MAKING MODELS

Summative Evaluation Report
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Museum of Science
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INTRODUCTION

Making Models is the fourth permanent activity center developed by Boston's Museum of Science, with funding from the National Science Foundation. These activity centers—Seeing the Unseen, Investigate! and Natural Mysteries—were opened to the public in 1991, 1996 and 1999, respectively. These centers were developed in order to "help visitors understand science as a way of thinking and doing, and provide experience with the kinds of thought and action typical of scientific inquiry" (Project Proposal).

As stated in the project proposal and related documents, the overriding goals of Making Models are to:

- Help visitors recognize the presence and value of models in the museum environment, in other educational settings, and in their everyday lives
- Help visitors become familiar with several types of models that are essential elements of science and engineering: physical models, conceptual models, mathematical models, and computer simulations
- Provide visitors with practice in four specific science thinking skills associated with making and using models:
  - Recognizing the similarity between models and the things they represent
  - Assessing the strengths and limitations of models in explaining and predicting the behavior of the objects or phenomena they represent
  - Using models to raise questions, communicate ideas, and test hypotheses in many different contexts
  - Creating their own models to explain things they cannot observe directly, and to communicate ideas

(Project Proposal)

Exhibit developers also set goals related to universal design and disabled visitors:

- The aspects of universal design should provide access to learning for visitors with disabilities, and impact the learning of those visitors without disabilities;
- Disabled visitors should leave the exhibition feeling that they had a satisfying and meaningful experience;
- The exhibition should achieve its educational goals with people who have disabilities.

(Project Document)

Making Models incorporates many of the principles of universal design, with various adaptations designed to make the exhibition more accessible to both disabled and non-disabled visitors. Features such as audio labels, "hearphones" (manufacturer's terminology for assistive listening devices), large-print signs, stools and height adjustments were incorporated into Making Models to provide a welcoming and accessible environment to visitors with a range of disabilities.

Note: The Making Models gallery also contained several mapping components that were not included in our evaluation. Some of these were altered during the evaluation period; *Mapping the Coast* was developed and the *Mt. Everest* display was opened and expanded during our evaluation period.

EVALUATION

In the spring of 2004, Boston's Museum of Science (MOS) contracted with the Program Evaluation and Research Group (PERG) at Lesley University to conduct a summative evaluation of Making Models. The evaluation was conducted by PERG staff during the spring and summer of 2004. The plan was developed in conjunction with MOS staff to answer the following major questions:

- Do visitors engage in modeling skills?
- Do visitors recognize that they are engaged in the process of scientific modeling?
- How does the visitors' understanding of models change as a result of this exhibition?
- Is the exhibition a successful example of universal design?

EVALUATION ACTIVITIES

In order to obtain this data, our fieldwork consisted of several activities, described below.

EXIT INTERVIEWS

PERG evaluators completed 67 exit interviews that included 133 respondents with general visitors over a period of approximately four months in the spring and summer of 2004. These randomly selected groups varied in size and were interviewed as they left the Making Models gallery. (See Appendix A for the exit interview protocol.) In addition, evaluators completed 4 exit interviews with disabled visitors who had been specifically invited by MOS staff to view Making Models and to be part of the evaluation (see section below). The standard protocol was used with these visitors, with an additional question about their assessment of the "user-friendliness" of the exhibition. Of the 133 visitors who participated in the exit interviews, 43 were children under the age of 18.

INTERACTIVE OBSERVATIONS

Evaluators conducted 40 interactive observations with a variety of visitor groups. These 40 groups ranged in size from 1 to 5. Thirty-four (34) of these groups were randomly selected, while another 6 of these groups consisted of invited visitors with disabilities. (See below for a fuller explanation of interactive observations with disabled visitors.) PERG evaluators used these interactive observations to gain more insight into how visitors used the components within Making Models, to observe their discoveries and questions related to exhibition content, and to gauge how the universal design features

impacted their visits. The evaluators asked respondents to "think out loud" while going through the exhibition, and periodically asked visitors for their reactions to various components and to identify questions that were raised during their visits to Making Models.

FOLLOW-UP PHONE INTERVIEWS

When they exited Making Models, evaluators asked some visitors if they would be willing to complete brief follow-up interviews by phone, either 3–7 days or 4-7 weeks after their visit. The evaluators completed 25 short-term follow-up interviews and 21 long-term interviews with a total of 46 visitors throughout the United States.

These visitors had not participated in exit interviews or interactive observations, and had no previous contact with the evaluators. Follow-up interviews were conducted to determine if visitors were more aware of models since their visit, were cognizant of how they used models in their lives, and to gain a sense of the impact of Making Models on visitors, some time after their visits to the MOS. (See Appendices for interview protocols.)

DISABILITY INTERVIEWS AND OBSERVATIONS

As noted above, MOS staff invited members of various disability communities to visit Making Models on four specific dates during the summer of 2004. PERG staff completed 4 full exit interviews and 13 interactive observations with disabled individuals. A total of 17 individuals participated in these sessions. (Many of the disabled visitors who participated in interactive observations also completed partial exit interviews with PERG evaluators). Participants had a range of disabilities, including blindness, low-vision, mobility-impairments, cognitive disabilities, and deafness. Some of these disabled visitors went through Making Models with a friend or museum volunteer, others were with an evaluator, and a few went through primarily on their own.

Note: Six (6) of these interactive observations were included in the total of 40 listed above; these visitors engaged with many of the components in ways similar to non-disabled visitors and were not solely focused on issues of accessibility. The other 7 interactive observations were not included in the general (non-disabled) interactive observations, since these visitors focused their comments and concerns on issues of access; they functioned primarily as consultants for the purposes of evaluation.

VISITOR SAMPLE

The total number of participants in the evaluation was 272. Visitors came from across the United States and from a number of foreign countries including India, the United Kingdom, Spain, Greece, and Canada.

Note: Follow-up phone interviews were usually conducted with one visitor, and were primarily with adults. All quotes that are not identified by age and gender were by adults; quotes from children were identified by gender and age, for example B12 for a 12-year-old boy.

Visitor Sample

Visitor Info.	Exit Interviews	Disability Exit Interviews	Interactive Observations	Disability Interactive Observations	Phone Interviews 3–7 Days After Visit	Phone Interviews 4-7 Weeks After Visit
# of visitors	133	4	83	13	25	21
Male	61	3	45	11	6	10
Female	72	1	38	4	19	11
Children < 18	43	0	27	3	2	1
Adults = > 18	90	4	56	12	23	20

Note: Nine disabled visitors were included in both the interactive observation and disability interactive observation categories.

REPORT

The Making Models Summative Evaluation Report addresses questions posed by the exhibition developers and other staff at Boston's Museum of Science. The Findings include data about overall reactions to the exhibition. This report includes a Findings section, with data analyzed from exit interviews, interactive observations, and follow-up phone interviews; a Discussion and Recommendations section, in which the data is synthesized, and recommendations for further development of the exhibition are presented; and a series of Appendices, which include the protocols used by the evaluators.

FINDINGS

> We use models more in our daily lives than I'd realized. (Exit interview)

> I'd send almost anyone to look at it. I've been to many science museums all over the world and I haven't seen any place where they've tackled the issue of modeling . . . (Exit interview)

> I thought it was a reasonable exhibit. It's a good idea. I think . . . the content of the displays will have to evolve over time, as they always do, into more interesting models. (Short-term phone interview)

VISITORS' REACTIONS TO MAKING MODELS

OVERALL REACTIONS TO MAKING MODELS

Most of the visitors to Making Models, both children and adults, reported that they enjoyed the exhibition and found it to be interesting and engaging. Many commented specifically on the interactive nature of the exhibition.

> I came in and saw the signs and said, "Oh, models [sigh]," but it turned out to be better than I expected. (Exit interview)

> I think it's interesting. It gives you different perspectives on what you think a model would be and challenges it. Makes you think outside the box. (Interactive observation)

> [It's] hands-on. Really cool. It's interactive. It pulls you in. (Exit interview)

A number of visitors especially appreciated the wide variety of models presented by the exhibition.

> I liked the variety of the *Pyramids* model with the interactive stuff. I liked the breadth of the exhibit, including the floating paper on the rods. (Exit interview)

> I thought it was great. I loved the variety. From *Mt. Everest* to the fashion model, the games . . . it was very interesting. It got me thinking about how models help us learn about things . . . there are so many models that show us examples of behaviors, ways that we can learn about things. (Short-term phone interview)

> The main thing I liked is you have models of different types—analog models and computer. Most people think of only physical models. (Interactive observation)

Many visitors commented that Making Models was interesting for children. Those in family groups often reported that the interactive components within Making Models provided learning experiences for their children.

> I thought it was great for the kids to do all that hands-on learning. (Short-term phone interview)

> Overall, it was a wonderful exhibit. It held the children's attention much more than I thought [it would]. (Short-term phone interview)

> B10: How cool it was. I got to play, I learned a lot. It's good you can learn while playing. (Exit interview)

> It was good for my [5-year-old] niece and I liked that it was really interactive so that was really entertaining for her. (Short-term phone interview)

Some adult respondents felt that the exhibition was most appropriate for younger visitors. One, however, felt it was not well-suited for her young child.

> I thought everything was visually eye-catching but catered toward younger children. (Exit interview)

> Interactive, that's the nice thing about it; and it's aimed more at kids than adults. I'd recommend it to colleagues [other teachers] rather than friends. (Exit interview)

> I enjoyed it, but it wasn't actually age-appropriate with my child . . . When I saw the title I was expecting something that would be more engaging for a small child. (Short-term phone interview)

Some visitors became frustrated when directions at the components were difficult to follow, the components themselves were not clear, or when components were not working.

> For the most part, it was interesting. Some of the stuff [required] too much reading to figure out how to do it; I would get frustrated trying to do it. [Says that several components were not working.] (Short-term phone interview)

> It's got a ton of information that's helpful for adults and kids. It needs clearer signage. I think adults and kids benefit from questions rather than long explanations, like [asking them] about shadows on the wall [near *23 Scraps*]. (Interactive observation)

> . . . What is the mystery? Even after listening, it's not clear. Did the buttresses work? The colors—do they show what didn't work? I'm not sure what the colors mean . . . I guess the colors show where it's less strong. Is the turning the wind? (Interactive observation)

Other visitors, while enjoying aspects of Making Models, felt the exhibition lacked a "logical flow" or clear "thematic approach."

> A more thematic approach might have been more effective. It seemed like a lot of different people worked on this. It could be more coherent . . . [it is] too scattered. There are some neat things here. Models are important. (Interactive observation)

> It's a bit confusing in that there's not a logical flow. It would be worthwhile from a kid's perspective to have models get more complex along the way. It doesn't have a flow. It's a bit of a mishmash. (Exit interview)

> They were all interesting. I had trouble at times [making connections]—What is the exhibit trying to emphasize? (Interactive observation)

A few visitors (who had more scientific/technical backgrounds), found Making Models somewhat basic for adults, or were not engaged by the exhibition.

> Interesting; more [geared] toward younger audiences. Not as focused as I'd like. (Interactive observation)

> I thought it was OK. I wasn't all that impressed. (Short-term phone interview)

WHAT STOOD OUT/HIGHLIGHTS

PERG evaluators asked exit interview visitors to describe aspects of Making Models that "stood out" for them during their visits. These visitors identified a wide range of components, including many of the interactive components, such as the *Mystery Objects;* the two *Packaging* components, one with shapes and the other with rectangular blocks; *Pyramids of Giza diorama*; and the *Wave Tank*, among others.

About two-thirds of visitors identified the interactive components as highlights of their visits.

> The interactive aspect. I do this for a living. There's a real nice balance between intuitive and obvious. (Exit interview)

> I liked a lot of things. The fish [computer] . . . and the models in general, and the games you can play for children; it's interesting. (Exit interview)

> Arranging the blocks, maybe because it's mathematical, and the *Heart* exhibit. (Exit interview)

> [I liked] the ones where you have to pick up the flaps in sequence to guess what the object is. (Exit interview)

> The game about cooperation because I like game theory. It's nice to play and not just to read. I like the interactive games. You can understand better . . . (Exit interview)

The *Grasshopper* attracted visitors to Making Models, and the *Wave Tank* and *Pyramids of Giza diorama* were also especially popular among visitors.

> The grasshopper model. It guided you in [to the exhibit]. (Exit interview)

> I liked the wavemaker because it's near my job. I'm a civil engineer, so I had lessons about waves. (Exit interview)

> I find Egyptology interesting and thought the model there was good. (Exit interview)

Many of the other components within Making Models also "stood out" for some visitors.

> I liked the theater scene with daylight time, and the Everest model, with its changing light. (Exit interview)

> The wave machine. It's fun to see science in action, [and the] cathedral model showing the wind. (Exit interview)

> The beads on the magnetic boards, using the clues to guess what it was. (Exit interview)

> The exhibit that's circular [*Heart*]. The beauty is that modeling has many meanings and that summarizes it very well.

> [I liked the] models of the flying machine and the glass sea creatures. (Exit interview)

Children reported that they particularly enjoyed the interactive components, as described below.

> B11: I could see how many different things I could build out of something. (Exit interview)

> G13: Reaching in and guessing what the object was. (Exit interview)

> B11: Guessing what the sounds were and when you got to make your own models. (Exit interview)

> B10: Daytime changing thing [*What Time Is It?*], making it look like different parts of the day, that was cool. (Exit interview)

> B7: Bead strings, you make your own designs. (Exit interview)

> G12: [I liked] the cookie game. (Exit interview)

Adults who visited Making Models as part of family groups were pleased with their children's engagement with the exhibition.

> I would say the mental models held their [children's] interest. (Exit interview)

> The kids and the adults had just as much fun. (Exit interview)

LASTING IMPACT

Making Models had some lasting impact on all but 3 of the 25 visitors who were interviewed 3–7 days after their visits. These respondents cited an example either of a change in their understanding of models, an increase in their appreciation of the value of models, or something they learned in the exhibition; often they cited examples of at least

two of these categories. About a third of these respondents said they had been reminded of the exhibition since their visit.

Visitors described what they remembered most about Making Models. More than one-third identified interactive components that they enjoyed.

> I remember what my son liked—a model of a bedroom, to move furniture to make your own bedroom, and one had magnetic links [beads] and he liked that, and the sound part, where you had to put sounds in order and had to guess . . . (Short-term phone interview)

> I would say the hands-on exhibits. I can't particularly remember which ones, but they were nice to fool around on. (Short-term phone interview)

Several other visitors were impressed by the large scale model of Mt. Everest (not part of this evaluation) and by the giant grasshopper at the entrance to Making Models.

> [I remember] the train around the grasshopper . . . (Short-term phone interview)

> I think it was that model of Everest. A lot of things kids could stick their hands in and feel. A mobile of some leaves that looked like birds flying [*23 Scraps*]. (Short-term phone interview)

One follow-up respondent was particularly interested in how models are used, for both scientific and educational purposes, and clearly remembered and appreciated how concepts were presented in the exhibition.

> I'm very interested in modeling and simulations from an academic point of view. I'm a computer scientist and educator. I'm interested in conceptualization and how you broke it out. I was interested in the models for education [*Models that Teach*]. I'm doing a talk about modeling and how someone takes a complex concept and breaks it down . . . I thought the subtitles you had in the exhibit were a good example of how to take a difficult concept like modeling and break it down into sub-concepts. (Short-term phone interview)

Visitors queried 4-7 weeks after their visits revealed a much smaller lasting impact than short-term follow-up visitors. All but a few could remember something they did or saw in the exhibition, but some had only slight memories of Making Models. About two-thirds said that they valued models more, had been reminded of Making Models, or both. While just under half of these visitors credited Making Models with helping them to appreciate the value of models, about one-quarter could not think of any examples of using models in their lives. (More specific data about these findings can be found in other sections of this report.)

> I remember the access to the models and the different areas [in the exhibition] . . . the cathedral was one of my favorites. (Long-term phone interview)

> I remember seeing it, but not much about it; we were rushing from exhibit to exhibit. (Long-term phone interview)

I think we look at things differently, particularly the structure of buildings. (Long-term phone interview)

I've always believed in models. It was just refreshing to see how it was presented in creative ways, especially the contrast between the large grasshopper and the small train. Our sons are crazy about trains. We could really relate to the exhibit. We have lots of models in our house. (Long-term phone interview)

VISITOR DESCRIPTIONS OF THE EXHIBITION

In order to get a sense of visitor understandings and experiences of the overall exhibition, those who took part in exit interviews were asked how they would describe Making Models. Some visitors described the exhibition as interesting, interactive, and often, aimed toward children—similar to the overall reactions as detailed above. Many made characterizations about the overall themes of Making Models, as they understood them—most often about models generally, about the learning/teaching functions of models, and about how models are used.

For many, the exhibition provided an opportunity to learn about and think about models generally.

[It's a] cute exhibit that talked about the purpose of models. (Exit interview)

[It's about] helping you to think about things in a different way. (Exit interview)

[It's about the] limitations and uses of models. (Exit interview)

It's about the concept of modeling, understanding where something is created to look or behave or act like something else. You can experience something without having to see the actual thing itself. (Exit interview)

B10: [It's] an exhibit about different models from different ages and how to make them and what different models are. They don't have to be still; they can move, like at the ocean wave [tank]. (Exit interview)

B11: How things can represent the real thing. (Exit interview)

[It's about] recognizing that there are a lot of different kinds of models. (Exit interview)

Many others described the exhibition in terms of presenting the learning function of models, or giving visitors a chance to learn from the models.

G14: [It's about] making models that teach children. Glass creatures. (Exit interview)

[It's about] things that explain how things work. (Exit interview)

[It's about] showing how models can represent real-life situations so that you can learn from them. (Exit interview)

> [It's about] how we use models to learn about other things around us that are too small, large, or complex to understand. (Exit interview)

> It's the application of the human imagination to create representations of reality to depict aspects of real things in a way that makes them comprehensible. Reality is not easy to comprehend! These models chose particular aspects of real things. It's enjoyable to see how we can construct representations of complex real things. (Exit interview)

Other visitors focused more on the exhibition's presentation of the value of models and how they are used.

> [It's about] how to use models, where to find them in the world. (Exit interview)

> B13: [It's about] showing how different models are and showing how to create them and how you can use them in everyday life. (Exit interview)

> [It's] about understanding real-life applications of science. (Exit interview)

> B13: [It's about] how people use models to demonstrate things. (Exit interview)

SCIENTIFIC THINKING

USE OF SCIENTIFIC THINKING SKILLS

A major goal of Making Models is to involve visitors in practicing scientific thinking through the use of four primary skills. Exhibition developers hoped to engage visitors in: recognizing similarities between models and the things they represent; assessing the strengths and limitations of various models; using models to raise questions, communicate ideas, and test hypotheses in a variety of contexts; and creating their own models to explain things they cannot observe directly. Data show that some visitors engaged in all of these processes in the exhibition, and that just about all visitors to Making Models used at least one of these skill areas during their visit.

Recognizing Models

Visitors to Making Models often talked about the similarity between the models in the exhibition and the things they represented. They seemed most familiar with pyramids, waves, hearts, toys, and the packaging models, but also mentioned a variety of other components when asked about models in the exhibition "*that relate to things you know about.*"

> The display about the hearts. We're both scientists. I've worked on the artificial heart project. (Exit interview)

> The pyramids and the packaging because I'm a quilt-maker. (Exit interview)

G13: Voice interaction—guessing what the sounds were. (Exit interview)

The fish; we used to have an aquarium. (Exit interview)

I know about atomic structures. I understand the concept of the mental model. (Exit interview)

During conversations with evaluators in the interactive observations, visitors often related models to the things they represented, and sometimes compared these models to the real thing.

G12: It's faster than the waves on the beach. *Do you think it is similar to the real thing?* No, because it all starts with the same wave; there aren't any new waves. We went to the beach yesterday. It's a little bit [similar] because it crashes at the end. (Interactive observation)

[Looking at the *Pyramids of Giza diorama*] It makes you think about the labor they went through. A lot of work, and people. They must have used children. What were their lunch breaks like? Did they carry food with them?(Interactive observation)

I assume it's for much younger people, but it did cause me to think about where things in my room are. I don't usually think about that. I'm living in an accessible apartment; the rooms are tiny. (Interactive observation)

Some visitors had difficulty recognizing some of the objects within the exhibition as models. These respondents were confused as to why games like Monopoly and Go were included in Making Models. Other visitors were able to identify these games as models.

Assessing Models

Most visitors did not directly discuss the ability of the models in the exhibition to explain and predict the behavior of the objects or phenomena they represented. However, some visitors did share their assessments of the usefulness and adequacy of the models within the exhibition, particularly during the interactive observations. Some also made suggestions, or identified points of confusion.

F to G12: What starts the wave?
[Both read, other kids in their group stand around tank with worksheets.]
F: It doesn't really say what starts the waves. I think I understand waves, but don't know what starts the waves in this model. (Interactive observation)

I never quite knew the way ibuprofen worked; it's neat to see a physical representation of it. (Interactive observation)

G12: I don't get that. I don't get what it's supposed to be. It changes colors. I don't get it. I think it's supposed to be a heart rate. [Points.] That doesn't look like the heart. [Goes to next model, EKG; only sound works.] I don't get what

this is supposed to be. [Goes to auto pump.] It doesn't resemble a heart.

(Interactive observation)

Some visitors had difficulty using and understanding some of the components, particularly *Flying Over the Atomic Landscape*, and to a lesser extent, *Blowing in the Wind* and *Fish Farming*.

[Both read. M begins to explain it to F. M has trouble manipulating it; he's not getting any color on the wheel because he isn't moving the wheel vertically, only horizontally. F tells him to go vertically, and after several minutes he figures out how to manipulate the wheel.]

M: [Sits down..] I don't understand this one."

F: You have to replace those. [Someone else had left the pegboard full.]

M: I'm confused.

[F explains what to do.]

[M does figure it out after 5–10 minutes]

(Interactive observation)

[G11 sits, reads instructions, pushes some buttons at *Fish Farming*.]

Do you understand what it's asking you?

G11: No, not really; just a lot of fish.

[G11 gets up and leaves: "Confusing."]

(Interactive observation)

I'd have the question [under 800-year-old mystery text in sign]. What is the mystery? [She feels the signage isn't clear.]

Even after listening, it's not clear—did the buttresses work? The colors—do they show what didn't work? I'm not sure what the colors mean . . . I guess the colors show where it's less strong. Is the [wheel] turning the wind?

(Interactive observation)

Using Models to Raise Questions, Communicate Ideas, and Develop Hypotheses

Many of the models caused visitors to ask, and sometimes answer, questions. When groups went through the exhibition together, these questions sometimes provided opportunities to communicate ideas to each other. Components such as the *Wave Tank*, the *Grasshopper*, *This is a Model of a . . .* , and the *Pyramids of Giza diorama* often provided visitors with information they were curious about.

M: Like that day when you were at the beach—remember the waves were pushing sand back and you were trying to surf?

F: [To son; father is reading off label] When it makes a wave, is it transporting water?

B9: No, water is moving on its own.

M: No, come here and read this.

(Interactive observation)

F: I'm curious why there's a train going underneath the giant grasshopper.
[They go over to take a closer look. Read sign.]
Does it answer your question?
F: To show different proportions can affect everything.
F: It might collapse under its own weight. Can its legs support it?
(Interactive observation)

M: Interesting. I'm trying to figure out how it works and what they did with the ramps when they were done [building pyramids]. [He feels the tactile model of the pyramid for several seconds.] (Interactive observation)

One curious 9-year-old girl was prompted to wonder about the different meanings of the word "heart" by that component.

G9: [To me] I wonder why—a heart helps your body move, but people say your heart is someone you love, that's more like your mind. I've always been confused about that. (Interactive observation)

Mystery Scenes and *Mystery Objects* engaged visitors and often stimulated them to form hypotheses and ask questions. Visitors at the *Packaging* and *Fish Farming* components tested their hypotheses, and those playing *Me vs. Us: Take it or Leave it and Compete or Cooperate* also created hypotheses to predict the behavior of their partner.

[B11 reads sign, feels clue #3, then goes back to beginning.
After 2 clues, I ask, *Do you know what it is?*]
B11: This one feels like a phone; this feels like a rope.
[B11 feels all objects.]
B11: This feels like a bottle . . . I really like this because you can build your guess, step-by-step, and build a mental model.
(Interactive observation)

[Puts hands in. Feels and listens. Reads one of the signs.]
When I felt the boot, I thought fireman. The last three, I had no thought.
[Looks at scene.]
Oh, boy. I had no idea what the buckle was; I used to sail. I knew the microphone, and the boot.
(Interactive observation)

The one where you try to fit as many as the shapes in as you can—I thought the octagonal ones would fit better, but it was the hexagons. (Exit interview)

Other components, such as *What Time Is It?*, the *Can you make a model of...?(Beads)* station, and the *Sound* model components especially encouraged visitors to communicate their ideas to friends and family.

[B10 comes over; G12 reads directions, moves knobs.]
G12 to M: Guess what time that is.
M: Noon?
G12: No.
[Makes changes.]
G12: Guess what time that is.
M: Dusk?
G12: Yeah.
What clues are you using to guess?
M: The difference in the light.

(Interactive observation)

Creating Models

During the interactive observations, PERG evaluators observed visitors actively making models at a number of stations within the exhibition. The *Sound* models, *What Time Is It?* and the *Can you make a model of...? (Beads)* station were popular with visitors, especially with children and family groups. Components such as *Where am I?* and *What time is it?* Allowed visitors to create models for things they couldn't observe directly, which was one of the key goals of Making Models.

[F chooses several sounds, B10 pushes the buttons.]
F to B10: See if you can do one [sound] and I'll guess.
[She turns away and guesses.]
B10: Now guess them all together.

(Interactive observation)

[B12 manipulates light, and I ask, *What are you trying to do?*]
B12: Get the sun set to noon.
B12 to M: At noon the sun is overhead; no shadow, right?
M: You're going to have a shadow.
B12: But not much.

(Interactive observation)

Visitors' Awareness of Their Scientific Thinking

A related goal of Making Models involved metacognition—to stimulate visitors' awareness that they were engaged in scientific thinking while in the exhibition. When

visitors were asked, *"Did you do anything in the exhibition that is similar to what scientists do in their work?"* more than 80% reported that they had.

> B11: We were observing the acupuncture body and how the parts relate to each other. (Exit interview)

> Being aware of more detail of everything, like the pyramid and the grasshopper . . . being more observant. (Exit interview)

> Just putting things together; scientists do the same thing . . . (Exit interview)

> I observed many things, and observation is a scientific skill. (Exit interview)

> I guess the iterative process of packaging things is like the scientific process of repeating things, and the psychological point of view, like SAD, related to the change in light, for example. (Exit interview)

Many visitors said that their investigations in Making Models were more basic than those of scientists.

> G15: Scientists get more into the work. They have to get more details. (Exit interview)

> Yes and no. Science is about testing, discovery, experiment. I'm not sure there's a lot of support [here] to experiment. Science is about cause and effect. This exhibit doesn't seem so that way to me. (Exit interview)

> It's somewhat similar, but what they [scientists] do is more sophisticated. (Exit interview)

> At its most shallow level [we investigated]. If we had gone to the center [of Making Models], we would have [done more]. (Exit interview)

Several visitors identified new discoveries or information they had obtained in the exhibition, equating that with scientists' explorations.

> Looking at the waves and learning [about] the movement. (Exit interview)

> I did one. I looked at the wave simulator, and one of the hardest things to understand is surface waves are circular and in the sand there is a perfect circle, so what I did was careful observation of phenomenon. (Exit interview)

One visitor related the model of *Me vs. Us: Take it or Leave it* to a popular model used in American society.

> The cookie exhibit. Some people study cooperative behavior . . . maximizing profit or your gain . . . when you are in competition, where how you do pertains to how much you cooperate. That's a popular model. (Exit interview)

Finally, some visitors made connections to the work of particular types of scientists, even if they did not engage in similar processes.

G13: The wave thing [*Wave Tank*] reminds me of a marine biologist. (Exit interview)

I thought about [the work of] oceanographers. (Exit interview)

VISITOR DEFINITIONS OF MODELS

MOS staff and PERG evaluators were interested in exploring visitors' concepts of models, and asked them to share their definition of a model after having seen the exhibition, either right away or 3–7 days later.

ON THE DAY OF THE VISIT

PERG evaluators asked visitors to share their definitions of "*what a model is*" in exit interviews conducted immediately after viewing Making Models.

Exit interview respondents who answered this question generally had clear but concise opinions on how to define models. The majority of visitors described models in one of a few ways—something that helps with understanding, as representations, or as replicas, and often referred to scale in their definitions. (See the following section for data on changes in understanding caused by the exhibition.)

Immediately after viewing the exhibition, visitors frequently (twice as often as any other single explanation) described models in terms of making something easier to understand.

It makes things conceivable. (Exit interview)

Life-size version of something and an easy way for you to see it to understand how something works. (Exit interview)

B13: It shows something you are trying to explain in a way that would make people understand. (Exit interview)

It helps you to understand the real thing so you can take it apart and put it back together. Mostly scaled down. (Exit interview)

G14: Something you use to explain something. (Exit interview)

A model is something you learn from. (Exit interview)

Visitors leaving Making Models also discussed models as representations. This was the second most popular response. They usually focused on physical representations, but some visitors explicitly included non-physical models in their explanations.

B13: Something that represents something without actually being the object. (Exit interview)

A representation of something real. (Exit interview)

An accurate representation of something. not necessarily same size or same materials, like a 3-D picture of what it's trying to show. (Exit interview)

A model is an approximate representation of reality where you enhance those features you want to make more significant. Models are like analogies—they can be deceptive. And the exhibit tries to explain the issue—models by definition focus on a certain thing, like one aspect of heart function; you have to neglect others by definition. (Exit interview)

Physical or virtual representation of an object or an idea. (Exit interview)

Several visitors described models as replicas, sometimes referring to scale. Five visitors specifically defined models as smaller than the real thing, and one defined them as larger.

G13: A bigger or smaller replication of the original thing. (Exit interview)

A miniaturized version of the real thing. (Exit interview)

A replica of something real-life but drawn larger. (Exit interview)

Other definitions used by individual visitors included: "anything that recreates an activity," something that "conveys ideas without too many words," and something that "shows something you can't actually see or touch at present."

Very few respondents, perhaps because of the nature of the exit interview, shared more complex or detailed definitions of a model. The following is an exception:

Some models are man-created, some are natural imitations. Pyramids are one kind of model, others are a kind of hypothesis . . . (Exit interview)

3–7 Days Later

Visitors contacted by phone 3–7 days after their visit to Making Models were generally not as clear in their definition of a model as those just leaving the exhibition. However, several phone respondents conveyed more complex definitions than those of exit interview visitors. These visitors also frequently described models as increasing understanding.

It details things for you to tell you how it works. (Short-term phone interview)

Something that portrays what point you are trying to get across, or not so much a point, as an example. (Short-term phone interview)

A model is an outline of something you can build or a blueprint of something. It helps you understand how things work. (Short-term phone interview)

A few of those interviewed on the phone also talked about models as representations or replicas. These visitors tended to give a much more thorough description of what they

meant than exit interviewees, perhaps because of the different nature of the phone interview process or because they had had more time to reflect on what they had experienced.

> A model is a scaled representation of a much larger concept. A model could also represent different stages of a project, such as in the case of pyramids. (Short-term phone interview)

> A scale representation of something, generally a three-dimensional object, place, or something, though 3-D could be in software, too. (Short-term phone interview)

> My definition was a replica of something tangible, physical . . . like a car or plane. (Short-term phone interview)

> A scaled, idealized representation of a real-world problem that lends itself to study and to experimentation and gives insight into the real-world situation. (Short-term phone interview)

A high proportion (one-fifth) of these visitors referred to models as objects that are smaller in size than the originals.

> I would say it's a drawing or a figure of something on a smaller size than the real thing is. If I was explaining this to my niece, I would say, "This is how it would look if they shrunk it so that it's a lot smaller than it is in real life." (Short-term phone interview)

> A scaled-down version of a projected, completed work of art or completed structure. (Short-term phone interview)

A couple of those visitors called in the week following their visits talked about models as prototypes. Others gave more complex definitions.

> A prototype . . . it's a vehicle with which to try something out that's going to be a permanent thing. (Short-term phone interview)

> I don't think I could define it as one thing. 3-D models show how you want a building to look, or how you need to pack boxes to increase productivity. 2-D models are kind of more for measuring things, like graphs or tables. They're equally important as 3-D models. They're just used for a different thing. (Short-term phone interview)

> They had a good definition written. I wish I could remember the words! I would describe it as a three-dimensional replica that's used to represent a real object for the purpose of being able to learn more about it. For example, an architect might make a model of the building they're intending to build to see if everything fits together as they've anticipated, and also so it has the appearance and function they're looking for. Models are also used to demonstrate concepts. (Short-term phone interview)

A few of those interviewed several days after their visit appeared to be confused about how to define a model.

> I basically think a model is a design of something. That's what I think, and I can't really say more about that; that's a hard question.
> (Short-term phone interview)

> Dimension; if you have an idea in your head, you put it together in dimension, shape, and color. (Short-term phone interview)

CHANGES IN VISITORS' UNDERSTANDING AND APPRECIATION OF MODELS

Over one-quarter of exit and short-term follow-up respondents reported changes in their understanding of models as a result of their visits to Making Models. Many also came away with a greater appreciation for the value of models, and an increased awareness of models in their lives. Visitors realized that:

- Many more objects and types of objects could be models
- Models are not always objects at all
- Models can be defined by function
- There are many more applications for models than they had previously realized

CHANGES IN UNDERSTANDING

Many visitors to Making Models left with a greatly enlarged overall picture of the existence and uses of models.

> It makes you more aware that a lot of things that you do in your everyday life [involve] models. (Exit interview)

> I didn't know you could do so much with models. (Exit interview)

> I think [my understanding has changed]—How ubiquitous models are.
> (Exit interview)

The majority of those who experienced a change in understanding cited their realization that many more types of things can be considered models than they had previously thought. Many visitors were surprised by the inclusion of particular objects in the exhibition, such as the bottle of vanilla, the glass sea creatures, the heart, dolls, and games.

> Things I wouldn't have considered models before, I now think of as models.
> (Exit interview)

> I didn't realize there were so many different kinds of models that teach things. Models at play—I didn't realize games are actually models, like [the game] Go.
> (Exit interview)

> Before I would have said something along the lines of a model train; this exhibit tells you there's more to models. For example—the display . . . with questions [by the staff]. Different takes on what a model might be. It expanded the definition of models. (Exit interview)

The *Grasshopper* prompted some visitors to change their understanding of models in relation to size—that a model can be larger, and not just smaller or the same size as the real thing. A few also realized, often with the help of the *Heart* component, that models are not always replicas of what they are modeling.

> B13: I always thought models were about learning about something on a large scale by looking at a smaller scale. (Exit interview)

> [I was] thinking that a model was an exact replica, but [I'm] learning from the grasshopper that it isn't. (Exit interview)

> G12: [The actual heart] looks different than the regular dog's heart and that heart pump. (Interactive observation)

> With the thermometer [in *What is a model?*]. . I think of a replica. Models can be more than a miniature replica—like the heart. (Exit interview)

> I didn't realize you could be so creative [in using models to represent a range of objects]. (Short-term phone interview)

Making Models also helped some visitors realize that models are not always physical or visual objects.

> I would only have thought of a model as visual before. (Exit interview)

> The sounds—[the exhibition developers] used them as a model. I thought of models as 3-D. I never thought of sounds as model; this changed that. (Interactive observation)

> [There were] things I hadn't really thought of. I liked the game with money and cookies, hadn't thought of that [as a model]. (Short-term phone interview)

Other visitors began to think about function when deciding whether something is a model. They realized that a model might be an object that is real by itself, but is also a model of something else. This realization occurred in several places, particularly at *What is a Model?* when visitors looked at items such as the thermometer, imitation vanilla, and the whoopee cushion, which were displayed at that component.

> [Now I understand that] the word model can mean lots of different things. At first I'd just thought of a model as a representation. I came in with a child's view . . . a perfect representation of something. Then I began to realize the function of the model—whether it's to explain something or to answer a question.. Gradually, as I walked around, I began to see a much larger meaning. (Exit interview)

> A thermometer models something you can't see. (Interactive observation)

> Imitation vanilla—I never thought of it. A model could be anything that duplicates the function of the original . . . I hadn't thought of it that way. (Interactive observation)

> The whoopee cushion. It substituted for something real, even though it is a real thing itself. (Interactive observation)

A few visitors spoke about changes in their understanding in terms of possible applications for models.

> [The exhibition] gave me more practical applications. A model represents items or ideas from an alternative perspective. (Exit interview)

> I can see a more sophisticated application for them, especially the one about sharing the money, about human behavior and physical behavior. (Exit interview)

> [Making Models] increased my image of what models can do. (Exit interview)

Some visitors felt that their understanding of models had not changed, but had been enhanced by the exhibition.

> [My understanding has been] enhanced but not changed. [The exhibition] reinforces the idea that models are used to understand everyday stuff. (Exit interview)

> I just think the basic principles that were presented, we knew . . . we're pretty well educated. Some things did become more clear, like the beads and the bell curve. (Short-term phone interview)

> No [it hadn't changed], but I have more sense of what the word means. It built up my sense of understanding of that word. (Interactive observation)

When asked if his understanding of models had changed, one visitor felt the exhibition had left him confused, citing the *What is a Model?* component. He disagreed with some of the opinions about whether an object could be considered a model or not, but noticed that those quoted were all museum employees, and hence "experts."

> I'm more confused now. I'm at a Museum of Science. I assumed I would learn what a model was. This didn't clear it up. I disagree with the opinions, but they [all the people who gave their opinions] all work here. (Interactive observation)

Making Models did not impact the understanding of some visitors who had extensive pre-existing knowledge of models.

> I have a pretty strong background in the area. (Short-term phone interview)

> No, I make models of things all the time. (Exit interview)

When asked, visitors credited a large variety of components for causing a shift in their understanding of models. Multiple respondents mentioned the *Grasshopper, Hearts,* vanilla, the *Mystery Scenes, The Blaschka Legacy, What is a Model?*, and the *Models at*

Play case. Other components cited were *What Time Is It?, Mystery Objects, Flying Over the Atomic Landscape, Blowing in the Wind, Me vs. Us: Compete or Cooperate,* large cases, the whoopee cushion, thermometer, sound components, and buildings.

APPRECIATING THE VALUE OF MODELS

Those visitors who were interviewed in follow-up phone calls, either days or weeks after their visits, were asked to comment on whether the exhibition helped them to "think about the value of models." Approximately half of each set of interviewees said that it had.

Several visitors shared accounts of noticing models more as a direct result of their experiences in Making Models, including noticing models more at the MOS.

> The kids are pulling out more of their toys that they have to put together instead of being together already. (Short-term phone interview)

> I tend to notice now just stopping in a restaurant . . . a model of a salad. I am more tuned in to how people use models to teach us.
> (Short-term phone interview)

> I look at more things and realize it's a model or representation. I just spent the weekend at Mystic Seaport. You're surrounded by models there. It takes many models to understand the experience. (Long-term phone interview)

> We went down to the Big Dig exhibit afterwards. My son was able to make the correlation between the models upstairs vs. the models downstairs. For my 4-year-old—she's at the stage of understanding the difference between reality and fiction. The smaller models upstairs and the bigger models downstairs . . . made her more aware of a model building vs. a real building.
> (Short-term phone interview)

Others cited a new appreciation for the usefulness of models in "the work world" generally, and in education, in particular.

> It showed me models kind of help figure out a lot of things. They are important for businesses, the work world . . . it shows how you can do things or how you do things for a task or an assignment. (Short-term phone interview)

> I teach social studies. Models are an important part of teaching. I use dioramas. I use a variety of teaching methods, including models at the 7th grade level.
> (Long-term phone interview)

> I don't know if the issue interests everyone, but it's very important; as an educator, it's crucial. (Long-term phone interview)

One visitor became more interested in models generally, and another talked about the role of models in helping people to understand each other better.

> I seek [models] out more. In our hometown they're talking about building a new bridge. I went on line to look at the plans. I was more aware and more interested after the exhibit. (Long-term phone interview)

> Models really help decipher everyone's opinion of something . . . say I'm talking to you—and you really don't understand; it's the same thing, but we're talking about it in a different way. The model would show the right way or what it should look like. (Long-term phone interview)

Several respondents said that they already had a very high appreciation for the value of models.

> I always had a high appreciation for the value of models. That's one of the main reasons we were there. (Short-term phone interview)

> I'm a firm believer in models because I'm a software engineer—so we use computers to model the real world. (Long-term phone interview)

RELATING MODELS TO PERSONAL LIFE EXPERIENCES

The various components in the Making Models exhibition often prompted visitors to think of models (or experiences) in their own lives. In fact, when asked directly, only four visitors who were interviewed several weeks after their visits said that they could not think of any examples of using models in their daily lives. Almost all other visitors had some awareness of using models, though a few could not come up with specific examples.

When asked, "*Did the exhibit remind you of any models you use or see in your everyday life?*" visitors gave a range of responses, from very brief to more detailed and complex. Many cited toys—Legos, erector sets, chess, model trains and cars, video games, etc. Maps, including weather maps, were also frequently mentioned.

> B11: Toy cars, Legos—The models at play made me think of what toys kids use everyday. (Exit interview)

> B11: Legos you can use in everyday life. Pyramids remind me of Lego blocks. (Exit interview)

> Something very simple—charting our route into Boston today using a map. (Exit interview)

> I follow weather models of radar. They give two or three models of what could happen. (Interactive observation)

The exhibition reminded many visitors, both educators and students, about models related to teaching and education, including dioramas, science projects, and teaching about diabetes.

> We take chemistry, so the carbon molecule. (Exit interview)

> Yes, if I need to make a science project, it would help to make a model. I've made dioramas, and I draw a lot. I like to go outside and draw what I see.
> (Long-term phone interview)

> [Pause] . . . in my work I do. I do diabetes education, so when I talk about cells and other things I have different-colored balls; and I have wands with liquid, which shows normal blood sugar and how it's thicker when it's not normal; lots of food models to show portion sizes, things like that.
> (Long-term phone interview)

> It looks like my audiology class. We use a lot of models in my classes. I'm very familiar with this model. (Interactive observation)

Multiple visitors also cited *Packaging, Me vs. Us: Take it or Leave it and Compete or Cooperate, Teeth, Wave Tank,* models of the body, computer simulations, and architectural models as components that reminded them of something from their lives.

> The pallets—like past summer jobs in shipping and receiving. (Exit interview)

> When you're thinking about doing something, even rearranging the living room, building something, how to pack the car! (Exit interview)

> The sharing thing [*Me vs. Us: Take it or Leave it and Compete or Cooperate*]. I'll use a verbal model to explain a situation to someone. The sharing method is about saving face. (Exit interview)

> This model reminds me of a dentist office when I was a kid.
> (Interactive observation)

For a few, the exhibition brought to mind more unusual examples of models.

> I consider my father a model to follow. (Long-term phone interview)

> I am time- and calendar-oriented, personally. I've come up with my own personal models to represent units of time . . . I will often think to myself that a chore is going to take a unit and a half of time. (Long-term phone interview)

> It reminded me of metaphors. A metaphor is a concrete representation of an abstract idea. [She teaches literature.] (Exit interview)

A few visitors were explicit about their new realizations about models they use.

> B11: I play Monopoly and games. I didn't think of that before. (Exit interview)

> I have a 2- and 4-year-old. I realize the pictures I draw for them, I am creating models. I am not just simplifying the drawings. I am constructing a model they can understand. I came to that realization here. It helped give me perspective.
> (Exit interview)

A few visitors could not think of any models that they use.

I'm not so much a visual person. I learn through reading, so models are out of the ordinary for me. (Exit interview)

Maybe we use them but don't realize it. (Exit interview)

VISITOR LEARNING IN MAKING MODELS

More than three-fourths of visitors (who were questioned about their learning within Making Models) reported that they had learned something new during their visit. Many visitors cited a broad variety of components as sources of learning in the exhibition, while others talked about their new awareness of the value of models in general.

The components in Making Models cited most frequently included the *Pyramids*—how they were constructed and displayed, the *Wave Tank* and how waves are formed, *Packaging* and how to solve the challenges presented there, and *Me vs. Us: Take it or Leave it and Compete or Cooperate*—learning about sharing and cooperation. The following responses were typical.

B11: The pyramids—I didn't know the blocks were so big and it took so many people [to build them]. (Exit interview)

The pyramids. It's so amazing that people were dragging these stones. No animals! No oxen, no camels. (Exit interview)

Maybe the water [*Wave Tank*]. I never thought about how it looks underneath. We don't have beaches in Switzerland! (Short-term phone interview)

With the shapes, I grabbed the black octagon shape first . . . it seemed to have the smallest area; I figured I could fit more in there. I then grabbed the hexagon . . . it was a good introduction to hands-on [learning]. (Exit interview)

. . . the game we played on the computers . . . with the money; you can take it or share it. Looking back I now realize that was a model.
(Short-term phone interview)

In addition to the previously mentioned components, visitors cited many others which stimulated their learning and interest, including the *Grasshopper, Packaging, What Time Is It?, Hearts,* and *The Blaschka Legacy.*

The grasshopper. I learned about the muscle in his hind leg which helps him to jump. Reading the plaque [sign] is where I got the information about the grasshopper. (Exit interview)

The description of the glass specimens that the father and son did. Methods they used were proprietary, that they didn't share. Apparently they've never been reproduced; they had unique knowledge. (Exit interview)

> It was interesting, because I hadn't thought of the heart in some of those ways. (Short-term phone interview)

> . . . the lighting one [*What Time Is It?*], about how powerful light is to set mood, its intensity and color . . . (Exit interview)

> Glass models, how they were made. Also the waves; ocean waves don't really move! I didn't know that before. (Exit interview)

One blind visitor gained new information about pyramids, by using the tactile model near the diorama.

> Well, for me, the pyramid model was interesting. I've been blind for most of my life. I'd never had the opportunity to see their ramps and how they are set in a spiral. I liked that so many of the models were immediately available to touch and not all inside cases. (Short-term phone interview)

Other visitors, rather than focusing on a specific component, described new learning related to the properties of models and their usefulness.

> I ascribe the term model to more things in everyday life. (Exit interview)

> [I learned] that you can use a variety of mediums to make models. (Short-term phone interview)

> [I learned] that models are all around us . . . I am a model as a teacher. It got me thinking about the hugeness of the concept and how important it is to learning. (Short-term phone interview)

> [I learned] that models can be viewed using various means, for example, computer animations as well as the hands-on exhibits. (Short-term phone interview)

Several visitors had new insights about how to explore models, and their complexity.

> I realized that I can't tell something just by feeling it. I have to see it, as well. (Short-term phone interview)

> [I learned] that they can be difficult to do, or they can be intricate [to create]. (Short-term phone interview)

During interactive observations, PERG evaluators saw evidence of visitor learning at many of the components within Making Models. Visitors often talked about new discoveries they made while they toured the exhibition, as demonstrated by the following comments.

> There's a magnet; now I understand. There's a magnet here, that's the red color. It's a mechanical model that simulates the behavior of electrons in STM. (Interactive observation)

> I've been on the Jersey shore many summers. I understand now how you get breakers. (Interactive observation)

> Ah hah. It [*Fish Farming*] also teaches you about the percent you have and the percent you vaccinated, and how many you can keep without losing them. (Interactive observation)

> I never quite knew the way ibuprofen worked. It's neat to see a physical representation of it. (Interactive observation)

> B11: If you cooperate you can get further. Each will get half. (Interactive observation)

Some visitors broadened their understanding of models by making connections to their daily lives.

> Looking at this makes you remember that almost everything starts as a scale model—cars, buildings go from paper to a model to actual size. Even furniture, something as basic as a chair or table, probably uses a model before the actual piece [is made]. (Interactive observation)

> It's interesting. When you see Monopoly, it's a model of how to behave in the future. It's not automatically [that you realize it's a model]. (Interactive observation)

> It seems like anything can be considered a model, depending on your perspective. (Interactive observation)

> G9: I just read that and now I get it—it's like learning how to do stuff, like having a doll and learning how to be a parent or a Monopoly game about how to handle money. (Interactive observation)

GENERAL TRENDS FROM DISABILITY INTERACTIVE OBSERVATIONS AND EXIT INTERVIEWS

EXPERIENCES OF VISITORS WITH DISABILITIES IN MAKING MODELS EXHIBITION

Evaluators observed or interviewed visitors with a variety of disabilities who were invited to the museum specifically for the evaluation. Disabilities experienced by these visitors included blindness, low-vision, mobility-impairments, deafness, cerebral palsy, and developmental disabilities/cognitive impairments. All of these disabled visitors were able to interact with at least half of the Making Models exhibition, and evidenced a similar range of responses to the content as non-disabled visitors.

Disabled visitors' experiences and their ability to interact with Making Models were influenced by their disabilities—the exhibition was more "user-friendly" for people with some disabilities than others. For example, wheelchair users with full upper-body mobility were able to travel independently and interact with almost all of the components within Making Models.

Most of the disabled visitors reported that they found Making Models to be interesting. Examples of accessible components that disabled visitors enjoyed included *Packaging, Mystery Objects, Fish Farming,* and *Me vs. Us: Compete or Cooperate.* Components cited by disabled visitors were also popular with non-disabled visitors. Some visitors expressed frustration or disappointment when components turned out to be not fully accessible to them. Some described the exhibition as geared more for children, too basic, or "below your level of interest." One visitor experienced the exhibition as "a dichotomy—some things were too low level, some too high," requiring a science background.

Note: Evaluators also obtained very limited data for those with learning/cognitive impairments, and could not determine the exhibition's level of accessibility for those visitors.

Overall Impact on Disabled Visitors

Data show that all of our disabled respondents interacted with many components within Making Models and appeared engaged during those interactions. Like our able-bodied visitors, disabled visitors didn't necessarily alter their understanding of models—about two-thirds of disabled respondents (among those we asked) said that their understanding of models had not changed after going through the exhibition, while a third reported that it had.

> The sounds, they used them as models. I think of models as a car or something physical, but it's not just that. It could be [a model of] cooperation or something hypothetical. I was simplifying it before. (Amputee)

> No [understanding didn't change], because I used to draw models. (Scooter user)

About half of disabled visitors reported that they used models in their daily lives, while others may not have made the connection between models as a tool and their lives outside the museum. (This trend was also noted among many non-disabled visitors).

> [I used models] to help me remodel a galley kitchen in a new condo a few years ago so carrying food from the kitchen would be easier, but it cost too much. At the Carroll Center they use a lot of street models to train [blind people] to ask the right questions, so the next time you don't need the model. You have to figure out how to live your life without models. A model is an intermediary tool. Most things I have to experience in real size and real time. (Blind visitor)

> If I'm working on a website, computer work, web design . . . [you're making] abstract models in your head. When I make a web page, I start on paper, then create it in the computer. (Low-vision visitor)

One blind visitor found out new information about pyramids through one of the models in the exhibition.

> I particularly liked the pyramid—not the one with the ramps but the other pyramid with the ladders. That one is tactile. I just got the concept of pyramid today! I knew it was conical, but I hadn't realized it got smaller and smaller as it goes up. (Blind visitor)

It should also be noted that some of our visitors focused so heavily on issues of access that they did not fully engage with the components; the experience may not have been a typical museum visit for them, due to the nature of the scheduled interactive observations and the evaluator's questions about accessibility within the exhibition.

Experiences of Mobility-Impaired Visitors

Those with mobility impairments—wheelchair and scooter users and amputees—could get around the exhibit without major difficulty. They found most of Making Models to be easily accessible, though there were some components that were difficult to see from a wheelchair —some of the (front) glass cases, the Pharaoh in the *Pyramid* model, and the two-dimensional drawing in *What Is A Model?* Wheelchair users and others who had limited upper body mobility and poor manual dexterity had to depend on others to manipulate some of the components by pushing buttons, feeling "mystery objects," etc.

> So far it's user-friendly, [except] the windows up front [glass cases]; you do have pictures, but I couldn't see the ones up top, that's all. (Wheelchair user)

> Accessibility was great. I was surprised that I fit into the booth [construction scene]. Easy to read, the level was good, even the computer screens. (Wheelchair user)

An amputee found the exhibit generally accessible but recommended having more places to sit down, particularly at the *Shape is Key* component. She planned to recommend the exhibit to her amputee support group and appeared to be fully engaged by some of the interactive components.

> On the whole, I found it user-friendly. One place in particular [*Shape is Key*], if I could sit, I'd listen. I'd recommend having more places to sit for listening or reading. I do have a little hard time getting up and down; the stools are a little low for me. (Amputee)

Experiences of Blind and Low-Vision Visitors

Issues with low-vision and blind visitors were more complex. Most of these visitors found parts of Making Models to be very accessible while other parts were difficult or impossible to access. In general, those visitors who had some vision were able to experience the exhibition more fully than blind visitors.

Blind respondents especially appreciated all of the "hands-on" portions of Making Models, and would have liked more. They were sometimes disappointed or frustrated when they couldn't touch the actual objects that were described in the audio descriptions, such as at the *Hearts* and *What Is A Model?* components. (Some heart models could be

touched, but the doors always swung shut too quickly.) Some visitors would have liked a chance to touch some of the objects in the large glass cases, as well.

> [Making Models was] a mixed bag, as far as learning from things. Some were fun/stimulating, others weren't—feeling a cylinder. An audiotape lecture would work just as well. (Blind visitor)

> [Looks for audio but there is none.] Big print, but not close enough where I can see it. I can see contrast, sticks, bold colors, but I don't know what they are. This is a typical museum experience. I can't see the explanation, there's nothing to interact with, no audio. Give me enough of these and I want to leave. (Low-vision visitor)

Low-sighted visitors fared better than the blind; they were able to investigate the exhibition using multiple sensory pathways and were not as dependent on a guide. Some used the audio selectively, particularly when they could see the components and did not find the audio description to be necessary. Unlike those with no vision, they were not automatically "shut out" from the cases, but most could not read the text inside. Visitors with limited vision appreciated signs that were easy for them to read, but wanted larger signs and bigger print throughout the exhibition.

> For the most part [the exhibition was] user-friendly. A number of things I would've liked to do—time of day, electron microscope—that was disappointing [they weren't fully accessible]. The descriptions were good; it was fun. (Low-vision visitor)

One blind respondent suggested having an orientation audiotape to help blind/low-vision visitors orient themselves to the gallery.

> The exhibit needs an overall orientation, and a Braille map would be helpful, too. Some of the stations need to provide more feedback to blind visitors in order to be accessible: stage lighting, atomic, etc. Some type of clearer pathway would benefit some disabled visitors. (Low-sighted visitor)

Experiences with the Audio

Blind and low-vision visitors relied heavily on the audio components in Making Models. The audio descriptions made it possible for them to experience large portions of the exhibition. However, most of these visitors also found use of the audio to be frustrating for a number of reasons. Issues they cited included: the inability to stop or re-start the audio; problems with volume—it was often hard to hear; inconvenient, inconsistent and confusing locations for the audio labels; confusing audio directions, and a need for "clues" to let blind/low-vision visitors know how they're doing (for example, tones or sounds to indicate correct answers). It was difficult for blind visitors to reach/feel objects and have the audio descriptions coincide with what these visitors were feeling, hearing, etc.

> Pushes audio button and listens. Confused by instruction which talks about a panel to the right, but she is already sitting in front of the panel; it is the audio phone that is to the left. She follows directions, "press audio button until . . ." No audio—it appears to be broken. Eventually the audio text turns on, but it's not clear why or how. (Interactive observation of low-vision visitor)

> I don't know if someone else set this before I got here, but it's in the middle. Make it so it resets when [button] hit. (Blind visitor)

Also, some disabled visitors preferred not to hold the cone of the earphone directly to their ears (and therefore had problems hearing), while others couldn't hold or pick up the cones due to mobility issues. Visitors also experienced frustration at components like *Where Am I?* when the audio wasn't working or the sound model noises didn't work. Sometimes these visitors were not sure if the audio or the entire component was broken, or if they were simply not using it properly.

> I didn't know you can pull it up [earphone] and then once it starts you can't restart it. It could be louder. [He doesn't put the earphone flush against his ear.] . . . I'd like to restart it [audio loop]. I hear facts but don't know what I'm listening to. If you just pick it up, you don't know what it is, because you get it in the middle. (Low-sighted visitor)

Experience of Deaf Visitor

Only one deaf visitor (with his hearing wife, who functioned as an explainer/interpreter) participated in these interactive observations. He had a low reading level in English (typical of many deaf adults), and relied on American Sign Language to communicate with the evaluator. While he enjoyed parts of the exhibit, he reported that he wouldn't have understood much of it without his wife's help. He recommended incorporating ASL video into the exhibit, since he had difficulty reading English text.

> It would be nice to have a [video of a] signer at each station [at *Hearts* component] but it's expensive! (Deaf visitor)

> My wife helped assist me, but if she wasn't here, [the exhibition would] not be successful at all . . . My language and reading level—most deaf read at 3rd grade level. This was at 10th–12th grade level. (Deaf visitor)

Summary of Suggestions

Disabled visitors made numerous comments based on their experiences within Making Models. Their suggestions included the following:

- Improve the audio text; allow visitors to pause or restart the descriptions
- Increase the volume of the audio
- Have larger signage at some components for low-vision visitors
- Increase the number of tactile models for blind visitors

- Have less of the exhibition "behind glass," including the cases in the back of Making Models
- Incorporate more Braille, including a Braille map of the exhibit
- Have an audio orientation for visitors
- Include video of an ASL "signer" for deaf visitors
- Add more seating for those with physical disabilities
- Adjust the height of some components for wheelchair users
- Consider other options to earphones; some visitors couldn't or didn't want to hold the cones
- Use scanners rather than buttons for visitors with limited manual dexterity
- Improve directions for operating the components
- Have bars or rails for mobility-impaired visitors

Universal Design Features

By incorporating principles of universal design, MOS staff sought to make Making Models accessible to the largest possible number of visitors. Our data show that both disabled and non-disabled visitors used some of these features, including the audio labels, tactile models of the pyramid and the Aztec temple, and large-print signs which were placed throughout the exhibition.

During interactive observations with non-disabled visitors, evaluators frequently observed both adults and children using the audio labels, including the text descriptions. Adults in family groups often pushed the audio buttons to enable their young children to more easily explore the *Mystery Objects*, the *Hearts* component, and other stations.

PERG evaluators asked selected visitors, in exit interviews and follow-up phone interviews, if they had used the audio descriptions (the universal design feature most commonly used by visitors). More than half of these visitors reported that they used the audio devices within Making Models. Some visitors commented that the audio was difficult to hear, and made suggestions to improve this feature.

> The kids liked the audio because they might not want to read. (Exit interview)

> Yes [used audio]. It's interesting to hear because you get sick of reading things. (Exit interview)

> Definitely, because I couldn't read the signs myself. My husband could see, but it's difficult with three children [needing attention]. If they chose to, they could listen along with me. Sometimes the volume wasn't loud enough, so it would be good if there were a volume control. (Short-term phone interview)

> Oh yeah. It helped to get the full experience; the kids started looking at something—it makes them slow down and listen and get more out of it.
> (Short-term phone interview)

Several visitors said that they found the audio labels helpful, especially for their children. Some of their children learned new information by listening to the audio.

> We listened to . . . the audio that read the little clues [*Mystery Objects*] . . . it was helpful for my niece because she just listened to the clues, because she can't read yet. (Short-term phone interview)

> It [audio] had more detail, which was a plus. (Short-term phone interview)

Many of the universal design features were used by disabled visitors, who were invited to visit Making Models for the purposes of this evaluation. Their reactions and feedback are presented above.

ADDITIONAL VISITOR SUGGESTIONS

Some visitors shared their ideas for improving Making Models with evaluators. Most of these suggestions detailed some specific or type of model a visitor would like to see added to the exhibition, including:

- More interactive components for children, especially Legos

> It would have been nice to have Lego pieces. The kids can really relate to that . . . Also another toy, K'nex which the kids love. There are also some really good books—with plastic models built into them, like the human body, which you could display. Even more interactive child-friendly stuff. The more hands-on the better. Pushing buttons on a computer gets old fast.
> (Long-term phone interview)

- Models relating to technology, especially computers

> Today is all computers. Some models should be installed that show how computers work, cell phones, more technical function. (Exit interview)

> It might be interesting to add how a computer can act as a model . . . perhaps more of an emphasis on that. (Exit interview)

- Architectural and engineering models—models of buildings, bridges, planes

> I didn't look carefully, but if there aren't model planes there ought to be. Great way to learn about aerodynamics and flight characteristics. (Exit interview)

> I think there should have been an atomic energy plant model and a model of . . . plants in Maine that take trash and turn it into usable energy. There are 7–8 plants in our state. It would be fascinating for people—models of technical things. (Long-term phone interview)

- Mathematical models

> I'm a physicist and a professor and modeling is very important for professors, and I think you did an outstanding job of presenting models, but you don't have mathematical models. Maybe you could get a computer to do that . . .
> (Exit interview)

- Model of an airbed, wind tunnel, human organs, more maps, more 3-D models, more three-dimensionality

> It would be an interesting challenge to add more three dimensionality to more of the models. It would be hard, but interesting. I'm a physician/scientist, and I work in computational genomics. (Short-term phone interview)

Other visitors would have liked more information about some of the models, such as the *Wave Tank* and *23 Scraps Of Paper* component. One mother suggested explanations on two levels—one for adults and one for children.

> I've really been dying to know about the wave, but they don't say anything about the sand. Does the sand erode? Does the sand only travel in one direction?
> (Exit interview)

> I like that, I want to buy it. I'm trying to figure out how it works; it's impossible. [Studies gears to see how it moves.] I wish they had a label to explain how it moves. (Interactive observation)

> Some of the explanations were in heightened language. It was difficult for my 7-year-old . . . You almost need two definitions, one for the child, one for the parent, using examples that a child would understand.
> (Short-term phone interview)

One visitor suggested adding "a list or photo display of examples in our everyday lives." Another talked about the role of metaphor in relation to modeling.

> Metaphor is an important concept in modeling. Educators are always looking for metaphors to capture and model educational theories. I don't remember if the exhibit addresses that. I would go back and see how much metaphor comes though, as a method for modeling and the issue in general.
> (Long-term phone interview)

Several visitors suggested better guidance for visitors, through the exhibition as a whole, or at specific components. One visitor wanted a clearer explanation/orientation to the overall focus of the gallery.

> At the entrance, have a few words about what you might be able to see in this room. Better signage about the objective of this exhibit. There wasn't something at the entrance to help you focus. (Exit interview)

> The only thing that would work better would be to direct people to individual stations in a better way. People are sheep . (Exit interview)

DISCUSSION AND RECOMMENDATIONS

Making Models met its goals of expanding most visitors' recognition and appreciation of models, of introducing them to a variety of models, and of engaging them in practicing scientific thinking skills while using models. The variety of experiences offered by the exhibition ensured that the majority of visitors left with new information or new understanding. While some visitors could not recall many specifics about Making Models 4-7 weeks after their visits, the majority did remember some aspect of the exhibition and reported that they learned something from it. The exhibition was particularly successful with family groups, who almost always used the interactive components, whereas adult use varied; however adult visitors were also impacted by their visits to Making Models. While most of our respondents enjoyed their time in the exhibition, a very small minority of visitors did not like the exhibition and felt that it had nothing to offer them.

Visitors experienced Making Models primarily as an exhibition about models in general, about the learning and teaching function of models, and about the value and uses of models. In addition, almost all visitors reported or were observed practicing one or usually more of the four scientific thinking skills targeted by Making Models—recognizing, assessing, using, and creating models. When asked, over 80% reported that they had behaved like scientists in some way during their time in the exhibition. However, some visitors might not have made that connection on their own (without being asked by evaluators), and would have needed specific information at the components to realize they were engaged in scientific processes.

Making Models impacted visitors' understanding of models, but not universally. About one-third of those interviewed reported changing their understanding of models due to the exhibition. (Some already had a thorough understanding of models.) Most of these cited an expansion of their idea of what a model is and how models can be used. However, most visitors did not notice the signs that were meant to help visitors understand and categorize the different types of models in the exhibition. Visitors who played *Me vs. Us: Take it or Leave it and Compete or Cooperate* often did not realize how their actions constituted a model unless they had thoroughly read the signs. Some other visitors appeared uncertain as to why various items were included in Making Models, such as the games and children's toys.

Many visitors also altered their understanding of the value of models—when asked specifically about a change in their ability to *"think about the value of models"* as a result of Making Models, either a few days or a few weeks after their visit, slightly more (from the first group) and slightly less (from the second group) than half of each follow-up

group said that it had. However, while the exhibition prompted some visitors to reflect on the nature of models, it did not appear to promote reflection among many others.

Making Models provided interesting components that stimulated visitor learning—over three-fourths reported learning new information, either about or from models. However, it was not always successful in imparting an overview of its content, of conveying a clear theme. The majority of visitors did not appear to read the separate signs that grouped the components by area and gave an introduction to the different types of models present in the exhibition. Therefore, some visitors could not identify the links between the different models in the gallery and did not view the exhibition as a coherent "whole." Visitors' experiences may have been shaped by the lack of clear pathways within the exhibition. While many adult visitors circled around the outside of the gallery, others (particularly adults in family groups and children) headed for the interactives in the center of the exhibition. As a result, many visitors did not view the *What Is A Model?* component, which appeared to give visitors the best comprehensive picture of the exhibition's approach to models.

While visitors' responses indicated that the goals of Making Models were generally met, there also appeared to be missed opportunities, as noted above. With slight changes, the exhibition might have helped visitors to better understand the larger themes of Making Models and promoted more reflection about models, including their presence and uses in visitors' lives.

DISABLED VISITORS AND UNIVERSAL DESIGN

Making Models also met many of its goals related to universal design, although more access issues remain. All of the disabled visitors observed or interviewed by evaluators were able to interact with at least half of the exhibition components and most reported that they enjoyed their visit to the exhibition. Some disabled visitors identified areas of new learning, while a few others (generally those with more science background) found the exhibition to be somewhat basic and more geared toward children. Their reactions were similar to those of non-disabled visitors; some were fully engaged with the exhibition, while others were not.

Many non-disabled visitors also used and benefited from universal design features within Making Models. Young children and family groups often used the hearphones and tactile models, and many seniors (and other visitors) appreciated the large signage and lighting within the exhibition.

It should be noted that significant parts of Making Models were not fully accessible to visitors with certain disabilities. While wheelchair users—particularly those with good upper body mobility—could interact with most, if not all the components, the exhibition

posed a greater challenge for deaf or blind visitors, for reasons discussed in the Findings section of this report. Some disabled visitors expressed frustration that they could not feel or interact with many of the components.

Overall, it does appear that Making Models enabled most disabled visitors to enjoy, learn from, and interact with significant portions of the exhibition, and to gain value from their visit to the gallery.

RECOMMENDATIONS

Based on evaluation data and visitors' suggestions, the evaluators offer the following suggestions to improve the exhibition:

- Making Models provides multiple opportunities for visitors to experience and learn about models, but many of these lead to a particular "right" answer. The exhibition would be stronger with additional open-ended experiences that encourage visitors to construct meaning and reflect on their experiences with models.
- Evaluation data suggest that visitors did not always make very full connections to model use in their everyday lives. Including pictures or other media demonstrating common usage of models might help meet this goal more effectively.
- Models are often used in the process of making other models on the way to a final product, such as a blueprint, model building, and final structure. Visitors would gain from seeing examples of the model-making process, perhaps including examples of how they were utilized in the making of the Making Models exhibition.
- Visitors requested many additional types of models, including more mathematical, engineering, and technology-related models, as well as more building toys for children (and others) to use to create their own models.
- Many models that would be interesting to touch, for both disabled and non-disabled visitors, are behind glass in this exhibition, such as the doll house, the model of the human body, and the dioramas. The exhibition would be strengthened by using models which could be fully accessible to visitors (and withstand handling). This would also extend the application of the principles of universal design to more of the exhibition.
- Visitors often lacked a thematic overview of the exhibition, which could have given them a better overall understanding of models. Several changes might address this:
  - Issues related to signage:
    - Improve the placement of the signs that delineate types of models to encourage more readership

    - Produce larger and clearer signs to help visitors identify various types of models and see the similarities and differences between them
    - Integrate signage into individual components that would allow visitors to make connections among the various types of models
  - Place the *What Is A Model?* component in a location more likely to be on a variety of pathways
  - Consider establishing clear pathways through the exhibition gallery
- Blind and low-sighted visitors have the potential to experience major sections of Making Models independently, but only if they have access to an audio orientation to the gallery.
- Disabled visitors were particularly frustrated by the *Hearts* component—by the quick closing of the doors, the repetition of the audio, and the limited access to feeling the models themselves. Improving this central component would make many visitors' gallery experience more satisfying and instructive.

Making Models is an innovative, enjoyable, and generally successful exhibition that met its primary goals. While most visitors engaged with and learned from the exhibition, there remain additional opportunities for MOS staff and the exhibition developers to present the concept of modeling in ways that will likely increase visitor understanding and encourage more reflection on this important topic.

APPENDICES

APPENDIX A
EXIT INTERVIEW PROTOCOL

Visitor Demo. Info.: Interview # ____ Date:____ Time: _____

Family Group:_____

#Adults ___ M___ F_____ Ages: 18-25___ 26-35___ 36-45___

46-55___ 56-65___ 66-75___

#Children____ M___ F___ Ages: <10___ 10-18___

Location: _____ Ethnicity if known: _____ Visible disabilities?_____

1a. What stood out? What did you like the best?

2a. In the exhibit, did you see/use models that relate to things you know about?

2b. How did these models compare to the real thing? *(strengths and limitations).*

3. How would you tell a friend about this exhibit? What would you say it is about?

4a. After seeing the exhibition, has your understanding of models changed in any way? How?

4b. If yes, was there anything in particular that caused that change?

4c. How would you explain what a model is?

5a. Did the *exhibit* remind you of any models you use or see in your everyday life?

5b. Can you think of any models you use or see in your life?

6. Can you tell me about something you did or looked at in the exhibit? Did you learn anything from it?

7a. Did you do anything in the exhibition that is similar to what scientists do in their work?

7b. If yes, is this something you do in your normal course of activities?

8. Did you listen to any of the audio in the exhibit? If yes, how do you think it affected your visit?

9. Anything else you would like to add? *(science or math background?)*

APPENDIX B
SHORT-TERM PHONE INTERVIEW PROTOCOL
3–7 DAYS FOLLOW-UP

Name:

Date: 6//04

Location:

Phone no:

1. What was your overall reaction to this exhibit?

2. Has your understanding of models changed in any way? How?

3. Has anything you've seen or done since your visit reminded you of the exhibit?

4. Can you comment on whether the exhibit has helped you to think about the value of models, and if so, how?

   Have you noticed more models around you since your visit?

5. If someone asked you to describe one new thing you learned about models from this exhibit, what would you say?

6. How would you explain what a model is?

7. Did you listen to any of the audio? Do you think it affected your experience of the exhibition?

8. Is there anything else you would like to add?

Do you have a scientific or mathematics background?

APPENDIX C
LONG-TERM PHONE INTERVIEW PROTOCOL

Name:

Location:

Date:

Phone no.

[Remember the exhibit or need prompt?]

1. What do you remember most from your visit to the Making Models exhibit?

2. Can you describe anything you or other members of your group did during the time you spent in the exhibit?

3. Has anything you've seen or done since your visit reminded you of the exhibit?

4. Can you comment on whether the exhibit has helped you to think about the value of models, and if so, how?

   Have you noticed more models around you since your visit?

5. Can you think of any examples in your own life of using models?

6. Is there anything else you would like to add?

Do you have a scientific or mathematical background?

APPENDIX D
DISABILITY EXIT INTERVIEW PROTOCOL

Visitor Demo. Info.: Interview # ____ Date:____ Time: _____

Family Group:_____

#Adults ___ M___ F_____ Ages: 18-25___ 26-35___ 36-45___

46-55___ 56-65___ 66-75___

#Children____ M___ F___ Ages: <10___ 10-18___

Location: _____ Ethnicity if known: _____ Visible disabilities?_____

1a. What stood out? What did you like the best?

- How was your experience in the exhibit? Please comment on the level of accessibility/ease of use within Making Models.

2a. In the exhibit, did you see/use models that relate to things you know about?

2b. How did these models compare to the real thing? *(strengths and limitations).*

3. How would you tell a friend about this exhibit? What would you say it is about?

4a. After seeing the exhibition, has your understanding of models changed in any way? How?

4b. If yes, was there anything in particular that caused that change?

4c. How would you explain what a model is?

5a. Did the *exhibit* remind you of any models you use or see in your everyday life?

5b. Can you think of any models you use or see in your life?

6. Can you tell me about something you did or looked at in the exhibit? Did you learn anything from it?

7a. Did you do anything in the exhibition that is similar to what scientists do in their work?

7b. If yes, is this something you do in your normal course of activities?

8. Did you listen to any of the audio in the exhibit? If yes, how do you think it affected your visit?

9. Anything else you would like to add? *(science or math background?*

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