NISE Net Research on How Visitors Find and Discuss Relevance in the *Nano* Exhibition

Research Report

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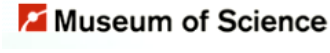

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Executive Summary

Over the final five years of the Nanoscale Informal Science Education Network (NISE Net), the "Research on Public Learning and Decision-Making" (PLDM) team studied how visitors make decisions and learn about nanotechnologies through a variety of NISE Network educational products. The focus of this report is an exploratory study conducted on the *Nano* exhibition in order to answer the research question:

> How do visitors use, interact with, and talk about the exhibit components within the *Nano* exhibition to learn about the relevance of nano to their lives?

To answer this question, PLDM team members video- and audio-recorded 33 groups of visitors that used and had conversations in the *Nano* exhibition. They then conducted a reflective interview with these groups to further understand what visitors were doing and thinking as they used the exhibition.

Researchers analyzed the data beginning with a framework from Kember, Ho, and Hong (2008) who define four types of personal and career relevance: applying theory to practice, relevance to local issues, relevance to everyday applications, and relevance to current topics. This starting framework was used to understand the kinds of relevance that visitors found within the exhibition. However, a *post hoc* coding scheme was also added to understand how visitors were making connections to nano: whether it was directly through exhibition content (internal relevance connections) or by adding examples from their own lives and experiences (external relevance connections).

Findings from this study indicate that visitor groups found relevance predominantly at the exhibition panels where most of the content about applications and societal issues was contained. Many visitor groups also found relevance at the interactive "Balance Your Nano Future." In finding relevance, visitor groups' discussions touched on all of the different kinds of relevance described by Kember, Ho, and Hong (2008). However, most commonly, these conversations were about relevance to current topics and relevance to everyday applications. It appeared that visitors tended to rely on content contained within the exhibition components (internal relevance connections) for their conversations of relevance to current topics. However, they often extended the component content to include examples from their own lives (external relevance connections) as a part of conversations about relevance to everyday applications.

These findings may have implications for future exhibit and program design as it appears that purposefully adding content about applications and societal issues will lead visitors to find the relevance of a STEM topic. However, it appears important to provide a variety of examples of societal issues for visitors to draw upon to be able to discuss relevance to current topics. It may not be as important to provide a variety of examples related to the relevance of everyday applications because in these cases it appears that visitors are more easily able to draw on examples from their own lives and experiences.

I. Introduction

Over the last five years, the Nanoscale Informal Science Education Network (NISE Net) "Research on Public Learning and Decision-Making" (PLDM) team, which has members from the Museum of Science, Boston, Science Museum of Minnesota, and University of Notre Dame, has studied how visitors make decisions and learn about nanotechnologies through a range of educational products developed by the NISE Network. Specifically, the team focused on understanding how the design of public deliverables containing nano and society or societal and ethical implications content can help visitors learn and make decisions.

The first phase of this work focused on visitor decision making about nano within the NISE Net forums. The primary focus of this report is the second phase of the PLDM work, which began in 2013. During this phase, the PLDM team expanded the scope of the research in order to examine how visitors come to understand the relevance of nano to their lives when visiting the *Nano* exhibition.[1] The shift in focus was due in large part to the findings of the *Nano* exhibition summative evaluation (Svarovsky et al., 2013), which suggested the exhibition was not only successful in providing visitors at a variety of Network partner institutions with an engaging experience that promotes learning about nano concepts, but that it also helped visitors see and make connections between nanotechnology and their lives. Specifically, 59% of visitors felt there was a connection between the *Nano* exhibition and their daily lives (Svarovsky et al., 2013). This idea, "Nano is connected to our lives," was the lesson from the NISE Net content map that visitors most commonly reported having learned. However, while the evaluation found that visitors learned this content through *Nano*, it did not explore how or why visitors learned this content. Therefore, the question guiding the second phase of this exploratory research is:

> How do visitors use, interact with, and talk about the exhibit components within the *Nano* exhibition to learn about the relevance of nano to their lives?

By beginning to examine the ways in which visitors connect with ideas and concepts within *Nano*, this study can help shed light on how new and current STEM topics—which can sometimes feel overwhelmingly complex, abstract, or irrelevant to visitors—can engage the public in meaningful ways within informal learning environments. It can also help museums and other informal science education institutions think about specific ways that they might include content in exhibits and programs if they want visitors to make a relevance connection.

Background and Theoretical Framework

There are many references within educational literature about the importance of relevance to learning (Assor, Kaplan, & Roth, 2002; Chang & Lehman, 2002; Frymier & Shulman, 1995; Keller, 1987; Kember, Ho, & Hong, 2008). In terms of education,

[1] The *Nano* exhibition is a 400 square foot exhibition on nanoscale science, engineering and technology with 93 copies distributed to museums nationwide. Further information about the *Nano* exhibition can be found on the NISE Net website (http://www.nisenet.org/catalog/exhibits/nano_mini-exhibition).

relevance is defined as linking content to students' needs and goals (Keller, 1987). These needs and goals can either be personal or related to students' future careers (Frymier & Shulman, 1995). Educational research indicates that relevance, along with other factors, including interest, confidence, and satisfaction, can be incorporated into the design of a learning experience in order to motivate people to learn about a topic (Chang & Lehman, 2002; Keller, 1987). However, relevance appears to be especially important as a method of enhancing the intrinsic motivation of learners (Chang & Lehman, 2002). In other words, relevance can be used to motivate learners to continue learning about content on their own, without the influence of outside factors, such as the need to pass a test. This kind of motivation is especially important in museums, where visitors have the ability to decide which content they want to engage with or ignore.

Previous NISE Net evaluation studies have looked at the use of relevance within the context of NISE Net public educational products. The chapter, "Making the Unfamiliar Interesting and Relevant for Museum Visitors," in the *Review of NISE Network Evaluation Findings: Years 1–5* (*Review*) discussed findings on interest and relevance within evaluation studies from the first five years of the NISE Net (Reich, 2011). The *Review* reported that motivating people to learn about nano in the moment as well as after they leave the museum is the reason why the NISE Net has created products for the public that help them understand the relevance of nano to their lives. This echoes the findings from Chang and Lehman (2002) that show that relevance can lead to intrinsic motivation for learning.

Additional analysis of evaluation data in the *Review* indicated that interest and relevance are not the same thing in the minds of visitors. Rather, visitors can find an activity interesting or relevant, but an activity does not need to be relevant to make it interesting, and vice versa (Reich, 2011). This finding is supported by literature (Chang & Lehman, 2002; Keller, 1987), which found that interest and relevance are two different factors that can be used separately to motivate learning. Furthermore, the *Review* found that content—more specifically, the inclusion of applications and technologies—was called out by visitors as the factor that made an experience relevant (Reich, 2011).

These two areas of content-focused relevance that emerged as touchpoints for public audiences who engaged with NISE Net educational products align with the types of relevance reported by Kember, Ho, and Hong (2008) as a part of their study of relevance and learning within undergraduate learning environments. Specifically, Kember, Ho, and Hong (2008) define the following four types of personal and career relevance as part of a broader relevance framework:

- *Applying theory to practice*: This is showing how a theory can be used in real life situations. For example, this type of relevance can be seen if visitors discuss how scientists make use of the physical property that things act differently when they are small.

- *Relevance to local issues*: This refers to content related to a local context or situation. For example, this type of relevance is seen if visitors in Boston discuss a nanotechnology company located in Cambridge or a Boston law to ban nanotechnologies.

- *Relevance to everyday applications*: This refers to content related to an individual's everyday life or experiences. For example, this type of relevance can be seen if visitors discuss how using nanomedicine to treat cancer reminds them of their aunt undergoing cancer treatment.

- *Relevance to current topics*: This refers to content about current news or societal issues. For example, this type of relevance can be seen if visitors discuss how a nano water filter reminds them of something they read regarding the need for clean drinking water in a developing country.

Using these initial categories as a lens to explore the types of relevance visitors found during their experiences with the *Nano* exhibition, this study sought to extend the Kember, Ho, and Hong (2008) framework into an informal learning context, where relevance and connection are often hallmarks of meaningful and memorable learning experiences. In particular, the study aimed to better understand how visitors develop a sense of relevance through a museum exhibition, the types of relevance they are likely to find as a part of their exhibit experience, and how the design of the different components impacts visitors' understandings of relevance. As such, this study provided implications for the development and implementation of future informal science education (ISE) experiences that seek to leverage and catalyze relevance and connection for the public to current and complex science topics.

II. Methods

Getting at the "how" of the research question required a window into participants' thought processes as they moved through the *Nano* exhibition. The research team therefore designed a qualitative, exploratory study that would capture both recordable behavior/discussion in the exhibition area and visitors' own reflections of their behavior/discussion, via the following methods:

- Direct observation,
- Video/audio recordings,
- Surveys, and
- Reflective post-survey interviews.

Data collection occurred over a five-month span, from September 2013 to January 2014, at the Science Museum of Minnesota. More information about the methods is described below.

2.1 Study Participants

Participant groups were comprised of two to three individuals including at least one adult. All group members were required to be over the age of ten.[2] This group composition was purposely chosen by the research team because these criteria would be more likely to (a) allow/encourage conversation between visitors, and (b) produce audio that was clear of interruption and overlap.

Participant groups were continuously sampled (Randi Korn & Associates Inc., 2000): once data collectors were ready to recruit a new group, the lead data collector would approach the nearest eligible group and engage them in the recruitment process. All participants signed consent forms stating that they agreed to participate and to be video and audio recorded; a legal parent or guardian signed consent forms on behalf of minors, who verbally assented. In total, researchers collected data from 35 cases, two of which were dropped from the final analysis because of human subjects protection concerns. This resulted in a final sample size of 33 cases for the study, with a mean dwell time of 17:24 minutes in the exhibit across all participant groups.

2.2 Data Collection Site and Equipment

Data collection took place in the *Nano* exhibition, first housed on the third floor and later moved to the fourth floor of the Science Museum of Minnesota (See Figure 1 for a diagram of the exhibit area layout.) During data collection, the entire exhibition area was stanchioned off to deter entry by non-participant visitors. A stationary video camera was

[2] It should be noted a few changes were made to participation criteria over the course of the study. The first change was decreasing the maximum group size from four to three because of audibility issues for researchers. The second change was increasing the minimum age of participants from 7 to 10 because younger visitors had difficulty answering interview questions. There were a few early groups that had more than three participants or group members under the age of 10 who remained in the sample.

preset to capture all activity occurring within the exhibition area. Audio from each group was captured via body microphones worn by two visitors in each group during the study.

Video recording began as soon as participants entered the exhibition area, where the interviewer prompted them: "Take as long or as little time as you would like, and let me know when you're done." The interviewer stood outside the exhibition area while study participants visited the exhibition, listening in to their conversation via a second set of audio receivers and taking notes on an observation form. This setup prompted the interviewer to align her observations with specific components and allowed her to note specific questions and interesting interactions for reference during the reflective interview with participants.

Figure 1. Data Collection Area as seen from the first of two camera angles, labeled with the names of each component.

2.3 Reflective Interview

After participants indicated they were finished with their visit, the interviewer entered the exhibition area and began the interview, which was intended to prompt participants to describe what they were thinking during specific parts of their exhibition experience. The

interviewer used notes made while observing and listening to participants during their time in *Nano* to probe for further clarification and reflection as appropriate; this fruitful technique yielded additional insights into participants' thoughts and actions while in the exhibition. During the interview, participants also completed a survey[3] exploring changes in confidence before and after visiting *Nano*.

2.4 Data Analysis

For data analysis, the team first created transcripts of the video recordings. These transcripts included visitor conversations while they used the *Nano* exhibition and participated in their interviews.

The team coded the transcripts using Dedoose (http://www.dedoose.com), an online qualitative data-analysis software that allows for coding of transcript data. By using this software for coding, team members in different locations were able to access and code at the same time. Coding occurred in a two-round process, which is described in detail below.

2.4.1 Round 1: Coding for instances of relevance and exhibit component

The first round of the coding process was broad-category coding. The large categories used to code the data during this step included the following:

- Exhibit Component: Coders watched the videos and noted on the transcripts the components[4] visitors were using or talking about while visiting the exhibition. They also noted components that visitors were discussing within the post-visit reflective interview.

- Relevance: This was any instance when visitors were making connections to their lives or experiences while visiting the exhibition or during the post-visit reflective interview.

At this point in the coding process, team members defined relevance as any connection that visitors made to their own lives or experiences. A broad definition of relevance was used to ensure that all possible instances of relevance would be part of the second step of the coding process.

2.4.2 Round 2: Coding for Kember, Ho, and Hong (2008) relevance types and kinds of relevance connections

Once the first round of coding was complete, the coding team members looked at aspects of the visit and interview that were coded as relevance and applied the *a priori* codes from the Kember, Ho, and Hong (2008) framework. They also created two sets of *post hoc*

[3] This survey was the same as one used as a part of the *Summative study of the Nano mini-exhibition* (Svarovsky et al., 2013).
[4] A list and description of the *Nano* exhibition components can be found in Appendix A. The components that were coded for as a part of this study can be found in Appendix B.

codes. These *a priori* codes, which are discussed in more detail in the Background and Theoretical Framework section above, included the following four kinds of relevance[5]:

- Applying theory to practice
- Relevance to local issues
- Relevance to everyday applications
- Relevance to current topics

Additionally, the two *post hoc* code books were created because of observations that were made during the analysis process. First of all, coders found that there were distinct themes within the "Relevance to everyday applications" code. Therefore, they decided to create sub-codes for this relevance category to understand the prevalence of the different themes they observed in this area. The sub-codes they created for "Relevance to everyday applications" included the following:

- Use/application: This was a reference to a use or application that visitors personally knew of or might utilize themselves.
- Prior experience or knowledge: This was a reference to something the visitor already knew about or had experienced through work, school, or media.
- Relation to a friend/ family member: This was a reference to how the content might impact or be related to a visitor's friend or family member.
- Other: This was a reference within the everyday application code that did not fit within the other sub-codes.

For the second *post hoc* code book, coders observed that at times visitors were relying on content contained within the exhibit components to find and discuss relevance. Other times, they brought up examples from their own lives and experiences. To explore what was happening when these two different kinds of connections to the content were being made by visitors, the coders created two codes:

- Internal relevance connections: This was when visitors discussed a specific example of relevance that was part of the labels within the exhibition. This was seen when visitors read specific parts of labels out loud or just mentioned them in discussion or as part of the interview as an example from the exhibition labels that they found relevant.
- External relevance connections: This was when visitors brought up a new example or application that they found relevant which was not explicitly included in the exhibition. This also included when something they saw or read in the exhibition

[5] Coders also added an "other" category for any instances of relevance that did not fit into the Kember, Ho, and Hong (2008) codes.

reminded them of something else in their life. For example, this was seen when visitors talked about how a part of the exhibition related to a class they took, an experience they or a friend/family member had, or an application or technology they know of that was similar to but not explicitly included in the exhibition content.

2.4.3 Inter-coder reliability

Two team members conducted all of the transcript coding. Each of the coders completed the coding for half of the transcripts. As part of coding, the two coding team members first had to reach consensus about what transcript excerpts fit into the different code books. To do this, they each coded one of the transcripts and compared how much their coding overlapped. If their inter-coder reliability rate was less than 0.7, they would discuss any discrepancies, come to consensus about the most appropriate code, and refine the code definitions. Then, they would code an additional transcript and repeat the process until the code book led to an inter-coder reliability rate of 0.7. For Round 1, coders had an inter-coder reliability rate of 1.0. For Round 2, coders had an inter-coder reliability rate of 0.7 for the Kember, Ho, and Hong (2008) code book and an inter-coder reliability rate of 0.8 for the relevance connection code book.

Once the two rounds of coding were complete, the PLDM team looked at the kinds of relevance that visitors found to see if there was a link between the type of relevance and the component being used. The team also looked more broadly to see if there were common features of the exhibit components that seemed to lead visitors to understand the relevance of nano to their lives.

III. Findings

3.1 All visitor groups found relevance in the *Nano* Exhibition.

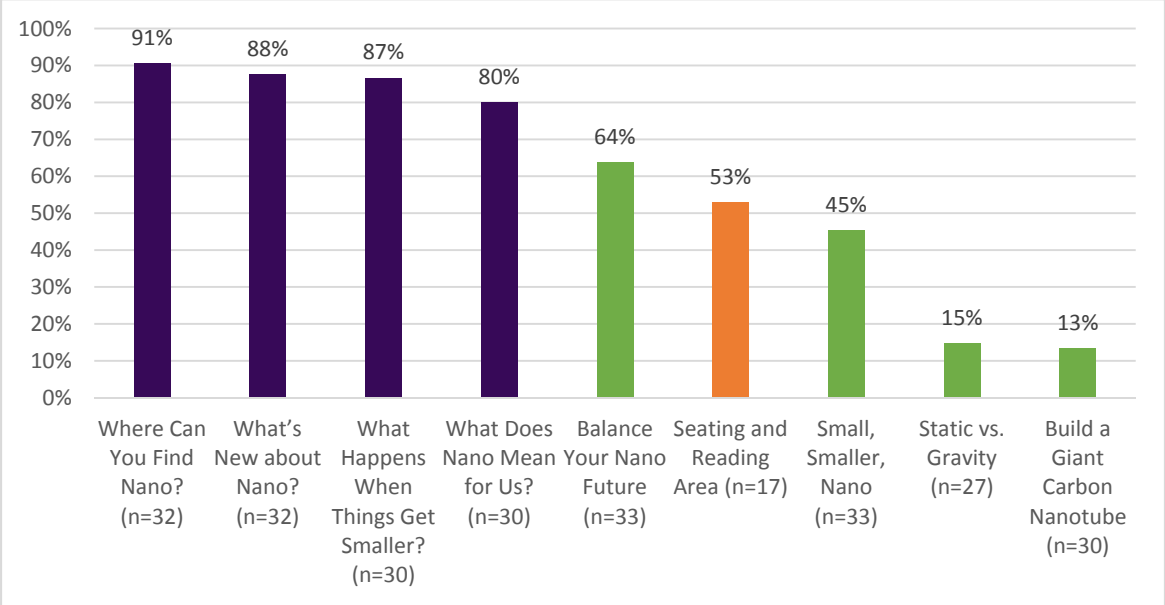
As explained in the Introduction, this study defined relevance as a connection a visitor makes between *Nano* exhibition content and his/her life or experiences. According to this criterion, the number of study groups who found relevance at some point during their exhibit experience was 33 out of 33. In looking more closely at the data, it was discovered that no groups found relevance at all of the components that they visited. However, there do seem to be patterns around where in the exhibition visitor groups tended to find relevance (Figure 2).

Data indicated that visitor groups most commonly found relevance at the panel components:

- "Where Can You Find Nano?" (91%, 29 of 32 groups),
- "What's New about Nano?" (88%, 28 of 32 groups),
- "What Happens When Things Get Smaller?" (87%, 26 of 30 groups), and
- "What Does Nano Mean for Us?" (80%, 24 of 30 groups).

Additionally, over half of the study groups found relevance at two other components. Almost two-thirds of groups visiting "Balance Your Nano Future" found relevance at that component (64%, 21 of 33). Finally, just over half of the study groups visiting the "Seating and Reading Area" found relevance at that component (53%, 9 of 17 groups). More information about the kinds of relevance content visitors discussed while using these and the rest of the *Nano* components can be found in section 3.2.

Figure 2. The percentage of groups visiting each *Nano* exhibition component who found relevance.

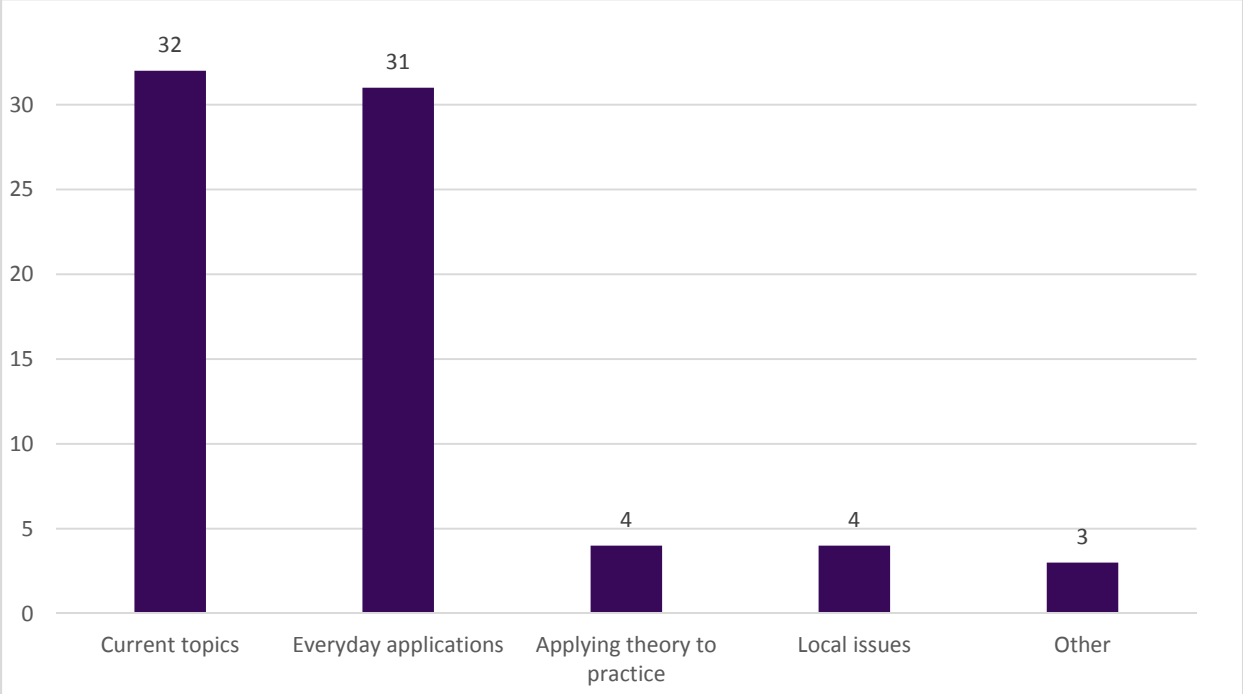


Note. In this graph, purple bars represent panel components, green bars represent interactive components, and orange bars represent other kinds of components.

3.2 The most common kinds of relevance visitor groups found in *Nano* were with current topics and everyday applications.

Findings indicate that the kinds of relevance that visitors discussed in *Nano* generally matched the Kember, Ho, and Hong (2008) framework, and that there were only a few instances when the kinds of relevance visitors found did not fit with the existing framework (Figure 3). The following sections detail number of groups who found each kind of relevance and the range of topics they discussed within the exhibition.

Figure 3. The number of visitor groups whose discussions included the types of relevance from Kember, Ho, and Hong (2008) (N=33).



3.2.1 Visitor groups most commonly discussed current topics relevance in the exhibition.

As can be seen in Figure 3, visitor groups most often made a connection between nano and current topics (32 of 33 groups). Relevance to current topics was coded when visitors discussed content related to nano and current issues or news, either as a part of their interactions within the *Nano* exhibition or during the interview. In other words, this code was applied when visitors talked about implications of nano on society at large or on a broader group of people than just themselves.

In looking at the ways in which visitor groups discussed relevance to current topics in the *Nano* exhibition, it was found that visitors covered a number of different topics. One way that visitors discussed relevance to current topics was in terms of how nano might impact the **creation or design of technological applications**. Some examples of this kind of current topic relevance found in visitors' discussions or interview responses include the following:

INTERVIEWER: Was there anywhere else in the exhibit where you feel like nano connected to daily life? Like, your life or other people's lives that we haven't already talked about?

ADULT MALE: I think it was "What's New about Nano?" where they talked about water cleansing and cleaning up… I know they have this straw thing that they're doing donations for over in South America and Africa where you can just suck up water through a stream from a straw and it'll clean it for you by the time it reaches your mouth through a whole bunch of different filters and catalysts and whatnot.

Group 20 about "What's New about Nano?"

ADULT FEMALE 2: Touch. It says touch [this fabric], can a toy use nanotechnology and you touch it. Where does it say- it's not doing anything is it? ... You can't see the nano silver they contain. Lots of things are made of nanotechnology, but you can't tell. Food, clothing, appliances, and toys can include nanotechnology… Okay so this little bear can include it.

Group 32 at "Where Can You Find Nano?"

Another way that visitors discussed relevance to current topics was to talk about how nano might have **implications for human or environmental health**. Some examples of this kind of discussion found within the study sample include the following:

INTERVIEWER: Did anything connect to your neighborhood, community, outside of yourself at-large?

ADULT FEMALE: Just kind of maybe the idea of planning. That ["Balance Your Nano Future" activity] is a good example of how we have to balance [the use of nano], not because everything is going to slide off but just because it's interesting to think about.

Group 27 about "Balance Your Nano Future"

INTERVIEWER: Shall we talk about… identifying at least one way that nano will impact our life in the future? Any increased confidence there? Yeah?

ADULT FEMALE: [Nano's] going to come up with a cure for diabetes.

Group 28 about "What Happens When Things Get Smaller?" and "Seating and Reading Area"

Finally, another way that visitors discussed relevance to current topics was to describe how nano might become **more common in society**. Some examples of this kind of visitor discussion from the study sample include the following:

INTERVIEWER: If a friend asked you, "What did you learn about nanotechnology at the exhibit today?" what would you say? There's no right or wrong answer, of course.

ADULT FEMALE: I don't know, one of the things that stuck out to me was …the tea filters to clean things in other countries, and it's cheap. And then also the fact that it's already being used quite a bit in food and other areas that we're not aware of and don't know all the ramifications of.

ADULT MALE: Yeah, everything I had seen [previously] is generally something that's on the horizon. I didn't know that they're already having a lot of practical applications for it.

Group 1 about "What Happens When Things Get Smaller?"

INTERVIEWER: So if a friend asked you what did you learn about nanotechnology from the exhibit today? What would you say?

ADULT FEMALE: How... nanotechnology [is]… taking what's already in nature to build what we have and how it affects so much of our lives and can help it.

Group 15 about "What's New about Nano?"

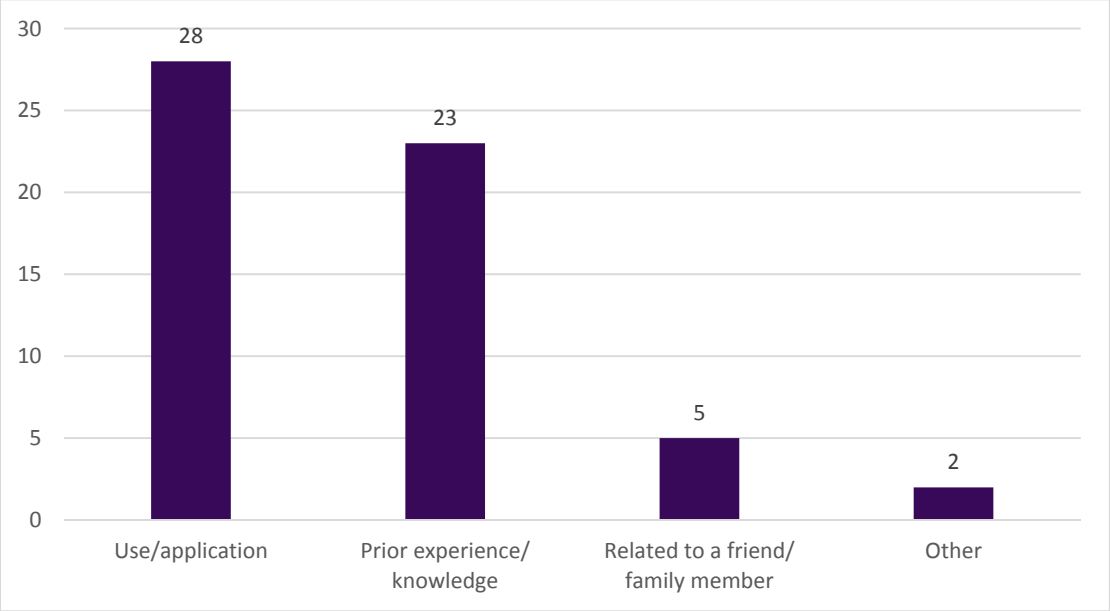
These quotes from visitors' exhibition interactions and interviews indicate that groups made a number of different kinds of connections between *Nano* and relevance to current topics. Some visitors discussed how nano might impact the creation or design of technological applications; some discussed how nano might have implications for human or environmental health; and others talked about how nano might become more commonly used in society. All these data show that the *Nano* exhibition enables visitor groups to discuss the relevance of nano to society, and not only that this kind of conversation is possible, but likely, within the exhibition.

3.2.2 Almost all visitor groups discussed everyday applications relevance in the exhibition.

Figure 3 shows that most visitor groups (31 of 33) found a connection in the exhibition between nano and everyday applications. Relevance to everyday applications was coded when visitors discussed content related to nano and their own everyday lives or experiences, either as a part of their interactions within the *Nano* exhibition or during the interview. In other words, this code was applied when visitors discussed how nano or a related topic might impact them directly.

For this particular code, *post hoc* sub-codes were created because researchers found that there were distinct topics that visitor groups discussed about how nano related to them personally. As described in the Data Analysis section, those four sub-codes included: use/ application, prior experience or knowledge, relation to a friend/ family member, and other. The breakdown of the everyday application sub-codes can be found in Figure 4. They are also described in more detail below.

Figure 4. The number of visitor groups whose discussions fell into different *post hoc* sub-codes for relevance to everyday applications (n=31).



In looking at these sub-codes, findings indicate that visitor groups most commonly discussed use/application (28 of 31 groups). Examples of the kinds of topics that visitor groups discussed when talking about **use/applications** include the following:

ADULT MALE: Okay. So the ferrofluid is made of a tiny nano-sized particles of iron oxide suspended in liquid… And it was invented by NASA in the 1960s…

ADULT FEMALE: Why'd they invent it?...

ADULT MALE: As a way to control liquids in space. Nowadays it's used in loudspeakers to dampen vibration.

FEMALE CHILD: Oh, that's so cool!

ADULT FEMALE: Can we dampen our children with nano? [Laughs]…

ADULT MALE: Pack them in ferrofluids! [Laughs]

ADULT FEMALE: Hey guys, we're going to get some ferrofluid for you guys. We can dampen your yelling and fighting.

FEMALE CHILD: No, you're not! Stop!

Group 3 at "Small, Smaller, Nano"

INTERVIEWER: Thinking back to different areas of the exhibit overall, did you ever feel like nano connected at all to your everyday life?...

ADULT FEMALE 2: Yes… like these socks I'm wearing!

ADULT FEMALE 1: [They] have the silver in there… That's the reason we picked them. We're not from here, we're from Louisiana. Someone told us about the snow and cold and all that. And someone told us that you need to get the socks with the silver in them and we thought "Silver thread, what's silver thread? What's important about that? It seems dumb." We didn't get it…

ADULT FEMALE 2: Yeah, they work great. It's supposed to not smell and not get grungy as easily, and it totally works. They're awesome.

Group 10 about "Where Can You Find Nano?"

Also within the everyday applications code, it was found that many groups (23 of 31) discussed how content in the exhibition related to **prior experiences or knowledge** related to things they had learned in class, from the media, and/or had experienced through work or life (Figure 4). Examples of this sub-code can be found below:

ADULT MALE: But if a friend said, "Well, what did you learn?" I'd be like, well, they're so tiny that you can do this and this and this and this with them.

INTERVIEWER: Would you mind giving me some examples? Just like [what] you would [say] to your friends, hypothetically in this situation?

ADULT MALE: Uh, well I- I'd start out- I don't know if you heard me talking about the birds, but I was reading an article in Scientific American about… a new study about the evolution of feathers. Not necessarily being natural selection, but sexual selection. That feathers were kind of developed for beauty… To attract a partner rather than adapt to new scenarios, and how from that then came the beautiful iridescent flower… and how, like I was telling her, they're trying to make displays [for tablets and Kindles] that once it paints an image it can shut down to conserve energy and that colorful image will stay.

Group 11 about "Where Can You Find Nano?"

ADULT FEMALE: [Reading label] "Geckos can walk up walls because their feet have millions of nano sized hairs that are attracted to the wall's surface." Spiderman, again!... This whole exhibit is Spiderman. "Climbing robots have feet that imitate geckos. Very cool."

Group 23 at "What's New about Nano?"

ADULT FEMALE 1: And trying to balance the table with the different sections of nanotechnology.

MALE CHILD: [That's] something we're learning about in social studies…

INTERVIEWER: What is it that you're learning?

MALE CHILD: About government and stuff like that, how to balance things out.

Group 32 about "Balance Your Nano Future"

Only a few groups (5 of 31) within the everyday applications code talked about the relationship between nano and a **friend or family member**. Some examples of this code, from groups' interactions in *Nano* or through the interview, are below:

ADULT FEMALE: I was thinking, um, "gee I wonder if my son would be interested because [nano] looks like a good field to go into."

INTERVIEWER: [laughs] Right. That makes sense. Um, where did you… where did it first occur to you that it might be a good field to go into? Like was it something in here that made you think of that?

ADULT FEMALE: …This one. "How do we study and make nanotechnology?"... [Because] my older son is… studying electrical engineering.

Group 12 about "Seating and Reading Area"

INTERVIEWER: Okay. Yeah, we kind of talked about a lot of this already. Anything else come to mind for you?

FEMALE CHILD: Well, when we were building that… molecule… [It] kind of made me think of my dad building stuff.

INTERVIEWER: Made you think of what?

FEMALE CHILD: My dad builds stuff… and it kind of made me think of that.

Group 28 about "Build a Giant Carbon Nanotube"

Finally, the responses of two groups (out of 31) did not fit into the previous *post hoc* sub-codes for everyday applications. Therefore, they were coded as **other**. These responses were about the realization that nano is a part of many things that the visitors personally use or experience. Those responses were the following:

INTERVIEWER: Alright. So if a friend asked you today what did you learn about nanotechnology from the exhibit today, what would you say?

ADULT FEMALE 2: Pretty much that it's in almost anything, whether you know it really or not.

ADULT FEMALE 1: Yeah. Even in animals, not even necessarily technology, like the butterfly thing.

ADULT FEMALE 3: Yeah. That was weird.

INTERVIEWER: …How does that make you feel, that it's everywhere?

ADULT FEMALE 1: It doesn't really bother me. Like, it makes everything easier.

Group 22 about "Where Can You Find Nano?"

INTERVIEWER: Great, so thinking back to the specific areas of the exhibit, did you ever feel that nano connected to daily life?

ADULT FEMALE: Yes.

INTERVIEWER: …What was it about that ["What Happens When Things Get Smaller?"] that connected you?

ADULT FEMALE: Just that it's small and in everything, or that it's in a lot of stuff, I guess. You just don't even realize half the time.

Group 29 about "What Happens When Things Get Smaller?"

These quotes indicate that visitor groups made a number of different kinds of connections between the exhibition content and everyday applications. Many groups discussed relevance between the exhibition and a use or application that they knew about; others found relevance with a prior experience or area of knowledge; and finally, others found relevance between the exhibition and a friend or family member. All of these examples show that *Nano* enables visitor groups to discuss the connection between the content and their everyday lives, and that this kind of discussion is commonly prompted by the exhibition.

3.2.3 Only a few visitor groups discussed relevance by applying theory to practice in the exhibition.

Figure 3 shows that only a few study groups (4 of 33) made a connection to nano in the exhibition by applying theory to practice. Applying theory to practice was coded when visitors discussed content related to how scientific theories might be applied or observed as a part of real life situations, either during their interactions within the exhibition or in the interview.

Looking at the ways that visitor groups discussed applying theory to practice, findings indicate that visitors talked about a number of kinds of scientific theories and how they

might be observed, understood, or used in real life. Examples of these kinds of relevance can be found below:

ADULT MALE: [Nano gives you] much more control over things. All the things.

INTERVIEWER: Interesting. Much more control over, like?

ADULT MALE: …Colors, shapes, textures, scents. Everything. …Obviously our senses are limited by things that impact us. Well, like the scent thing kind of opened my mind to that. I mean, I know scent just kind of works by this shape molecule fits well into this receptor, but you can make a fake molecule—well not a fake molecule—but you can... simulate it through something that isn't orange related at all. …But my nose just still picks up that shape, and recognizes it as oranges.

Group 11 about "Where Can You Find Nano?"

ADULT MALE: They're small enough [the beads] so static electricity just beats out gravity.

ADULT FEMALE: That's pretty cool.

ADULT MALE: That's kind of weird. I wonder if there's a way to increase static forces so we all stick to walls. Least those of us that are small enough.

Group 19 at "Static vs. Gravity"

ADULT MALE: It shows analog power, because analog power runs off magnets basically. So you'd be able to see- there would be- see? Oh, there it is! See, right now between those two polls, it's a straight line. But if you look out towards the edges, you see how it's kind of like an arc?

ADULT FEMALE: Mhmm.

ADULT MALE: That's how it works. They go straight and then arc to one side.

Group 24 at "Small, Smaller, Nano"

These data indicate that it is possible for visitor groups to make a relevance connection that relates to applying theory to practice. However, in the case of the *Nano* exhibition, only a few groups found this kind of relevance and discussed it.

3.2.4 Only a few visitor groups discussed local issues relevance in the exhibition.

Figure 3 illustrates that only a few visitor groups (4 of 33) made a relevance connection between local issues and *Nano* content. Finding relevance to local issues was coded when visitors discussed content related to nano and a local context, either as a part of their interactions within the *Nano* exhibition or during the interview. In other words, this code

was applied when visitors talked about how nano might impact a local situation or organization.

Looking at how visitor groups discussed relevance to local issues within *Nano*, findings indicate that visitor groups discussed how content might relate to Minnesota, the Science Museum of Minnesota, or local businesses. Examples of discussions coded as local issues can be found below:

INTERVIEWER: When you guys were balancing the table, were you thinking about what the message was at all or were you mostly focused on balancing the table?

ADULT MALE: Well pretty much both… I took a step back to look at the whole picture, not just the little section… so if you put too much industry in one location it's going to kill everything off. If you spread it out and multiply, like we have here in Minnesota, … you'd be able to work together and keep everything good, but if you overpopulate like you stay in one area it's not balanced … you're not going to have your parks or fresh clean water or anything else because your business just wiped everything out.

Group 15 about "Balance Your Nano Future"

INTERVIEWER: Was that what you were talking about, that you knew some stuff about ferrofluid already?

ADULT MALE: Yeah, [my uncle's company] used some of that for solar technology. I can't talk about it too much because we're in a lawsuit.

INTERVIEWER: Okay. I won't make you! Needless to say … you had been near ferrofluid or nanotechnology.

ADULT MALE: Mmhm.

Group 20 about "Small, Smaller, Nano"

ADULT FEMALE: [Reading label] "New solar cells are very thin layers of material that capture energy from the sun." I wonder if [those are] the [solar cells] they have up on the [museum's] roof…

MALE CHILD: I think [so] because that [picture shows] it's black.

Group 23 at "What Happens When Things Get Smaller?"

These data indicate that visitor groups are able to discuss connections between exhibition content and local issues. However, this kind of relevance connection was only made by a few of the *Nano* visitor groups in the study.

3.2.5 A few groups discussed other kinds of relevance in the exhibition.

Besides the kinds of relevance that were predefined by Kember, Ho, and Hong (2008), researchers found that there were a few cases (3 of 33 groups) where visitor comments

had to be coded as other (Figure 3). However, because these instances were infrequent, additional codes were not added to the framework. Occurrences of content relevance were coded as other when visitor groups made connections to people described in the exhibition or talked about how humans perceive the world. Examples of these kinds of comments can be found below:

INTERVIEWER: Did you find anywhere else that made you feel like you had a personal connection to nano or stuff that you were reading?

ADULT FEMALE: I'd say like the butterflies. Like you said, how you said you see things a certain color but they're not that color. How you perceive them to what they really are…

ADULT MALE: And it's all about perceptions, lighting, and angles.

ADULT FEMALE: Yeah.… People's perceptions of different things and when they first look at you, what they perceive you are, what you really are. I don't know, that's kind of like… the butterfly…

Group 25 about "Where Can You Find Nano?"

ADULT FEMALE: "What does nanotechnology mean to Gale [who's on this label]?" Guess, [Mark], guess.

ADULT MALE: That's the wrong spelling of Gale. My mom's name is Gail.

ADULT FEMALE: Is it?

ADULT MALE: But it's G-A-I-L.

Group 27 at "What Does Nano Mean for Us?"

Because the number of relevance instances coded as "other" were small, this indicates that the Kember, Ho, and Hong (2008) framework was a good match to the kinds of relevance connections that visitors made with the *Nano* exhibition. The existing codes were broad enough that they could be used in this specific context, and yet narrow enough that differences in the kinds of relevance connections that visitor groups found could be observed.

3.3 Visitor groups found relevance by both making internal connections to *Nano* content and bringing in their own external examples.

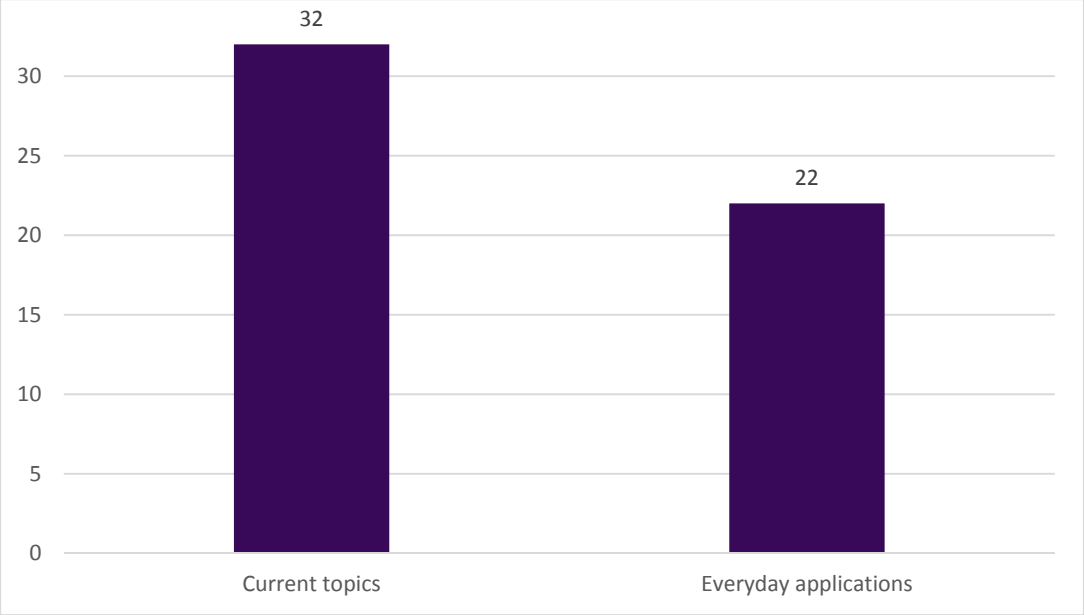
In coding for relevance as defined by Kember, Ho, and Hong (2008), it was discovered that how visitor groups made relevance connections could be defined in two ways: internal connections and external connections. Researchers defined internal relevance connections as when a visitor group found relevance with a specific example that was included as part of the exhibition. External relevance connections were defined as instances when a visitor group found relevance to the exhibition by bringing up a new example not contained in the exhibition. Visitor groups generally made both of these

types of relevance connections (internal relevance: 33 of 33 groups; external relevance: 32 of 33 groups) as part of their experience in *Nano*. The following sections describe how internal and external relevance connections relate to the different kinds of content relevance seen in Kember, Ho, and Hong's framework (2008) and provide specific examples of internal and external relevance.

3.3.1 All visitor groups made internal relevance connections in the exhibition.

All of the *Nano* visitor groups in this study (33 of 33) made at least one relevance connection by finding an internal link to the content. Looking at the topics visitor groups were discussing when they made this internal relevance connection can help illustrate what about the *Nano* exhibition prompted this kind of discussion. Therefore, researchers looked at the co-occurrence of internal connections and the two most common Kember, Ho, and Hong (2008) relevance topics that were found in the study data (current topics and everyday applications).

Figure 5. The number of visitor groups who made internal relevance connections about relevance to current topics or relevance to everyday applications (N=33).



In looking at the co-occurrence between these codes, it was found that groups (32 of 33) most commonly made a relevance connection tied directly to content contained within the exhibition when they were talking about current topics (Figure 5). This means that almost every visitor group in the sample made a relevance connection that involved examples provided directly in the exhibition about societal-level issues. Examples of this kind of **internal, current topic** relevance include the following:

INTERVIEWER: Any increased confidence in "Ways that nano apply to my life?"...

ADULT FEMALE 2: …in terms of cancer treatments and stuff like that, I thought that was really interesting and a huge step in medical breakthroughs.

Group 20 about "What Happens When Things Get Smaller?"

ADULT FEMALE: So how can nature inspire [nano]?

MALE CHILD: …That's cool. Nature's like helping us decide stuff.

ADULT FEMALE: Here…geckos can walk up walls… because their feet have millions of nano sized hairs that are attracted to wall surfaces…Climbing robots have feet that imitate geckos'.

Group 21 at "What's New about Nano?"

INTERVIEWER: Anything [in the exhibition] that relates to or you felt connected to your community at large? Maybe not your life specifically but maybe you're community or neighborhood?

ADULT FEMALE 1: The balancing thing ["Balance Your Nano Future"] was pretty good for that I think.… As far as a global community I [was] think[ing]… about nanotechnology for water filtration.

ADULT FEMALE 2: For safe drinking water, yeah…

Group 34 about "Balance Your Nano Future" and "What Does Nano Mean for Us?"

Fewer groups (22 of 33) made a relevance connection tied directly to content contained within the exhibition when they were talking about everyday applications (Figure 5). This means that there were not as many groups who referenced examples contained within the exhibition when discussing how nano connected to them personally. Examples of this kind of **internal, everyday application** relevance include the following:

INTERVIEWER: Thinking about the different areas of the exhibit did you ever feel that nano connected to daily life? Either yours or someone else's?

ADULT FEMALE: Oh yeah, definitely. I mean you use phones and stuff in daily life and all the food you buy at the grocery store, some of that is coated to keep its shelf life longer, so yeah, I would say daily life for sure.

Group 19 about "What Happens When Things Get Smaller?"

ADULT FEMALE 1: Stain resistant fabric, I could use some of that.

ADULT FEMALE 2: That's pretty dang cool.

Group 34 at "What's New about Nano?"

INTERVIEWER: When you were moving around the exhibit, where were you when you felt like nano connected to everyday life? Like yours or someone else's?

ADULT MALE: Probably that one right there ["Where Can You Find Nano?"], the home products… I don't know if the microchip was before that. Microchip… like I said we work in technology, so we work with microchips and stuff all the time. That probably would have hit us first, but you know what really hit home was looking at the personal items that normal average everyday Americans have around their house.

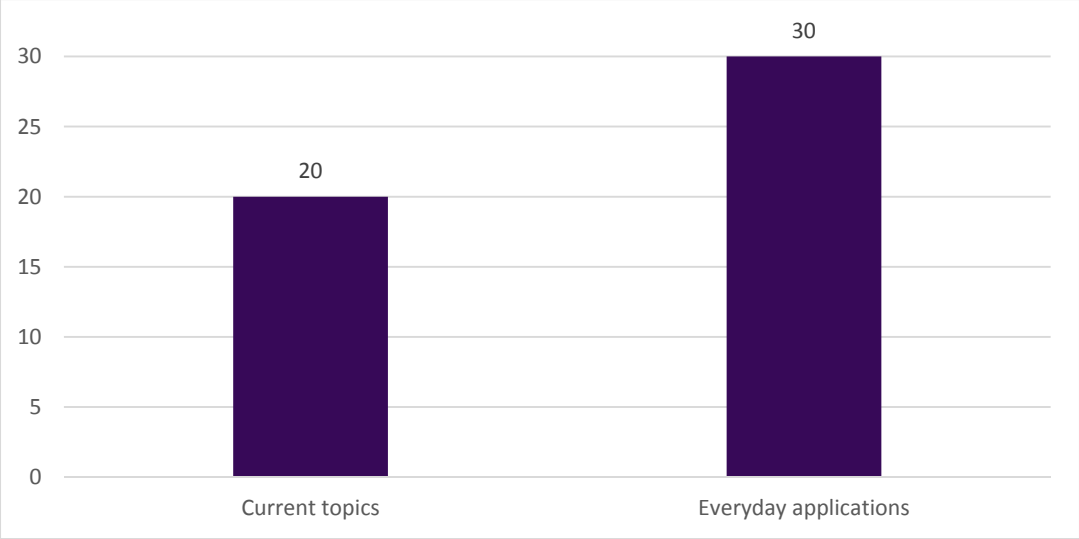
Group 35 about "Where Can You Find Nano?"

Together these findings illustrate the different ways that visitor groups made internal relevance connections to content contained directly within the *Nano* exhibition. While all groups made a connection to content contained directly within the exhibition, more groups made this connection through discussions of current topics related to societal implications as opposed to everyday applications related to impacts on daily life.

3.3.2 All but one visitor group made external relevance connections in the exhibition.

Almost all of the *Nano* visitor groups in this study (32 of 33) made at least one relevance connection by bringing up their own examples that were related to, but not directly contained within, the exhibition. As with internal relevance connections, researchers looked at the co-occurrence of the external connection code and the two most common relevance content codes (current topics and everyday applications) to better understand what might be prompting external relevance connections.

Figure 6. The number of visitor groups who made external relevance connections about relevance to current topics or relevance to everyday applications (n=32).



In looking at the co-occurrence between these codes, groups (30 of 32) most commonly made a relevance connection that brought in new examples and extended the exhibition content when talking about everyday applications (Figure 6). This means that almost every visitor group in the sample made a relevance connection that involved bringing in novel examples related to prior experience, knowledge, or use / applications. Examples of this kind of **external, everyday application** relevance include the following:

INTERVIEWER: When you first approached… this panel when you first came into the exhibit, you pointed to the text up there that says "how can tiny technologies… help us solve big problems?" And you pointed at it and you said something like, "this is like…" and I didn't catch what you said because I wasn't in position yet. Do you remember?...

ADULT MALE: Oh, that's where I was talking about that Michael Crichton book… yeah that you can program little nano robots with swarm theory… so that… millions of nano robots can act and gather information as a single entity, but they can all work independently. It's like, you know, when you see a school of fish, you see a school of fish, but it's actually, you know, thousands of fish.

Group 11 about "What Happens When Things Get Smaller?"

ADULT MALE 1: All the butterflies and whatnot … they make their colors by…how far away the little particles are, the little…hairs are. So they use those to help… make your phone or iPad make cool colors.

MALE CHILD: Wait … my phone… when it's like far away you, you can hardly even see it, because it's so black?

Group 14 at "What's New about Nano?"

ADULT MALE: [Our teacher] talked about this, and I worked on that.

ADULT FEMALE 2: Gold nano shells?

ADULT MALE: What they do is that they take the nano shells and stuff like that, they put it into your body and then they can use magnets and stuff to grab cancer cells and pinch them out and fight them and stuff like that and then new types of solar cells is what I worked on…

Group 20 at "What Happens When Things Get Smaller?"

A smaller number of groups (20 of 32) made a relevance connection that brought in new examples when they were talking about current topics (Figure 6). This means that there were not as many groups who extended the content and brought in their own examples in relation to societal level issues. Examples of this kind of **external, current topic** relevance include the following:

INTERVIEWER: Was there anywhere else where you were thinking about the future, your future?

ADULT FEMALE: Same stuff with the materials as far as the fashion industry goes. Think they've been using some of that in the 3D printing stuff... People are making clothes out of that now…

INTERVIEWER: I'm forgetting exactly where we have the materials and stuff. Like, was it…?

ADULT FEMALE: There's one in the "What's New about Nano?" They talk about the pants…

ADULT MALE: And there's one … here with the teddy bear…

Group 30 about "What's New about Nano?" and "Where Can You Find Nano?"

ADULT FEMALE 2: …That solar panel thing [was interesting] because I've heard a lot of talk about how they're going to develop that more and more in our country to [help with] the energy crisis thing and also the expense of heating your homes. Initially it might be expensive but in the long run it will be cheaper and not affect the environment like it's doing now with the different fuels that are being blasted into the air…

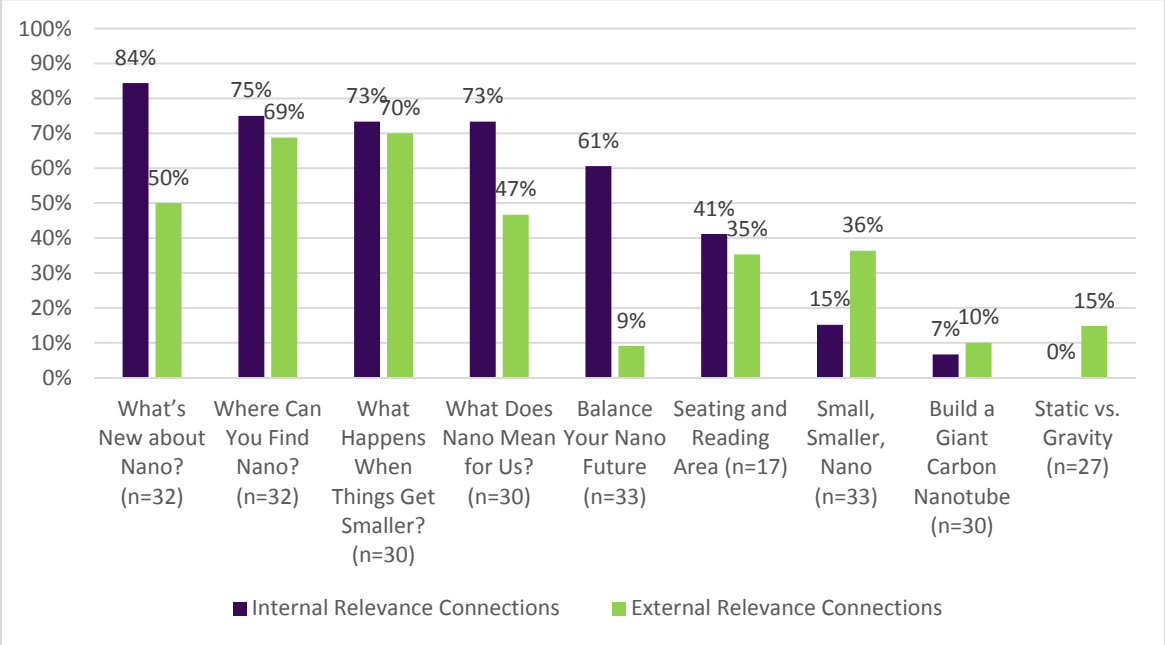
Group 32 about "What Happens When Things Get Smaller?"

Similar to internal relevance connections, many groups made external relevance connections to the *Nano* exhibition. This meant that they extended the content in the exhibition to add their own examples when finding and making relevance. In looking at the type of content visitors discussed when external connections occurred, it was found that visitor groups most commonly discussed everyday applications. Fewer groups who made external relevance connections discussed current topics. This finding is directly opposite the findings about internal relevance, where discussion of current topics was more common and discussion of everyday applications was less common.

3.4 Visitor groups most commonly made internal and external relevance connections at the panel components in *Nano.*

The data reported above show that it was common for visitor groups in the sample to make both internal connections by finding relevance with content contained in *Nano* and external connections by finding relevance with examples of their own. The previous data also indicate that internal connections are more often made with current topics content, and external connections are more often made with everyday applications. However, these data do not explain at which components visitor groups make these relevance connections within *Nano*.

Figure 7. The percentage of groups visiting each *Nano* exhibition component who made internal relevance connections and external relevance connections.



Researchers looked across the different components in order to understand where visitor groups made internal and external relevance connections (Figure 7). The data indicate that more than half of the groups in the sample who visited the following five components made **internal relevance connections**:

- "What's New about Nano?" (84%, 27 of 32 groups),
- "Where Can You Find Nano?" (75%, 24 of 32 groups),
- "What Happens When Things Get Smaller?" (73%, 22 of 30 groups),
- "What Does Nano Mean for Us?" (73%, 22 of 30 groups), and
- "Balance Your Nano Future" (61%, 20 of 33 groups).

The exhibit components where at least half of visiting groups made **external relevance connections** included the following:

- "What Happens When Things Get Smaller?" (70%, 21 of 30 groups),
- "Where Can You Find Nano?" (69%, 22 of 32 groups), and
- "What's New about Nano?" (50%, 16 of 32 groups).

These data demonstrate that visitor groups most commonly found relevance when using the panels that are within *Nano*:

- "What Happens When Things Get Smaller?",
- "Where Can You Find Nano?",
- "What's New about Nano?", and
- "What Does Nano Mean for Us?".

Over half of the visitor groups made internal relevance connections with these panels. Additionally, at least half of the visitor groups made external relevance connections at all but one of the panels, and even for that panel ("What Does Nano Mean for Us?") had close to 50% of visiting groups making external relevance connections.

There was only one other component where at least 50% of visitor groups made a relevance connection: "Balance Your Nano Future." At "Balance Your Nano Future," which is an interactive component, almost two-thirds of groups made an internal relevance connection to content contained within the component. However, less than 10% of visiting groups were able to make an external relevance connection to the content in this component (Figure 7).

IV. Discussion

Over the final five years of the NISE Network, the "Research on Public Learning and Decision-Making" (PLDM) team studied how visitors make decisions and learn about nanotechnologies through a range of NISE Network educational products. For the past two years, this team has conducted a research study about the *Nano* exhibition to understand:

> How do visitors use, interact with, and talk about the exhibit components within the exhibition to learn about the relevance of nano to their lives?

To conduct this research, 33 visitor groups were cued and told to use the exhibition for as long as they wanted and in whatever manner they wanted. After they were done using the exhibition, a data collector conducted a reflective interview to better understand what the visitor groups were thinking and doing while in the exhibition. During this experience, visitors were video- and audio-recorded in order to capture their discussions and behaviors during their experiences in *Nano* as well as to capture what they said during the interview.

After these data were collected, coders used an *a priori* coding scheme from Kember, Ho, and Hong (2008) to understand the content of visitor groups' relevance discussions. They also created a *post hoc* coding scheme to understand whether visitors were finding relevance by relying on internal examples or brining in their own external examples. Discussion further explaining the findings and how they might impact exhibit or program design are described below.

4.1 Extending the Kember, Ho, and Hong (2008) framework into informal science education

This study found that all visitor groups in the PLDM sample were able to find relevance with the content while they were using the *Nano* exhibition. In order to understand what relevance connections visitor groups were making, the Kember, Ho, and Hong (2008) framework was used. This framework was created by interviewing undergraduate students to understand how relevance could be established for them within their college courses. The framework describes four different ways that people can find relevance with a topic: current topics, everyday applications, local issues, and applying theory to practice.

PLDM researchers chose this framework for the study because it fit nicely with findings already described as a part of the *Review of NISE Network Evaluation Findings: Years 1–5* which found that visitors felt that the inclusion of applications and technologies helped make a museum experience relevant (Reich, 2011). This framework was also chosen because PLDM researchers felt that it would help differentiate the kinds of relevance discussions that visitors were having, allowing for a more nuanced understanding of relevance. Through the study, researchers found that this was true and that the Kember, Ho, and Hong (2008) framework could be used to describe visitors' discourse about relevance. In fact, there were only a few cases (in 3 groups out of 33) where visitors' discussions fell outside of the existing categories, and every study group had multiple instances of relevance that fit within the existing categories.

These findings demonstrate a number of things about the utility of the Kember, Ho, and Hong (2008) framework. First of all, they demonstrate that the framework can be used not only to think about ways to incorporate relevance into educational experiences but also to describe discourse about relevance. Second, these findings show that the framework is applicable to informal learning as well as formal education settings. Finally, these findings indicate that the framework can be used to differentiate between kinds of relevance.

4.2 Broadening the range of nano topics NISE Net visitors find relevance with beyond applications

According to the chapter, "Making the Unfamiliar Interesting and Relevant for Museum Visitors" in the *Review of NISE Network Evaluation Findings: Years 1–5*, visitors found a NISE Net experience to be relevant because of its content. Specifically, visitors in this earlier NISE Net study called out the inclusion of applications and technologies as making an experience relevant (Reich, 2011). The findings from the PLDM study indicate that applications and technologies do lead to discussions of relevance. However, other content can lead to discussions of relevance as well.

The main *a priori* code related to technologies and applications was everyday applications. According to Kember, Ho, and Hong (2008), relevance to everyday applications relates to how a topic might directly impact someone's life or experiences. As a part of the relevance discussions that fell into this code, many visitor groups (28 of 31) did discuss the uses and applications of nano. However, also within the everyday application code were discussions of how nano related to visitor groups' prior experiences and knowledge (23 of 31). During these discussions, visitors talked about how the exhibition content reminded them of science fiction books they read, classes they had taken, or things they had experienced at work. Additionally, a few groups (5 of 31) discussed how nano might impact a friend or family member (Figure 4).

Besides everyday applications, visitor groups also discussed relevance to nano in terms of current topics. All but one visitor group in the sample (32 of 33) discussed relevance to current topics in the exhibition. This code included discussion of how applications might impact society. Also within this code were more general discussions of societal and ethical implications of nanotechnology including potential risks and benefits for health or the environment.

The two other codes from Kember, Ho, and Hong (2008) describe relevance in terms beyond applications, and these codes were also seen for a small number of visitor groups in this study. Relevance to local issues refers to a local context or situation. In the PLDM study, four groups (of 33) discussed this kind of relevance when they brought up how nano related to regional companies or things that they knew about the Science Museum of Minnesota. Although applications were sometimes brought up as a part of these conversations, the main content of this discourse was local institutions. Finally, a few groups (4 of 33) discussed relevance by applying theory to practice. In these cases, visitor groups discussed things such as how static electricity might be used to help people climb walls.

The PLDM study extends the findings from the *Review* chapter, "Making the Unfamiliar Interesting and Relevant for Museum Visitors" (Reich, 2011). Similar to the *Review* chapter, findings from the PLDM study indicate that visitors find relevance through connections to content. However, this study indicates that it is not only with technologies and applications that visitors find relevance. Content related to societal implications, local issues, and applying theory to practice can also lead visitors to find relevance.

4.3 Explaining the presence and absence of aspects of the *a priori* framework in the findings

Visitor groups' discussions of relevance while they used the *Nano* exhibition and/or took part in interviews matched well with the Kember, Ho, and Hong (2008) framework. At least four visitor groups in the study fell into each of the *a priori* categories (Figure 3). Yet there were some codes that were more common than others. The prevalence and near absence of the *a priori* codes in this study might be explained by the nature of NISE Net and the *Nano* exhibition.

The NISE Net content map (Bequette et al., 2012) describes the different content areas that are the focus of the Network's public deliverables. The four main ideas included in the content map are the following:

- IDEA 1: Nanometer-sized things are very small, and often behave differently than larger things do.
- IDEA 2: Scientists and engineers have formed the interdisciplinary field of nanotechnology by investigating properties and manipulating matter at the nanoscale.
- IDEA: 3 Nanoscience, nanotechnology, and nanoengineering lead to new knowledge and innovations that weren't possible before.
- IDEA 4: Nanotechnologies—and their costs, utility, risks, and benefits—are closely interconnected with society and with our values.

Additionally, the NISE Net described specific public awareness and understanding goals for the *Nano* exhibition which align with the different areas of the content map (NISE Net, 2012). Those goals include the following:

1. Small and different: Nano is small and different.

2. Studying and making: Nano is studying and making tiny things.

3. New technologies: Nano is new technologies.

4. Nano and society: Nano is part of our society and our future.

These goals are distributed throughout the components within the *Nano* exhibition. However, some goals are more prevalent than others. The goals about "small and different" and "new technologies" are a primary or secondary goal for five of the nine components. The goal about "nano and society" is a primary or secondary goal of four of the nine components. Finally, the goal about "studying and making" is a primary goal of

three of the nine components. A breakdown of the goals for each *Nano* exhibition component can be found in Table 1.

Table 1. Alignment between *Nano* exhibition public awareness and understanding goals and different exhibition components (NISE Net, 2012).

	***Nano* Exhibition Goals**			
Exhibit Component	1 Small and different	2 Studying and making	3 New technologies	4 Nano and society
Balance Your Nano Future				✓
Build a Giant Carbon Nanotube		✓		
Seating and Reading Area	✓	✓	✓	✓
Small, Smaller, Nano	✓			
Static vs. Gravity	✓			
What Does Nano Mean for Us?			X	✓
What Happens When Things Get Smaller?	✓		X	
What's New about Nano?		✓	X	
Where Can You Find Nano?	X		✓	X

Note. A checkmark indicates that this was a primary goal of the component, and an "X" mark indicates that this was a secondary goal.

Another influence on the design of the *Nano* exhibition was the decision about how it would be distributed. *Nano* was created by the NISE Network so that it could be located in a range of informal education institutions from science centers and children's museums to libraries and universities. It was also created such that many copies could be made and distributed around the US. Because of this diversity in locations, the content had to appeal and work for a variety of audiences who covered included a wide range of ages and experiences with science.

These decisions about content and design may explain why certain Kember, Ho, and Hong (2008) categories were more or less commonly found in data from the PLDM study. Data indicate that the common types of relevance align with the goals that were stressed the most throughout the exhibition. For instance, almost all of the visitor groups discussed relevance to current topics (32 of 33 groups) or everyday applications (31 of 33

groups) as a part of their *Nano* experiences. The *Nano* exhibition goal most closely aligned with finding relevance to everyday applications was goal 3 ("new technologies") which was also one of the most commonly represented goals within the exhibition. Goal 4 ("nano and society") was most closely aligned with finding relevance to current topics. This goal was also fairly prevalent within the exhibition. Therefore, it is not surprising that these were also the most common topics of relevance discussed by study subjects.

Only a few groups (4 of 33) discussed relevance by applying theory to practice. In terms of the *Nano* exhibition, this kind of relevance most closely aligned with goal 2 which was only present in three components, one of which was the least visited component in this study ("Seating and Reading Area"). Therefore, it is not surprising that only a few visitors discussed relevance in terms of applying theory to practice. Finally, only a few groups discussed the relevance of nano to local issues. NISE Net created *Nano* such that it would work in a large number of locations across the US. As a result, it did not include goals or examples that involved local issues. Thus, once again, it is not surprising that very few visitor groups made this kind of relevance connection.

Despite the fact that the Kember, Ho, and Hong (2008) relevance categories were not equally represented in the PLDM findings, the findings illustrate that it is possible for visitors to find all four of these kinds of relevance within an exhibition. It is likely that current topics and everyday applications relevance were common within the PLDM sample because this content was also common within the exhibition. This may also explain why relevance to local issues and applying theory to practice were not as common. In the case of applying theory to practice, scientific theory was discussed only sparingly in the exhibition. Local issues were not included within the exhibition at all. More visitor groups may have brought up these Kember, Ho, and Hong (2008) topics as a part of their relevance discussions if additional content about them had been included.

4.4 Potential implications of the study to exhibition and program design.

The results from this study suggest that visitors are able to find relevance within an informal education experience and that the kinds of relevance that visitors can find covers a range of topics. However, while these findings indicate that visitors can make a variety of relevance connections, they do not explain how those are connections are made. More can be understood about how these connections come about by examining the relationship between three aspects of the visitor experience that PLDM researchers looked at through the study: relevance topic, relevance connection (internal and external), and the component being visited when these occur.

4.4.1 Including content about applications and societal issues in exhibits and programs may lead visitors to find relevance.

Figure 7 shows that most groups who visited the *Nano* panels found relevance while they were using these components, and that only one interactive ("Balance Your Nano Future") had some success in generating visitor discussions about relevance. More specifically, it was found that at least 73% of the visitors to the panels ("What's New about Nano?", "What Does Nano Mean for Us?", "What Happens When Things Get Smaller?", and "Where Can You Find Nano?") made internal relevance connections by discussing content

contained within the components, and 61% of visiting groups to one of the exhibition interactives ("Balance Your Nano Future") made these internal relevance connections. Except for one interactive and one panel ("Balance Your Nano Future" and "What Does Nano Mean for Us?") at least 50% of the groups visiting these components also made external relevance connections by bringing in their own examples during discussions of relevance. For all of the other components in the exhibition, less than 42% of the visiting groups made either internal or external relevance connections with the content. These findings may be explained by the kinds of content contained within the different components. The components which contained the most information about applications and societal issues, the panels and "Balance Your Nano Future," were also the components where visiting groups were most likely to have conversations about relevance. At the components where there was less or no information about applications or societal issues, there was less discussion about relevance.

The results of this study have potential implications for future exhibit and program design. It appears that including the kinds of relevance content described by Kember, Ho, and Hong (2008), specifically everyday applications and current topics, may lead visitors to discuss and therefore find relevance with STEM topics. As such, if the aim of an exhibit or program is for visitors to find relevance, it seems that designers should include application or societal issues content. Because there was no content about local issues, very little content about applying theory to practice, and visitors rarely discussed these kinds of relevance in the *Nano* exhibition, it is difficult to draw conclusions about the ability of content containing these kinds of relevance to help visitors find relevance. Therefore, additional study is needed to understand whether how, if at all, these kinds of content lead to discussions of relevance.

4.4.2 Including content about applications may help visitors to bring in their own examples while content about societal issues may not.

As described in the previous section, internal relevance connections, where visitors discussed exhibit content, tended to occur at the panels and the "Balance Your Nano Future" interactive, the components where much of the application and societal issues content was located. Results indicate that all of the groups (33 of 33) within the PLDM sample made at least one internal relevance connection while they used the *Nano* exhibition. The content of visitors' discussions when they made internal connections was most commonly relevance to current topics (32 of 33 groups). Everyday applications were discussed to a lesser extent (22 of 33 groups) when internal relevance connections were made (Figure 5).

External relevance connections, where visitors discussed examples from their own lives and experiences, were commonly made at three of the panels ("What Happens When Things Get Smaller?", "Where Can You Find Nano?", and "What's New about Nano?"), but were not made as commonly at the "What Does Nano Mean for Us?" panel or the "Balance Your Nano Future" interactive where there is less content about applications and more of a focus on societal issues. Results show that all but one of the groups in the PLDM sample (32 of 33) made at least one external relevance connection while they used *Nano.* In looking at the content of discussions when visitors made external relevance connections, it was found that visitor groups most commonly discussed relevance to

everyday applications (30 of 32 groups). A lesser number of groups (20 of 32) discussed relevance to current topics in this situation (Figure 6).

These findings imply that there may be instances when it is easier for visitors to rely on internal examples to find relevance and other times when it is possible for visitors to make connections that allow them to bring in their own external examples to find relevance. It appears that it may be more difficult for visitors to find relevance to current topics because visitors tended to rely on and discuss examples of societal issues that were included as a part of the *Nano* exhibition content rather than thinking of and talking about their own examples. In contrast, it appears that it may be easier for visitors to find relevance to everyday applications as they were able extend beyond the content within the components to bring in their own examples related to use and applications, prior experience and knowledge, and the relationship between content and friends or family members.

These findings have potential implications for exhibit and program design. It appears that for visitors to be able to discuss relevance to current topics, it is important to provide a number of different examples of societal issues because visitors will rely on this content to find and make relevance connections. It may not be as important to provide a variety of examples in order to prompt visitors to discuss relevance to everyday applications because in these cases it appears that it is easier for them to draw on their own lives and experiences to make these connections.

4.5 Limitations of the study

There are a few limitations in the design of study that should be taken into consideration when thinking about this Discussion section.

First off, this study is exploratory in nature. As described in the *Common Guidelines for Education Research and Development*, this kind of study "examines relationships among important constructs in education and learning to establish logical connections that may form the basis for future interventions or strategies to improve education outcomes" (U.S. Department of Education & National Science Foundation, 2013, p. 9). In this case, the purpose of the study was to try to understand what kinds of relevance visitors were discussing in the exhibition and how they made these connections to try to inform the design of future informal science education exhibits and programs. Because the researchers were trying to generate a theory for how and why relevance was occurring within the exhibition, the study was conducted under ideal conditions. This meant that researchers cued visitors to take part in the study ensuring that they would generally use the exhibition thoroughly. For example, it was found that nearly half of the groups in the study sample (12 of 33) visited all of the components in the exhibition, and no groups visited fewer than six of the exhibition components. Additionally, it was found that visitor groups in the study sample spent more time in the exhibition as a part of this study than they did as a part of the *Summative study of the Nano mini-exhibition*. The mean dwell time in the research study was 17:24 minutes, as compared to a mean dwell time of 6:07 minutes in the evaluation (Svarovsky et al., 2013).

Second, it was decided, after data were collected from a few visitor groups that additional sampling protocols needed to be put into place about who could participate in the study.

At first, data collectors cued groups with children over the age of seven to participate in the study. However, younger visitors had a harder time discussing relevance. Therefore, it was decided after data had been collected from a few groups that participants should be at least 10 years of age. Additionally, at first, data collectors did not put any limits on the sizes of the groups in the sample. However, it was discovered that if a group was too large it was hard to keep track of visitors' conversations. Therefore, it was decided that all study groups should contain between two and three individuals. For this reason, the study does not represent the complete range of possible group types to the exhibition.

In both of these cases, decisions were made such that researchers would have the chance to best study the nature of relevance within a particular exhibition context: how relevance connections occurred, where such instances occurred (i.e. how often within the exhibition and at which components), and the content of discussions about relevance.

V. Conclusion and Future Directions

The *Nano* exhibition was designed in part to encourage visitors to find connections between nano and their everyday lives. In fact the *Summative study of the* Nano *mini-exhibition* (Svarovsky et al, 2013) found that the most common takeaway by visitors was an understanding of the relevance of nano. Therefore, the PLDM team decided to study relevance within the *Nano* exhibition to answer the question:

> How do visitors use, interact with, and talk about the exhibit components within the *Nano* exhibition to learn about the relevance of nano to their lives?

To do this, researchers recorded what visitor groups discussed and how they used the *Nano* exhibition. They then conducted a reflective interview to understand more about what visitors were doing as they used the exhibition.

Data from this study indicate that visitor groups found relevance predominantly at the exhibition panels where most of the content about applications and societal issues was contained. Many visitor groups also found relevance at the interactive "Balance Your Nano Future." In finding relevance, visitor groups' discussions touched on all of the different kinds of relevance described by Kember, Ho, and Hong (2008). However, most commonly, these conversations were about relevance to current topics and relevance to everyday applications. It appeared that visitors tended to rely on content contained within the exhibition components for their conversations of relevance to current topics. However, they often extended the component content to include examples from their own lives as a part of conversations about relevance to everyday applications.

These findings may have implications for future exhibit and program design as it appears that purposefully adding content about applications and societal issues will lead visitors to find the relevance of a STEM topic. However, further study is needed to better understand these areas. For example, this study could not fully explore the impacts of two kinds of relevance in the Kember, Ho, and Hong (2008) framework because relevance to local issues and applying theory to practice were not highly represented in the exhibition. Therefore, it would be useful to study how visitors find relevance when these topics are included to see if they lead to as many instances of relevance as everyday applications and current topics do. Additionally, this study indicates a correlational but not causational relationship between content about applications and societal issues and finding relevance. Therefore, it would be beneficial to test this theory through an experimental design study of exhibits or programs.

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Appendix

Appendix A: *Nano* Exhibition Component Descriptions[6]

Exhibition Component	Description
What Happens When Things Get Smaller?	Vertical panel + attached table with flips • "What happens when things get smaller?" • "How can tiny technologies help us solve big problems?" Interactive exhibits • Small, Smaller, Nano: Visitors explore progressively smaller magnetic materials — magnetite sand, iron powder, and ferrofluid. • Static vs. Gravity: Visitors spin disks containing small and large plastic beads, comparing the relative effects of static electricity and gravity on different size beads.
What's New About Nano?	Vertical panel + attached table with flips • "What's new about nano?" • "Can nature inspire nanotechnology?" Interactive exhibit • Build a Giant Carbon Nanotube: Visitors work together to build a giant model of a carbon nanotube.
Where Can You Find Nano?	Vertical panel + attached table with flips • "Where can you find nano?" Interactive exhibit • I Spy Nano: Visitors try a series of interactive challenges, then search a complex image for

[6] These descriptions come from the *Nano* mini-exhibitions scope and goals document (http://www.nisenet.org/sites/default/files/catalog/uploads/8560/miniexh_scopeandgoals_25jan12.pdf).

	examples of real nano products and phenomena.
What Does Nano Mean For Us?	Vertical panel + attached table with flips • "What does nano mean for us?" • "What does nanotechnology mean to you?" Interactive exhibit • Balance our Nano Future: Visitors balance blocks on a tippy table, which represents the challenge of working together to build a stable nano future.

Seating and Reading Area	Sofa and armchair
	• Gecko and butterfly puppets
	
	Table with reading materials
	• Reading boards
	  o How small is nano?
	  o Try measuring in nanometers!
	  o What is stuff made of?
	  o How do we study and make nanotechnology?
	  o How is nano inspired by nature?
	  o What's surprising about nano materials?
	  o Will nano change my life?
	  o Will nano change the world?
	• Audio description
	  o Nano exhibition overview
	  o Small, Smaller, Nano
	  o Static vs. Gravity
	  o "What happens when things get smaller?"
	  o Build a Giant Carbon Nanotube
	  o "What's new about nano?"
	  o "Where can you find nano?"
	  o Balance Our Nano Future
	  o "What does nano mean for us?"
	• Trade books

Appendix B: Exhibition Components Coded For

Type of Component	Exhibition Component
Interactives	Build a Giant Carbon Nanotube
	Small, Smaller, Nano
	Static vs. Gravity
Panels	What Does Nano Mean for Us?
	What Happens When Things Get Smaller?
	What's New about Nano?
	Where Can You Find Nano?
Other	Seating and Reading Area