴ included within group arguments are the following:

- "Well, I have a bottle [of antibacterial sanitizer] in my bag, but I don't use it very much."
- "Flu season for example. It spreads so fast because people don't wash their hands... We're from Canada. Hand sanitizer dispensers are everywhere. It's required in buildings and stores."
- "Kids are not exposed [to germs] anymore."

Looking at the other supports, it was found that front-end groups, who were not exposed to the PQ exhibition, included social values (58.3%, 35 of 60) and scientific evidence (53.3%, 32 of 60) in their arguments about restrictions on the use of antibacterial soaps and sanitizers just over half of the time. Exhibition exit interview groups, who were exposed to PQ, used social values and scientific evidence as supports more frequently. In this group, participants more commonly included scientific evidence (80.5%, 70 of 87) as a support for their argument than social values (71.3%, 62 of 87). However, in both cases well over two-thirds of the participants included these supports. Examples of social values used as a part of these arguments include the following:

- "[If] people want to use it, they should be able to."
- "People should learn to do things in moderation."
- "People live in a bubble and individuals need to be exposed to new [germs]."

Examples of scientific evidence used as a part of these arguments include the following:

- "The overuse or incorrect use [of antibacterial soaps and sanitizers] can cause creation of a highly resistant virus that kills off the weaker viruses first. All it leaves left to breed are the stronger ones."
- "...I think we are generating unhealthy people by not allowing their natural immune system to fight against natural challenges... Increase in childhood allergies, asthma... Food sensitivity... Increase in antibiotic resistant bacteria..."
- "Some guy proved a theory that washing hands prevent sickness, so antibacterials are a way to do that."

¹³ Front-end interview participants, who answered questions about their argument for the question "Should there be a restriction on the use of anti-bacterial soaps and sanitizers?", were different from the front-end interview participants who answered questions about their argument for the question "Should sugary drinks be taxed?"

¹⁴ All the group responses reported in this section came from the exhibition exit interviews although their content is representative of front-end responses as well.

Statistical comparisons of the front-end and exhibit exit interview groups were conducted to understand if there were any differences in the frequency of use of the different argument supports. Chi-square tests indicate that groups, who used the *Provocative Questions* exhibition, were significantly more likely to include scientific evidence as a support for their argument about restrictions on the use of antibacterial soaps and sanitizers than groups who had not visited the exhibition (n=147, X^2 =12.302, df=1, p≤.0001) (see Table 21).

TABLE 21. Supports Used by Front-End and Exhibition Exit Interview Groups as a Part of Their
Arguments for the Socio-Scientific Question "Should there be restrictions on the use of anti-
bacterial soaps and sanitizers?" ¹⁵

	Front-E	nd (n=60)	Exhibition Exit I	nterviews (n=87)	
	Number of Groups using	Percent of Groups using	Number of Groups using	Percent of Groups using	
Support	Support	Support	Support	Support	
Social Values	35	58.3%	62	71.3%	
Personal Experience	50	83.3%	75	86.2%	
Scientific Evidence*	32	53.3%	70	80.5%	

* p ≤ .05

These data suggest that the *Provocative Questions* exhibition impacted not only visitors' abilities to construct arguments containing science about the socio-scientific question posed within the exhibition, but also their abilities to include scientific evidence in arguments about other socio-scientific questions. In this case, exhibition visitors, whether asked their viewpoint about taxation of sugary drinks or restrictions on the use of anti-bacterial soaps and sanitizers, were more likely to include science as a support for their arguments than non-users. This may be because content within the exhibition promoted science as an argument support or because visitors became more familiar with integrating science into socio-scientific arguments through practice at the "Argument Building and Analysis" component and through seeing and hearing example arguments throughout the exhibition. Whatever the cause, these findings demonstrate that *Provocative Questions* can increase publics' abilities to integrate scientific evidence into arguments for all socio-scientific questions – not only those they are exposed to within the exhibition.

3. OTHER FINDINGS

Besides the findings reported above, researchers discovered two other findings as they were analyzing the data. Those findings were the following:

- 3.1 *Provocative Questions* visitors seemed to feel that there was scientific evidence to support only the view that sugary drinks should be taxed.
- 3.2 Visitors, who used the *Provocative Questions* exhibition, may feel more comfortable expressing and supporting their viewpoints about socio-scientific questions.

¹⁵ Groups for which no individual group members' claims could not be determined through their interview responses were removed from these samples.

3.1 Provocative Questions visitors seemed to feel that there was scientific evidence to support only the view that sugary drinks should be taxed.

On the exhibition exit survey, participants were asked a series of Likert scale questions in order to understand whether they had achieved the various knowledge and awareness goals for *Provocative Questions*. Two of those questions asked visitors to rate their agreement with the following statements:

- There is scientific evidence that supports the view that sugary drinks should be taxed.
- There is scientific evidence that supports the view that sugary drinks should not be taxed.

Looking at the responses to these questions, it was found that just over one-tenth of the survey respondents (11%, 10 of 88) "Agreed" or "Strongly Agreed" that there is scientific evidence to support the view that sugary drinks should not be taxed. However, many more survey respondents (43%, 38 of 88) "Agreed" or "Strongly Agreed" that there is scientific evidence to support the view that sugary drinks should be taxed (see Table 22).

			Number of	Percent of
	Mean Rating	Standard Deviation	Respondents Choosing 6 or 7	Respondents Choosing 6 or 7
There is scientific evidence that supports			<u></u>	eneccing e en i
the view that sugary drinks should be taxed.	4.76	1.82	38	43%
There is scientific evidence that supports the view that sugary drinks <u>should not</u> be	3.26	1.59	10	11%
taxed.				

TABLE 22. Participants' Rankings of their Agreement with Statements about Availability of Scientific Evidence to Support Varied Views about Taxation of Sugary Drinks (N=88).¹⁶

Data collected in order to understand the supports that visitors' used as a part of their arguments about taxation of sugary drinks provides additional support that visitors felt there was scientific evidence only to support that sugary drinks should be taxed. Results from these questions show that respondents, who thought sugary drinks should be taxed, were most likely to include scientific evidence as a support in their argument (57.6%, 38 of 66). Respondents, who were unsure about taxation of sugary drinks, were less likely to include scientific evidence as a support in their arguments (32.1%, 9 of 28). Respondents, who felt that sugary drinks should be taxed, were least likely to include scientific evidence as a support in their arguments (24.7%, 24 of 97). Comparing these groups, there was a significant difference in the distribution of scientific evidence, with respondents, who thought sugary drinks should be taxed, being more likely to include scientific evidence than expected (n=191, X^2 =18.485, df=2, p≤.0001) (see Table 23).

¹⁶ Survey respondents were asked to rate their agreement on a 7-point scale (1="Strongly Disagree," 2="Disagree," 3="Somewhat Disagree," 4="Neutral," 5="Somewhat Agree," 6="Agree," and 7="Strongly Agree").

Claim	Total Number of Respondents	Number of Respondents including Science	Percent of Respondents including Science	Number of Respondents not including Science	Percent of Respondents not including Science
Yes, sugary drinks should be taxed.	66	38	57.6%	28	42.4%
No, sugary drinks should not be taxed.	97	24	24.7%	73	75.3%
I'm not sure.	28	9	32.1%	19	67.9%

TABLE 23. Number and Percent of Exhibition Exit Interview Respondents Including Scientific Evidence in Their Argument for the Socio-Scientific Question "Should sugary drinks be taxed?" Split by Claim.¹⁷

Not only were respondents less likely to include science as a support when they thought that sugary drinks should not be taxed and more likely to include it when they thought sugary drinks should be taxed, this was also the case when visitors were asked to create counterarguments that were in opposition to their own position. In order to understand whether visitors were able to create counterarguments that included supports, a number of questions were posed on the exhibition exit interview that gave visitors information about a person with a view opposite to their own. The interview participants were then asked what social value and scientific evidence supports this persona could use to support their viewpoint. Responses from these questions showed that almost all groups, who personally felt that sugary drinks should not be taxed, were able to articulate scientific evidence to support that sugary drinks should be taxed (93.8%, 45 of 48). Fewer groups, who personally felt that sugary drinks should be taxed, were able to articulate scientific evidence to support that sugary drinks should not be taxed (56.8%, 21 of 37). Comparing these groups, there was a significant difference in the distribution of scientific evidence, with groups, who created a counterargument for taxation of sugary drinks, being more likely to include scientific evidence than expected (n=85, X^2 =16.474, df=1, p≤.0001) (see Table 24).

¹⁷ Visitors whose claims could not be determined through their interview responses were removed from these samples.

Claim	Total Number of Groups	Number of Groups including Science	Percent of Groups including Science	Number of Groups not including Science	Percent of Groups not including Science
Yes, sugary drinks should be taxed.	48	45	93.8%	3	6.2%
No, sugary drinks should not be taxed.	37	21	56.8%	16	43.2%

TABLE 24. Number and Percent of Exhibition Exit Interview Groups Including Scientific Evidence in Their Counterargument for the Socio-Scientific Question "Should sugary drinks be taxed?" Split by Claim.¹⁸

These data indicate that *Provocative Questions* visitors felt there was scientific evidence to support that sugary drinks should be taxed, but not to support that they should not be taxed. This may be because visitors felt that the scientific evidence provided in the exhibition to support the view that sugary drinks should not be taxed was not strong or believable. Alternatively, these findings may indicate that visitors felt all the scientific evidence provided in the exhibition supported that sugary drinks should be taxed. Whatever the reason for this finding, it does bring up some important considerations for future socio-scientific issues posed within *Provocative Questions*. Is it important to make sure that there is scientific evidence that can be used to support any viewpoint on the socio-scientific evidence to support one point of view to show that sometimes values and personal experiences trump scientific evidence during the decision making process? Also, is it important to try to make sure that the scientific evidence to support their viewpoint, or is it okay to be unbalanced for some issues knowing that some visitors may not be able to find science to support their argument?

¹⁸ Groups who created counterarguments both for and against taxation of sugary drinks were removed from this sample because the person in the group who held each viewpoint often helped group members with an opposing viewpoint craft their counterargument.

Video Story 6:

Group 31 thinks that scientific evidence supports the taxation of sugary drinks.

John and Alice, both 24 years old, interacted with "What's Your Opinion" and visited the Personal Experience panel. Throughout this visit, John struggled when his value statement was contradicted by evidence from science. When they were prompted to choose scientific evidence at "What's Your Opinion," John chose the study about taxing tobacco increasing the health and longevity of citizens and explained his reasoning by saying "if you can increase the tax on something, make something a little more expensive and a little harder to get then eventually... but, then at the same time you can also run into government intervention which kind of cuts in on the freedoms if you really think about it. It's kind of subtle government manipulation, if you will." John started this statement by integrating the science of taxing sugary drinks into his argument but recognized it as a counterargument which led him to bring values into his explanation. John realized that the scientific evidence contradicted his value. Alice noticed this and asked him, "So why did you pick that one if you don't like it?" He replied that he didn't know why, he just chose it.

At the end of the activity, John decided that he thought there should be a tax on sugary drinks, presumably deciding that the scientific evidence outweighed his social value. Later on, at the Personal Experience panel, Alice said, "I think inherent inner freedom is the freedom to choose what we eat or drink," and John agreed with this statement. This led Alice to say, "But you just said they should be taxed," to which John justified his position by saying that people would still be free to choose what to drink even if it had a tax. Alice understood this statement and introduced the idea of the taxes being able to pay for some of the health issues associated with drinking sugary drinks. John's value, that the government should not interfere with individual liberties, conflicted with the scientific evidence, which he saw as supporting the taxation of sugary drinks. John ended up siding with the science side of his argument, claiming that sugary drinks should be taxed.

3.2 Visitors, who used the Provocative Questions exhibition, may feel more comfortable expressing and supporting their viewpoints about socio-scientific questions.

During data analysis, another finding unrelated to the two exploratory research questions emerged. While almost all visitors who used the *Provocative Questions* exhibition were able to construct arguments about socio-scientific questions, some evidence indicates that by using the exhibition they may also have become more comfortable expressing and supporting their viewpoints. This finding relates to exhibition Goal 6 relating to identity. It was considered a secondary goal of the exhibition by the PQ team.

As shown in sections 2.1 and 2.2, almost all PQ visitors were able to articulate arguments containing claims and supports both while using and after using the exhibition. However, additional questions were asked in order to gauge visitors' comfort discussing and supporting these arguments with others. Visitors, who responded to the exhibition exit survey, were asked to rate eight statements on a scale of 1 to 7, with 1 being "Strongly Disagree" and 7 being "Strongly Agree." Two of these statements were related to confidence or comfort supporting a view about taxation of sugary drinks. Those statements were the following:

- I can support my viewpoint in a conversation about the taxation of sugary drinks.
- I would feel comfortable expressing my viewpoint about the taxation of sugary drinks in a group discussion.

These statements were based on similar statements used as a part of the summative evaluation of the NISE Network "Nanotechnology in Healthcare" forum (Flagg & Knight-Williams, 2008). Results from the PQ exhibition exit survey indicate that over two-thirds of survey respondents "Agreed" or "Strongly Agreed" that they could support their viewpoints in a conversation about taxation of sugary drinks (67.8%, 59 of 87) and would feel comfortable expressing their viewpoint about taxation of sugary drinks in a group discussion (68.2%, 60 of 88) (see Table 25).

	N	Mean Rating	Standard Deviation	Number of Respondents Choosing 6 or 7	Percent of Respondents Choosing 6 or 7
I can support my viewpoint in a conversation about the taxation of sugary drinks.	87	5.79	1.058	59	67.8%
I would feel comfortable expressing my viewpoint about the taxation of sugary drinks in a group discussion.	88	5.73	1.201	60	68.2%

TABLE 25. Visitor Responses to Exhibition Exit Survey Likert Scale Questions about Identity.

Since these data were collected only after visitors used the exhibition and not both before and after using the exhibition, it is not possible to draw conclusions about the effect of the *Provocative Questions* exhibition on visitor comfort and confidence expressing their views. However, comparisons to the responses of participants who took part in the NISE Network forum summative evaluation may provide some clues as to what these data mean. NISE Network summative evaluation participants were asked to rate their agreement with the following two statements both before and after their forum experiences:

- I feel comfortable expressing my viewpoints about nanotechnology in a group discussion.
- I can support my viewpoints in a conversation about risks and benefits of nanotechnology.

Before the forum, evaluation participants rated their mean comfort expressing their viewpoints about nanotechnology in a group discussion 5.0 out of 7, and after the forum, their mean comfort was 5.7 out of 7. Forum participants' mean rating of their agreement that they can support their viewpoints in a conversation about risks and benefits of nanotechnology was 3.9 out of 7 before the forum and 5.6 out of 7 after the forum (see Table 26). In both of these cases, there were statistically significant increases in participants' ratings of their comfort expressing their

viewpoints¹⁹ and in their ability to support their viewpoints²⁰ after the forum (Flagg and Knight-William, 2008).

TABLE 26. NISE Network Forum Summative Evaluation Responses to Likert Scale Questions						
about Identity.						

	Ν	Mean Rating, Pre-Forum	Mean Rating, Post-Forum
I can support my viewpoints in a conversation about risks and benefits of nanotechnology.	32	3.9	5.3
I feel comfortable expressing my viewpoints about nanotechnology in a group discussion.	32	5.0	5.7

Note: This table is adapted from Flagg & Knight-Williams, 2008.

PQ visitors' post-exhibition ratings were similar to NISE Net forum participants' post forum ratings. After using PQ, the mean rating of survey respondents' confidence in their abilities to support their viewpoint about taxation of sugary drinks was 5.79 out of 7 (SD=1.058). PQ survey respondents' mean rating of their comfort expressing their viewpoint about taxation of sugary drinks in a group discussion was 5.73 out of 7 (SD=1.201) (see Table 25). The similarity in mean post-use ratings is somewhat surprising given differences between the "Nanomedicine in Healthcare" forum and Provocative Questions. Provocative Questions is a drop-in experience, unlike forums where participants register ahead of time. In addition, the "Nanomedicine in Healthcare" forum lasts three hours whereas visitors to PQ spend under an hour in the exhibition space. Still, the similarities in ratings may indicate that, as with the NISE Net "Nanomedicine in Healthcare" forum, Provocative Questions increased visitors' confidence in their abilities to support their viewpoints about sugary drinks in a conversation as well as their comfort expressing their viewpoints about taxation of sugary drinks in a group discussion. It is also possible that the PQ post-ratings are really a baseline for MOS visitors and do not indicate any impact from the exhibition at all. In order to understand whether these ratings indicate impacts from the exhibition or not, further study is needed to explore both pre- and post-comfort supporting and expressing viewpoints.

This finding may also have implications for visitor self-efficacy, which is defined as the perception of one's own ability to successfully perform tasks in a particular content domain. Perceived self-efficacy can have implications for learner motivation, persistence, and resilience in the face of challenges (Jenson et al., 2011). In this case, PQ visitors with higher self-efficacy related to their feelings of their abilities to support their viewpoints in discussions might be more likely to seek out or engage in such conversations outside of the exhibition.

¹⁹ Wilcoxon matched-pairs signed ranks test: N = 29, z = 2.5249, p = .0058.

²⁰ Wilcoxon matched-pairs signed ranks test: N = 29, z = 3.8829, p < .0001.

IV. CONCLUSION

The purpose of the *Provocative Questions: Supporting effective dialogue about societal issues informed by human biology in a changing world* grant was to create and test a series of prototype exhibit components designed to build visitors' capacities to engage in discussions of socio-scientific issues. In particular, the exhibits sought to improve visitors' abilities to recognize the components of socio-scientific arguments, evaluate them, and pose arguments of their own particularly with regard to the numerous human biology- and health-related socio-scientific issues present in their lives today. The argumentation framework used as a part of this work was a modified version of Toulmin's Argumentation Pattern (Toulmin, 1958) as adapted by Kolsto (2006). This abbreviated framework focuses on the three core elements of an argument: claims, data, and warrants. The framework posits that a socio-scientific argument is composed of a claim with supporting data (scientific evidence and personal experiences) connected to each other through a warrant (social value).

Throughout the course of this project, the socio-scientific issue explored through the exhibit components was "Should sugary drinks be taxed?" After individual exhibit components were prototyped on their own, an exploratory research study was conducted to understand how the components worked as a group. Through the exploratory research, researchers sought to understand the following:

- Will visitors engage in socio-scientific argumentation in an un-facilitated exhibit space, and are they aware that they are doing so?
- How do the un-facilitated exhibits impact visitors' socio-scientific argumentation skills?

In order to answer these questions, evaluators cued 88 visitor groups composed of teenagers and adults to use the *Provocative Questions* exhibition. While visitor groups used the exhibition, they were observed in order to understand which components they would use and how they would use them. In addition, 29 of these groups were videotaped to learn what they would discuss while using the exhibition. After using the exhibition, all the groups were interviewed and surveyed to understand whether they achieved exhibition goals. Additional questions on the interview asked visitor groups to create arguments for the questions "Should sugary drinks be taxed?" and "Should there be restrictions on the use of anti-bacterial soaps and sanitizers?" These data were the only data for which there was a comparison group. Answers to these questions were compared to data previously collected as a part of a front-end evaluation in order to understand how the exhibition impacted visitors' abilities to craft arguments.

Findings from the exploratory research study indicate that visitors were able to engage in socioscientific argumentation in an un-facilitated space. Visitor groups stopped at almost all the exhibit components within *Provocative Questions* and used them to completion. In particular, almost all visitors used the Social Values panel, "Break It Down," and "What's Your Opinion," which cover all the argumentation skills goals of the exhibition. Not only can it be assumed that visitors participated in socio-scientific argumentation because they used these exhibit components, analysis of the videotaped groups indicates that nearly half of the visitor groups demonstrated each of the socio-scientific argumentation skills that were included as goals for the exhibition. In particular, almost all of the videotaped groups justified their position about taxation of sugary drinks, and that almost all of the interviewed groups were able to create supported arguments as a part of the interviews. Additionally, during interviews and through observations, most participating groups were able to discriminate between the different kinds of argument supports and explore the reasoning behind different viewpoints. These findings demonstrate that visitors did participate in socio-scientific argumentation while using the *Provocative Questions* exhibition.

Additional findings demonstrate that not only did visitors participate in argumentation while using the exhibition, but they were actually aware that they were doing so. When asked what the Museum of Science was trying to have them learn through the exhibition, visitors most commonly said that the exhibition was about how others form opinions and about the kinds of supports that can be used as a part of socio-scientific argumentation. When asked what they learned through the exhibition, visitors also reported that they learned about these topics. Not only that, but participating groups were able to name the supports used within the exhibition: personal experience, social values, and scientific evidence. These data indicate that *Provocative Questions* visitors were aware that they were participating in socio-scientific argumentation while using the exhibition.

A second part of the exploratory research study was to understand how the exhibition impacted visitors' socio-scientific argumentation skills. In order to do this, researchers compared the arguments of visitors after they used *Provocative Questions* to a group of visitors who had not experienced the exhibition. Analysis of these data indicated that visitors, who experienced the *Provocative Questions* exhibition, were more likely than visitors who had not experienced the exhibition to be unsure about their position concerning whether sugary drinks should be taxed. Despite feeling more unsure, PQ visitor groups were more likely to include scientific evidence and social value supports as a part of their arguments than visitor groups who had not been to *Provocative Questions*. Scientific evidence was also more likely to be included in the arguments of visitor groups who had been to PQ about a second socio-scientific question that was not a part of the exhibition: "Should there be restrictions on the use of anti-bacterial soaps and sanitizers?" These findings provide evidence that the exhibition had a positive impact on visitors' abilities to include supports within their arguments, specifically scientific evidence.

This proof-of-concept study for *Provocative Questions* demonstrates that PQ was successful in achieving those impacts that previous research has shown might be difficult to achieve within an un-facilitated exhibit space. For example, previous research proposed that visitors may not be able to participate in argumentation in an exhibition (Allen & Gutwill, 2009). However, this study found that, at the very least, cued Museum of Science visitors were willing and able to take part in socio-scientific argumentation discussions while using the exhibition even if they might not agree with their other group members. This may be because *Provocative Questions* asked visitors to participate in discussions around socio-scientific evidence, as opposed to scientific issues which rely on knowledge of scientific evidence alone. It is also possible that visitors were more willing to participate in this kind of discussion in PQ because they were cued to do so. Nevertheless, the data from this study indicate that visitors are able to participate in argumentation museum space. Further research to confirm this finding should be conducted with visitors who are not cued to use the space.

Previous research also indicates that members of the public have difficulty including science in their arguments about socio-scientific issues (Kolsto, 2006; Sadler & Zeidler, 2005). This exploratory research study found that even when scaffolded it can be difficult for some visitors to integrate scientific evidence into their arguments. When asked to provide information for their argument about taxation of sugary drinks, scientific evidence was least likely to be included in group and individual responses. One possible explanation for this finding is that visitors, who thought that sugary drinks should not be taxed, may have felt that the exhibition did not provide them with adequate science to support their viewpoint. Nevertheless, this is not to say that visitors did not include scientific evidence in their arguments. In fact, nearly two-thirds of groups included scientific evidence in their arguments constructed during the exit interview.

Additionally, comparing visitors who had experienced *Provocative Questions* to those who had not, groups who had experienced the exhibition were significantly more likely to include scientific evidence in their arguments. Therefore, the exhibition still improved visitors' abilities to include scientific evidence in their arguments. The apparent contradictions related to visitors' use of scientific evidence suggests that there is room for improvement in the achievement of this goal. It is possible that there may be a further increase in the number of visitors including scientific evidence in their arguments if the science presented in the exhibition is chosen in such a way that a person of any viewpoint has access to rigorous, relevant scientific evidence. It is also possible that simply changing the socio-scientific question included within the exhibition may increase the percentage of visitors including scientific evidence to greater than 66%.

Finally, previous research has indicated that visitors have a difficult time considering or generating alternative explanations (Allen & Gutwill, 2009; Hein et al., 1996). Thinking about this in terms of counterarguments, we find that *Provocative Questions* visitors were also able to exhibit this skill. When asked to articulate social value or scientific evidence supports for a viewpoint opposing their own, almost all visitors were able to do so. In addition, nearly half of the videotaped groups discussed counterarguments when using the exhibition. It is also possible that the increase in visitors who were unsure about their viewpoint about taxation of sugary drinks after using the exhibition indicates that use of *PQ* increased visitors abilities to understand alternative explanations. *PQ* visitors' abilities to consider alternative explanations may result from the multiple kinds of supports and arguments presented throughout the exhibition. Once again, it may also be that members of the public, in general, have an easier time considering alternative explanations about a socio-scientific question than a science question. Still, these results indicate that *Provocative Questions* gave visitors the opportunity to practice exploring alternative explanations for an issue.

These successes provide the opportunity for further research in order to understand the broader ability of *Provocative Questions* to generate argumentation and improve visitors' socio-scientific argumentation skills. At this point, it is unknown how un-cued visitors use the exhibition space. It is quite possible that, at the very least, these visitors would not use the exhibition as thoroughly as cued visitors. Therefore, a study could look at the differences in the understandings and argumentation skills of visitors who are cued to use PQ versus those who are not cued. It is also unknown how the exhibition would impact visitors at science museums or informal science education venues other than the Museum of Science, Boston. Therefore, a study could be

conducted to understand how, if at all, placement of *Provocative Questions* in different informal science education institutions impacts visitors' socio-scientific argumentation skills.

Additionally, there is more research which could be conducted in order to understand the implementation of Toulmin's Argumentation Pattern in *Provocative Questions*. For example, a study could be conducted to understand if the topic or wording of the socio-scientific question posed in *Provocative Questions* impacts the frequency of inclusion of particular claims, data, or warrants in visitors' arguments. A study could also be conducted to understand if the socio-scientific question impacts *PQ* visitors' abilities to include science in their arguments, or if exposure to the exhibition increases the likelihood that visitors will include science in their arguments regardless of the socio-scientific question posed.

Finally, an interesting and somewhat puzzling finding of the current study was that visitors, who had experienced *Provocative Questions*, were more likely to be unsure whether sugary drinks should be taxed than visitors who had not been to the exhibition. Some have theorized that promoting dialogue and listening about not only science but also values and experiences makes people more open to different viewpoints (Ellenbogen, 2013; Johnson, Rochkind, & DuPont, 2011). A study could be conducted to understand if this is the reason that *PQ* visitors are significantly more likely to be unsure about their claim than non-*PQ* visitors. Additional studies could try to understand how, if at all, the socio-scientific issue posed within *Provocative Questions* impacts this finding allowing us to understand whether this finding is content dependent or exhibition dependent. It would be valuable to understand the answers to any or all of these questions to move *Provocative Questions* beyond proof-of-concept to field standard.

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APPENDIX A: VISTOR TRACKING AND OBSERVATION INSTRUMENT

Provocative Questions Area Testing Observation

- When choosing a group to cue, make sure the group contains 2-5 group members all of whom are 13 years of age or older.
- If the group is composed of only children under the age of 18, make sure to get parent / guardian permission before starting data collection.
- When you approach the group say, "Hi, my name is ______, and I work in the Research and Evaluation Department at the Museum. We're trying to understand what visitors learn from our new exhibit which is right here, and I was wondering if your group would like to use the exhibit and then answer some questions about it?"

[If no] "Thanks. Have a great day!"

[If yes] "These are the exhibits we are interested in having you use [point to the exhibits]. Please use the exhibits however you like for as long as you like. Once you're done come over to me, and I'll ask you some questions. You can end your participation at any time if you need to, just let me know."

Instructions: Collect this data about the behaviors of the entire group if possible.

Visitor Information								
# Ac	dult F	# Adult M	# Child F # C	hild M				
Gro □ A	<i>up type:</i> dults only	Children only	✓ □ Adults and kids	□ Other:				
Cluster (if applicable):								
<u>Did</u>	<u>the group visit</u> Intro Panel	<u>t</u> :						
	Values Panel Questions: Anti-depress Genetic mak Water fluorio	ants eup of babies dation	Looked at:	Interacted with:				
	Science Evide	nce Panel						
	Personal Expe	rience Panel Irphone						
	Science Readi	ng Area t binder						

Downloaded smart phone app

□ Break it Down

During activity, record each player's answers:

	Stat	emer	nt 1	Statement 2		Statement 3		Statement 4		Statement 5					
[Calories SE]		[Dia	bete	S	[Stu	pidit	y	[He	alth S	5V]	[Tea	acher	PE]		
				PE]		SV]									
	P1	P2	Р3	P1	P2	Р3	P1	P2	Р3	P1	P2	Р3	P1	P2	Р3
Personal Experience															
Scientific Evidence															
Social Value															

Argument Building and Analysis

- □ Listened to audio
- □ Visited alone
- □ Visited with another group member
- □ Chose personal experience
- Discussed their personal experience choice
- □ Chose science evidence
- Discussed their science evidence choice
- □ Chose value
- □ Discussed value choice
- □ Viewed arguments
- Discussed their entire argument
- Viewed visitor data
- Discussed other visitor data
- □ Completed the activity

Other Notes (conversations between visitors, questions about vocabulary/instructions, misuse of exhibits):

APPENDIX B: EXIT INTERVIEW

Provocative Questions Area Testing Interview

Introduction: Are you done using the exhibits?

[If no] Continue using the exhibits as long as you'd like. When you're done, let me know because I have some questions I'd like to ask you.

[If yes] Now that you're done using the exhibits, I'd like to ask you some questions. The interview should take between 5 and 10 minutes. You can skip any questions you don't feel comfortable answering and can end the interview at any time.

1. What are the ages and genders of your group members? (Please label question responses using group member number.)

Group Member	Age	Gender			
1					
2					
3					
4					
5					
6					
Other group members:					

- 2. What would you say the Museum is trying to have you learn about in these exhibits? Probe: [If they only mention one message, ask] Is there anything else you think the Museum is trying to have you learn here?
- 3. What, if anything, did you learn from these exhibits that you didn't know before? Probe: [If they only mention one thing they learned, ask] Is there anything else you learned that you didn't know before?
- 4. In the exhibits, different kinds of statements were described that can be used to support a viewpoint about taxation of sugary drinks. Can you please tell me what they were?
- 5. **[If they did not use "Break it Down," say]** Listed here are the three kinds of statements presented in the exhibits that can be used to support an opinion: Personal Experience, Science Evidence, and Social Values. Please sort these cards each of which has an example of one of these kinds of statements into the correct category.

	Personal	Scientific	
Statement	Experience	Evidence	Social Value
My friend drinks soda to keep awake for late night			
studying. (PE)			
I drink a six pack of soda every day, and I'm healthy.			
(PE)			
The government should stay out of personal decisions,			
like what we choose to drink. (SV)			

Companies that make these things should pay for the		
problems they cause. (SV)		
Studies have shown a direct relationship between		
drinking sugary drinks and obesity. (SE)		
Health costs related to obesity total more than a		
hundred billion dollars every year. (SE)		

<u>Introduction</u>: Now, I'd like to ask you some questions about your viewpoint about the question posed in these exhibits: *Should sugary drinks be taxed*?

- What is your opinion about this topic?
 Probe: Are you for or against sugary drinks being taxed?
- 7. Can you explain to me why you feel this way?Probe: Why do you think that sugary drinks [should / should not] be taxed?
- 8. What information, data, or evidence do you have to support your point of view?

<u>Introduction</u>: Now, I'd like you to think about someone who has the opposite point of view from you, for example:

[Person for taxing sugary drinks]: Andrea is a mother of two small children. She tries to make sure that her kids have a healthy diet. She is for taxing sugary drinks.

- 9. Why might Andrea think that sugary drinks should be taxed?
- 10. What values might Andrea hold that led her to this viewpoint?
- 11. What science evidence could Andrea use to support her point of view?

[Person against taxing sugary drinks]: Jeff is a teenager trying to complete high school and hold down a part-time job. He is against taxing sugary drinks.

- 12. Why might Jeff think that sugary drinks should not be taxed?
- 13. What values might Jeff hold that led him to this viewpoint?
- 14. What science evidence could Jeff use to support his point of view?

<u>Introduction</u>: I'd also like to ask you a few questions about your viewpoint on a second question that wasn't a part of the exhibits: *Should there be restrictions on the use of anti-bacterial soaps and sanitizers?*

- 15. What is your opinion about this topic?Probe: Are you for or against restricting use of anti-bacterial soaps and sanitizers?
- 16. Can you explain to me why you feel this way? Probe: Why do you think that use of anti-bacterial soaps and sanitizers should / should not be restricted?
- 17. What information, data, or evidence do you have to support your point of view?

APPENDIX C: EXHIBIT EXIT SURVEY

<u>Rating and Demographic Questions</u>1. Please rate your agreement with the following statements.

	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
There is scientific evidence that supports the view that sugary drinks should be taxed.	1	2	3	4	5	6	7
There is scientific evidence that supports the view that sugary drinks should not be taxed.	1	2	3	4	5	6	7
A person's values can influence whether or not they believe a piece of scientific evidence.	1	2	3	4	5	6	7
A person's values can influence whether they are for or against taxing sugary drinks.	1	2	3	4	5	6	7
The final decision to tax or not tax sugary drinks will impact people differently because they vary biologically.	1	2	3	4	5	6	7
The final decision to tax or not tax sugary drinks will impact people differently because they live in different environments.	1	2	3	4	5	6	7
I can support my viewpoint in a conversation about the taxation of sugary drinks.	1	2	3	4	5	6	7
I would feel comfortable expressing my viewpoint about the taxation of sugary drinks in a group discussion.	1	2	3	4	5	6	7

2. What is your age? _____ years

- 3. What is your gender?
 - □ Male
 - □ Female

4. What is your race/ethnicity? (Please check all that apply)

- □ African-American
- American Indian or Alaskan Native
- □ Asian-American
- □ Hispanic/Latino
- □ White, not of Hispanic origin □ Other:

5. What is your zip code?____

6. Are you a Museum of Science member?

- □ Yes
- **No**

7. Since July 2011, approximately how many times have you visited the Museum, including this visit?

1	G	□ 11	1 6
2	□ 7	1 2	2 7
3		1 3	1 8
4	9	1 4	□ 19
5	1 0	□ 15	□ 20+

8. Why did you decide to visit the Museum of Science today? (Check up to two that most apply.)

- □ To spend time together as a group/family
- □ To bring out of town friends/family
- □ Educational experience for group members/children
- **□** Educational experience for myself
- □ For fun/entertainment for group members/children
- □ To see a specific exhibit, program, or show
- □ For fun/entertainment for myself
- □ Something to do in poor weather
- □ Had a coupon/free pass
- □ Something to do while visiting Boston
- □ Other (Please specify): _____

Provocative Questions Exploratory Research

APPENDIX D: OTHER OBSERVATION DATA

TABLE D1. Visitor Group Behaviors Identified During Interaction with the Provocative Questions Exhibit (N=88).

Behavior	Number of Groups Displaying Behavior	Percent
Visits Intro Panel	44	50%
Visits Value Panel	75	85.2%
Looked at: Anti-depressants question	58	65.9%
Interacted with: Anti-depressants question	50	56.8%
Looked at: Genetic makeup of babies question	59	67.0%
Interacted with: Genetic makeup of babies question	53	60.2%
Looked at: Water fluoridation question	64	72.7%
Interacted with: Water fluoridation question	52	59.1%
Visits Science Evidence Panel	60	68.2%
Visits Personal Experience Panel	68	77.3%
Used hearphone	22	25.0%
Science Reading Area	4	4.5%
Looked at binder	0	0.0%
Downloaded smart phone app	0	0.0%
Uses Break it Down	74	84.1%
Uses What's Your Opinion	83	94.3%
WYO: Listened to audio	7	8.0%
WYO: Visited alone	20	22.7%
WYO: Visited with another group member	79	89.8%
WYO: Chose personal experience.	77	87.5%
WYO: Discussed their personal experience choice	70	79.5%
WYO: Chose science evidence	73	83.0%
WYO: Discussed their science evidence choice	65	73.9%
WYO: Chose value	71	80.7%
WYO: Discussed value choice	64	72.7%
WYO: Viewed arguments	69	78.4%
WYO: Discussed their entire argument	62	70.5%
WYO: Viewed visitor data	61	69.3%
WYO: Discussed other visitor data	53	60.2%
WYO: Completed the activity.	54	61.4%

Provocative Questions Exploratory Research

Code	Definitions	Example Quotes
Value	Evidence is categorized as a value when someone uses "should" or "need" statements or applies to other values such as a political or environmental value.	 "people should be educated on the danger" "It is up to people whether they want to use it." "people need to be informed"
Personal Experience	 Evidence is categorized as personal experience when someone refers to their own actions to justify the desirability of an action. Common knowledge statements including any about science that did not include any scientific explanation were also categorized as personal experience. Statements referring to the lack of personal experience were also classified here. Ex: I don't have much knowledge on the subject. 	 "I know people who overdo it and they're always sick!" "I work in a hospital." "Everyone drinks them, even if they aren't good for you."
Science Evidence	Evidence is categorized as scientific evidence when someone refers to universal science evidence or any knowledge that has been tested using the scientific method. This includes the usage of scientific terms and reasoning as well as information about health.	 "Antibacterial is actually killing good bacteria and bad bacteria." "You can develop resistance." "Sugary drinks have lots of calories, contribute to obesity/health problems."

APPENDIX E: ARGUMENT EVIDENCE CODING RUBRIC

Judgment calls

- Personal opinion: The evidence of "personal opinion" was classified as a value instead of personal experience because it did not mention any individual's actions.
- Television shows: TV was categorized as personal experience except for mentions of the News or shows about science.
- Taxation as a result of other taxes: Several statements were made about taxing an item in relation to the taxation of other items. When these stated the belief about taxation in comparison to other taxes, they were classified as a political value. Ex: "[X] is taxed so we might as well tax everything else too". When the statement only recognized the existence of other taxes, they were classified as personal experience. Ex: "Everything else is being taxed."

Provocative Questions Exploratory Research

APPENDIX F: OTHER EXIT INTERVIEW DATA

TABLE F1. Visitor Groups' Responses to the Open-Ended Exhibition Exit Interview Question: "What would you say the Museum is trying to have you learn about in these exhibits?" (N=88)

The Museum is trying to have me learn about	Number of Groups	Percent of Groups	Example Quote
How people form opinions or about other people's opinions.	30	34.1%	Group 40: [F1, 24]: Forming opinions. [M1, 24]: Different ways we form our opinion.
The health effects of sugar.	23	26.1%	Group 1: [F3, 18]: Think about health effects of these drinks.
How different kinds of evidence such as scientific research, personal experience, and values can be used to support socio- scientific arguments.	22	25.0%	Group 2: [M1, 20]: How opinions are generated between personal experience, social values, and scientific evidence. [M2, 58]: Focus on, these are the three key parts of an argument. [M1, 20]: The taxation question is just an example.
Current topics in society.	19	21.6%	Group 31: [F1, 24]: Make us aware of decisions the government is trying to make.
Other	18	20.5%	Group 46: [M1, 56]: Socialism.
How societal decisions impact people differently because of their varied biology & environment.	14	15.9%	Group 41: [M1, 43]: Providing insight into human dynamics and how it affects social issues.
How a person's values influence his or her interpretation of science and position about a socio- scientific question.	6	6.8%	Group 24: [F1, 29]: Recognizing your own social values in the process.
How science research is applicable to varied views or about varied science research.	2	2.3%	Group 50: [F1, 20]: Forming your own opinion also with scientific evidence. You can't have a legit opinion without evidence to support it.

	Number of Groups	Percent of Groups	Example Quote
Other	24	27.3%	Group 12: [M1, 16]: There are so many types of sugary drinks.
I learned that science research is applicable to varied views or about varied science research.	23	26.1%	Group 26: [M1, 20]: I didn't know the tax on tobacco lead to the increase in eating and obesity. [F1, 21]: The sugary drinks and obesity, that was obvious.
I learned about other people's opinions and/or how my own opinion compares to others.	23	26.1%	Group 15: [M1, 27]: Not a lot of people share the same ideas as me.
I learned that different kinds of evidence such as scientific research, personal experience, and values can be used to support socio-scientific arguments.	19	21.6%	Group 2: [M1, 78]: To see, social values, experience, science. That was interesting to learn.
I didn't learn anything.	19	21.6%	Group 7: [F1, 22]: Feel like it covered stuff I already knew.
I learned that taxation of sugary drinks is a current issue.	16	18.2%	Group 8: [F1, 19]: That there's a debate at all. [M1, 22]: Yeah, I didn't know this was an issue.
I learned that a person's values influence his or her interpretation of science and position about a socio- scientific question.	1	1.1%	Group 35: [M1, 25]: How much value people place on social views as opposed to personal experience.
I learned that societal decisions impact people differently because of their varied biology & environment.	1	1.1%	Group 88: [M1, 58]: Reinforced something I don't like, how many people think of just themselves.

TABLE F2. Visitor Groups' Responses to the Open-Ended Exhibition Exit Interview Question:"What, if anything, did you learn from these exhibits that you didn't know before?" (N=88)

TABLE F3. Visitor Groups' Responses to the Open-Ended Exhibition Exit Interview Question: "In the exhibits, different kinds of statements were described that can be used to support a viewpoint about taxation of sugary drinks. Can you please tell me what they were?" (N=88).

Type of Support Identified By Name	Number of Groups	Percent of Groups	Example Quote
Personal Experience	67	76%	[M1, 25]: Factual statements, things you've heard before - what society has said, personal experience.
Social Values	58	66%	[F1, 16]: I shouldn't be taxed for stupidity - social values.
Scientific Evidence	68	77%	[M1, 24]: Personal statement, scientific statements.
All three	55	63%	[F1, 55]: Scientific background, personal background, social, political values.
Other	35	40%	[M1, 26]: Effect on health. [F1, 26]: Role of government on decision on making health decisions for you. Bringing health care into it a bit too.

*Note: Percentages add up to more than 100% because groups could be counted in more than one category.

APPENDIX G: OTHER EXIT SURVEY DATA

TABLE G1. Visitors' Responses to Survey Rating Questions Not Included in Findings Section.

Survey Question	N	Mean	Std. Deviation	Number of Respondents Choosing 6 or 7	Percent of Respondents Choosing 6 or 7
The final decision to tax or not tax sugary drinks will impact people differently because they vary biologically.	88	5.04	1.474	39	44.3%
The final decision to tax or not tax sugary drinks will impact people differently because they live in different environments.	88	5.35	1.415	50	56.8%

TABLE G2. Demographics of Exploratory Research Study Participants Who Filled out the Exhibit Exit Survey (N=88).

Demographic C	ategory	Number of Visitors
Sex		
Male		35
Female		53
Race/Ethnicity		
African-Americar	า	2
American Indian/	Alaskan Native	0
Asian-American		6
Hispanic/Latino		7
White		67
Other		6
Age		
Under 18		11
18-24		33
25-29		13
30-34		7
35-44		11
45-54		5
55-64		7
65-74		1
75-85		0
85+		0

TABLE G3. Visitors' Responses to Exit Survey Questions: "Are you a Museum of Science Member?" (N=61).

Member Status	Number of Visitors	Percent
Member	9	14.8%
Non-member	52	85.2%

TABLE G4. Visitors' Responses to Exit Survey Question "Since July 2011, approximately how many times have you visited the Museum, including this visit?" (N=61).

Reason for Visiting	Number of Visitors Choosing
To spend time together as a group/family	25
Something to do while visiting Boston	22
For fun/entertainment for group members/children	17
For fun/entertainment for myself	15
Educational experience for myself	13
Educational experience for group members/children	10
Other	7
To see a specific exhibit, program, or show	6
To bring out of town friends/family	4
Something to do in poor weather	3
Had a coupon/free pass	2

*Note: Visitors could choose more than one answer. They were instructed to check up to two, but some checked more.