EXPERIMENT BENCHES

= Summative Evaluation Report =

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EXECUTIVE SUMMARY

This evaluation study set out to identify and describe the experience of visitors to the multiple-outcome labs in the Experiment Gallery at the Science Museum of Minnesota. Six hundred and two visitor groups were observed at three labs and two exhibits, the Electricity Bench, the Optics Bench, the Pendulum Bench, Waves on a String and Spectrum Window respectively. Sixty-six of these groups were interviewed. There were approximately 92 hours of data collection. The primary findings are summarized below.

1. Visitors spent longer periods of time at the labs than they did at the exhibits. The longest a visitor stayed at a lab was 19 minutes compared to 6 minutes at an exhibit. Approximately one-quarter to one-half of visitors to the labs spent more than four minutes. Only about five to ten percent of visitors to the exhibits spent more than four minutes.

2. Although visitors to both labs and exhibits engaged in experimenting behavior, visitors to the labs in particular developed and tested hypotheses, and designed and set up experiments.

3. Visitors to the labs tended to interact with each other in more meaningful ways than they did at the exhibits. When visitors interacted with each other, there was more appropriate learning guidance and cooperative problem-solving at the labs. However, more groups visiting the labs—compared to groups visiting exhibits—did not interact with each other at all.

4. Visitors to the labs and to the exhibits appeared to enjoy themselves equally. Visitors to the labs particularly enjoyed being more in control, to choose what they did, and to explore a topic in depth.

5. Some visitors experienced higher levels of frustration and intimidation at the labs. These feelings were attributed to a) being unable to figure out what they were supposed to do, b) being unable to succeed or to know if they had succeeded, c) not understanding how a particular component worked, and d) having basic questions left unanswered.

6. A few visitors in particular appeared to experience rich and meaningful learning experiences at the labs.

7. The Electricity Bench appeared to be the most successful of the three labs.

8. Overall, the labs appeared to be successful at providing an in-depth and meaningful museum experience for visitors.

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INTRODUCTION

Background of Project

The Science Museum of Minnesota has 60,000 square feet of exhibit space. Located on the Museum's third floor and occupying 10,000 square feet, the Experiment Gallery offers visitors experiences in physical sciences and technology. Within this space, there are numerous interactive exhibits, demonstrations, theater, interactions with science staff, and resource materials.

As theories of constructivism begin to take hold in the museum community, science museums are exploring opportunities to provide environments that encourage and enable visitors to construct their own meanings and continue to search for ways to engage museum visitors in more meaningful and thought-provoking interactions.

The Experiment Benches at Science Museum of Minnesota are a series of multiple-outcome participatory exhibits located within the Experiment Gallery. Designed to give visitors a large degree of control over their learning while promoting and guiding meaningful scientific thought, they provide an opportunity for visitors to create and set up their own experiments in order to explore a given phenomenon or topic. As such, they are designed to be responsive to the visitor's curiosity, allowing them to follow a personally directed inquiry.

Each bench has a particular theme such as sound, electricity, pendulums, or optics, a set of apparatus with which to set up and conduct experiments, and a series of activity cards to get the visitors started. Enclosed by a low fence, seating is included for a small number of people. A sign outside each bench instructs visitors to sign-up for a twenty-minute time slot.

The purpose of this summative evaluation project was to determine the degree to which the benches are a useful paradigm for designing stand-alone exhibits that are capable of engaging visitors in meaningful scientific inquiry. Three multiple-outcome benches and two single-outcome exhibits were selected for the study.

Definitions and Limitations

Throughout the remainder of this report, the term "lab" will be used to refer to the three selected Experiment Benches. The term "exhibit" will be used to refer to the two stand-alone exhibits. The term "unit" refers to the five exhibit units regardless of whether they were labs or exhibits.

Because of the high number of visitors who come to museums as members of a social group, one of the goals of the Experiment Bench project was to design units that respond to the specific dynamics of social groups. In accordance with other research literature, the term "group" will be used to describe visitors as defined below.

> *Each individual visitor to the [unit] was defined as being a member of a group even if that group consisted of only one member. Most groups contained more than one member. The members of the group were defined as only those individuals who approached the [unit].* (p. 128, Perry, 1989)

Included in this report are many quotes from visitors. In selecting quotes to use, ones were chosen that exemplified the point to be made, in the clearest manner. The number of quotes following each theme is not an indication of how many visitors expressed the sentiment. It is merely an indication of how many visitors expressed it succinctly. At the end of each visitor quote is a number referring to the group. It is preceded by a letter according to Figure 1. For example, (E143) refers to group #143 who visited the Electricity Bench.

Electricity Bench	E
Optics Bench	O
Pendulum Bench	P
Spectrum Window	S
Waves on a String	W

Figure 1 -- Abbreviations used for unit names

Research Methods

A research methodology that was open-ended and naturalistic was chosen due to the type of data sought. The emphasis of this study was to capture the visitors' experiences, concentrating on rich and detailed descriptions.

This report describes a range of behaviors rather than the percentage of people that acted in a certain way. As is typical of this kind of study, we were looking for trends rather than absolute truths. In conducting this type of evaluation, we rely on multiple sources of information. Taken together, data that is confirmed from a variety of sources tends to be stronger than that which is evidenced from only one source. In this type of research, all data becomes important, including visitor comments, visitor behavior, the data collectors' comments, and the evaluator's perceptions. Particularly useful information is that which describes the experience in visitors' own words.

Research Questions

The Experiment Benches at the Science Museum of Minnesota were designed to engage visitors in meaningful scientific thinking by providing them with appropriate apparatus and some direction in the form of activity cards. More specifically, we were interested in finding out about the following five issues.

1. **Time**. The more time people spend at an activity, the greater the likelihood that the experience will be a meaningful one. In addition, research indicates that the length of time a visitor spends at an exhibit is an accurate predictor of how much they learn at that exhibit (Falk, 1983). Because of this correlation between time at exhibit and learning, we were interested in finding out if there was a difference in the amount of time visitors spent at labs compared with how much time they spent at exhibits.

2. **Experimenting Behavior**. Time is only a partial predictor of the meaningfulness of a museum experience. It has been shown that when the length of time a visitor spends at an exhibit is combined with what they do at that exhibit, it is a more powerful predictor of the meaningfulness of the museum experience (Falk, 1983). More specifically, we were interested in the degree to which visitors engaged in experimenting behavior. Did they do more experimenting at labs than at exhibits? What kinds of experimenting did they do? Did they progress systematically through all the stages of experimentation, or did they randomly and haphazardly engage in different aspects of experimentation?

3. **Social Interactions**. It is increasingly shown that learning in museums occurs to a large extent as a result of meaningful social interactions (Diamond, 1986; McManus, 1987; McManus, 1988; Perry, 1989). The Experiment Benches were designed to address the social aspects of the visitor experience. At the labs we were interested in examining the effect of the labs on social interactions. Was there more quality social interaction at labs compared to exhibits? Was there cooperative learning, or did some visitors become observers while others interacted?

4. **Frustration/Intimidation**. Because of the open-ended nature of the labs, the exhibit development team was particularly interested in whether or not visitors were able to experience a sense of accomplishment and success, or whether it was more difficult to succeed, resulting in increased frustration. There was also some concern that the technical and scientific-looking apparatus and the scientific phenomena itself made visitors feel more intimidated about science than simpler, more straight-forward single-outcome exhibits. Did visitors feel more frustrated and intimated at labs than at exhibits? What were some of the sources of frustration and intimidation?

5. **Enjoyment and Learning**. As with most summative evaluations, the exhibit development team was interested in how much visitors enjoyed the labs and the kinds of learning outcomes they realized. Did visitors to the labs have a good time? Did they learn useful things? What kinds of things did they learn?

METHODOLOGY

The Exhibits

As described above, three labs and two exhibits were selected for this study. Each unit was selected because the exhibit development team agreed that it represented the best in labs and the best in exhibits respectively. The three labs were: the Electricity Bench, the Optics Bench, and the Pendulum Bench. The two exhibits were: Waves on a String and Spectrum Window.

- **Electricity Bench**. At this lab, visitors connect different electrical components together in a circuit to discover what they do and how they behave. Included in the lab are resistors, LED's, diodes, lamps, small motors, and switches.

- **Optics Bench**. Visitors to the Optics Bench construct a telescope, slide projector, a microscope and other optical devices. Different lenses, screens, and images can be put together in various combinations to explore reflection, refraction, translucence, and focal length.

- **Pendulum Bench**. This lab consists of a pendulum of variable length and/or weight connected to a computer. By changing the lengths and weights of the pendulums, the visitor uses the computer to plot various graphs and data tables of the different pendulum swings.

- **Waves on a String**. At this exhibit a visitor plucks or bows a cello string. A beam of light projects the shadow of the vibrating string to a rotating mirror which then "draws" a picture of the vibrating motion.

- **Spectrum Window**. At this exhibit the visitor makes a large sheet bubble and watches colors swirl as an overhead light is turned on and off.

The Data Collectors

Seven data collectors were hired. All of them were undergraduate students enrolled in a Museum Studies class taught by a Science Museum of Minnesota anthropologist. They were familiar with the museum prior to their participation in this study.

In addition to on-the-floor experience acquired as part of class assignments, training for this project consisted of an all-day workshop and repeated on-the-floor observation and interviewing practice.

Data Collection

Data was collected during twelve separate sessions on weekends from November 13, 1993 through December 5, 1993. Total data collection time was approximately 46 hours for the five units. Each unit was studied on at least two different occasions. Data collection was identical for all five units. During each session two data collectors—one observer and one interviewer—were assigned to a particular unit. A typical data collection scenario follows.

As a visitor group approached a unit, the observer used an observation form (see Appendix A) to assign a number to the group and record the group's composition. The group was then observed for the duration of their visit to that unit. During that time the data collectors noted the group's amount and quality of social, intellectual, and physical interactions. Brief notes were taken.

When the group left the unit, the observer recorded the amount of time they spent, and assigned a 1-5 numerical rating to each of the three types of interactions (see Appendix B). Observation data was collected on all groups that visited the unit during the data collection session. If groups overlapped, data was still collected on them. In these cases some of the time-at-unit data was at least partially estimated.

When the group left the unit, the interviewer approached and asked them to participate in a ten minute interview. They were taken to a table and engaged in a tape recorded in-depth open-ended interview (see Appendix C). Often these interviews lasted longer than ten minutes. When the interview was concluded, the group was thanked for their time and the data collector filled out a "debriefing form" (see Appendix D).

Usually one person of the group would become the sole or at least primary spokesperson for the group. Sometimes this individual would attempt to include other members of the group in the interview. This was particularly the case when an adult would try to draw a child in. Some of the interviews were conducted with individual children. The ages of the participants in the interviews ranged from about three years old to senior citizens.

After completing the debriefing form, the interviewer returned to the unit and began observing the next group in preparation for the next interview. A total of 602 groups were observed. Of these, 66 groups were interviewed (see Figure 2).

name of unit	interviews	observations
Electricity Bench	16	89
Optics Bench	10	88
Pendulum Bench	18	120
Spectrum Window	12	133
Waves on a String	10	172
Total	*66*	*602*

Figure 2-- Number of interviews and observations by unit

Forty-seven of the interviews were tape recorded and later transcribed. After all data was collected, a final three-hour group debriefing session was held with six of the seven data collectors, the evaluator, and the in-house evaluation coordinator for the project.

Data Analysis

Data were analyzed both quantitatively and qualitatively. Quantitative analysis consisted of performing standard numerical calculations (Hopkins & Glass, 1978). Qualitative analysis consisted primarily of constant comparison (Guba and Lincoln, 1985). Frequency distribution data were analyzed graphically (Fitz-Gibbon & Morris, 1987).

RESULTS AND DISCUSSION

Time

Time-at-Unit

Detailed time-at-unit data is located in Appendix E. A summary of these findings is presented in Figure 3.

name of unit	mean	median	mode	range	% > 4 mins
Electricity Bench	4.2 mins	3.2 mins	2.0 mins	0-19 mins	46%
Optics Bench	2.8 mins	2.0 mins	1.0 mins	0-11 mins	29%
Pendulum Bench	2.8 mins	2.2 mins	1.0 mins	0-10 mins	27%
Spectrum Window	1.7 mins	1.4 mins	1.0 mins	0-6 mins	11%
Waves on a String	1.7 mins	1.4 mins	1.0 mins	0-5 mins	4%

Figure 3 -- Time at unit

As can been seen from the data, the average (mean) time-at-unit appears to have been greater for the three labs than for the two exhibits. As has been shown in museum literature, the average amount of time spent at a museum exhibit can be a misleading figuring because of the accompanying implication that this figure represents a fairly typical visitor. In fact, this is often not the case. Falk (1981) has shown that many museum visitors spend very short times, and a few visitors spend very long times. When averaged out, the resulting figure often represents an amount of time that relatively few visitors actually spend.

In looking at the median scores, we can see that 50% of visitors spent less than a certain amount of time, and 50% spent more than that. The median scores are an additional way of documenting that visitors to the labs appear to have spent greater amounts of time than the visitors to the exhibits.

What is perhaps the most interesting however, and perhaps more illuminating of the visitor experience in general, is the percentage of visitors who stayed at the units for at least four minutes. This ranged from more than a quarter at the Optics Bench and the Pendulum Bench to almost a half at the Electricity Bench. Compare this to one in twenty at Waves on a String and one in ten at the Spectrum Window.

Another interesting finding is the range of visit length. Most visitors to the units regardless of whether they were labs or exhibits stayed relatively short periods of time; the Electricity Bench was the only unit at which the most frequent length of stay (mode)

was more than one minute. However, it is apparent from this data, that for those visitors who wanted to invest more time and energy and have a more meaningful experience, the labs provided this opportunity. The longest anyone stayed at an exhibit was six minutes. The longest a visitor stayed at a lab was 19 minutes. All three labs had visitors stay for longer periods of time than any visitor stayed at an exhibit.

Visitor Density

Museums constantly struggle with the dilemma of providing an in-depth experience for fewer visitors vs. providing a more superficial experience for many. At each unit, there is a maximum number of visitors that can comfortably use it at any particular time. There is also some research to indicate that the lower the visitor density at an exhibit (i.e. the fewer number of groups during a particular period of time) the longer visitors tend to stay (Perry, 1989). Figure 4 compares the visitor density among units during the observation times.

name of unit	average # of groups per hour of observation	average # of minutes per group
Electricity Bench	7.2	8.1
Optics Bench	11.4	5.2
Pendulum Bench	10.8	5.5
Spectrum Window	18.6	3.2
Waves on a String	21.0	2.9

Figure 4 -- Visitor density at units

As can be seen from the data, the labs had fewer visitors per hour than did the exhibits, with the Electricity Bench having the lowest visitor density of all. This data corresponds quite closely with the amount of time visitors spent at each unit; the longer visitors spent at an unit, the less frequently it was visited.

Window Shoppers vs. Buyers

Visitors to a unit, tend to fall into two broad categories, those who choose not to spend time or to interact with it, and those who do. We can think of these two types of visitors as window shoppers, and buyers (Falk, 1981).

All units in this study—regardless of whether they were labs or exhibits—tended to experience the same ratio of about one and a half buyers to every window shopper. The exception was visitors to the Spectrum Window which experienced more than six buyers to every one window shopper (see Figure 5).

name of unit	ratio
Electricity Bench	1.43:1
Optics Bench	1.53:1
Pendulum Bench	1.71:1
Spectrum Window	6.33:1
Waves on a String	1.48:1

Figure 5 -- Ratio of groups who invested time to groups who didn't

This might be explained in part by the location of this exhibit. Unlike the rest of the units which are out in the open, the Spectrum Window is set back in an alcove. In order to see it at all, a visitor has to go out of their way. It might also be because the primary interaction at this unit is to look at colors swirling around on a bubble. It is very easy to become a participant even when there are many other visitors crowded around. Additionally, the colors are quite attractive.

Summary of Time Data

Although time-at-unit cannot be the only indicator of a successful and meaningful experience for a visitor, one of the goals of the labs is to provide the opportunity for the visitor to spend more time if they wish. It appears that particularly with the Electricity Bench, the exhibit development team was successful at designing a unit that increased the time-at-unit for at least some of the visitors.

However, given the long times overall that visitors spent at the Electricity Bench, it is somewhat surprising that visitors did not spend as long at the Pendulum Bench and the Optics Bench. Visitor comments about their ability to a) understand the point of the exhibit and b) experience success at the tasks, may help us understand this. These issues will be discussed in more detail below.

Visitor Interactions

As described above, visitors were assigned ratings to describe the quantity and quality of their physical, intellectual, and social interactions. The ratings indicated increasing degrees of interaction (see Figure 6). The rating scale for all five units was identical regardless of whether the unit was a lab or an exhibit.

In conducting the data analysis, we were looking for two specific trends. First, we wanted to see if there were more four and five ratings at the labs compared to the exhibits. This finding would indicate more sophisticated use of unit components, more meaningful social interaction, and higher levels of intellectual engagement.

0 no interaction
1 minimal
2 some but inadequate
3 minimally successful, baseline
4 good, solid interaction
5 exceptional

Figure 6 -- Rating scale for quality of interactions

Second, we thought there might be flatter looking frequency distribution graphs at the labs. This would indicate a wider range of visitor behaviors. The detailed results and frequency distributions can be found in Appendixes F and G.

Sophisticated Interactions

As described above, four and five ratings indicated more sophisticated engagement with the unit. In looking at just the groups that demonstrated sophisticated interactions with the units—i.e. those groups that received a rating of either 4 or 5—it can be seen that the labs appeared to elicit more sophisticated engagement with the units than did the stand-alone exhibits (see Figure 7). The data indicates that about one quarter of the groups to the labs interacted very meaningfully—physically, intellectually, and socially—whereas fewer than a tenth of the visitors to the exhibits did.

type of interaction	exhibits	labs
physical interaction	8%	28%
intellectual interaction	7%	22%
social interaction	9%	25%

Figure 7 -- The percentage of four and five ratings

Range of Behaviors

One of the assumptions underlying this study was that if a unit can be designed in a certain way, it will give visitors the opportunity to engage in a wider range of more meaningful behaviors, i.e. instead of most visitors interacting in one particular way, there would be more variety of behaviors. This would be indicated by flatter frequency distributions.

As can be seen from the charts in Appendix G wider ranges of behavior were observed at the labs than at the exhibits. There was less homogeneity in how people interacted. This indicates that visitors to the labs who wanted to interact in more meaningfully ways, were able to.

The Ceiling Effect

From the data it appears that visitors to the exhibits ran up against a ceiling effect; they were virtually unable to interact much beyond a three and definitely a four. There was one group who did achieve a five rating (in social interaction) at the Spectrum Window. This worked out to less than half a percentage point and was dropped due to rounding. It appears that the labs were more successful at eliciting sophisticated manipulation of the exhibit components, high levels of intellectual engagement, and meaningful social interaction than were the exhibits.

Basic Success

As described above, a rating of 3 indicated that visitors had achieved a minimal level of success. It is interesting to compare the percentages of visitors to the units who achieved at least a three rating (see Figure 8). With the exception of social interaction, it appears that the units and labs were about equally effective at stimulating baseline successful interactions.

type of interaction	exhibits	labs
physical interaction	62%	59%
intellectual interaction	47%	53%
social interaction	33%	50%

Figure 8 -- Percentage of visitors who were rated >2

The difference in social interaction between the exhibits and the labs appears to indicate a trend toward more meaningful social interaction at the labs. However, it is interesting to note that even though social interaction appears to be more sophisticated at labs than exhibits, only 50% were able to be minimally successful, compared with only a third at exhibits.

No Interaction

Another interesting result of the visitor interaction data was the percentage of visitors who received 0 ratings (see Figure 9), an indication that they did not interact at all.

In the absence of more sophisticated statistical analyses, it isn't clear whether there is a difference between the labs and exhibits. However, there is some indication that more visitors to the labs stand by and do not interact. This is an interesting finding and requires

further investigation to see if it is the case. It might indicate individual ownership of an experiment in progress.

type of interaction	exhibits	labs
physical interaction	2%	5%
intellectual interaction	2%	6%
social interaction	5%	11%

Figure 9 -- Percentage of visitors who were rated 0

Another interesting finding from this data is the relatively high percentage of visitors to the labs that do not engage in any social interaction. This figure includes only those visitor groups comprised of more than one member, and consequently cannot be explained by an individual user. It might indicate visitors who are not sure of how to interact with each other given the different type of unit than they are used to, or it might reflect increased feelings of intimidation with the content and apparatus at the labs.

Experimenting Behavior

For the purposes of this study, experimenting behavior was defined as: playing with the apparatus, hypothesis making, designing and setting up experiments, observing results, making comparisons, and forming conclusions. Visitors were observed at all units engaged in at least some of these experimenting behaviors. Although this study did not set out specifically to quantify experimenting behavior, we did look carefully for trends to determine the kinds of behaviors visitors engaged in.

An analysis of the visitor interview comments indicated that many groups participated in experimenting behavior regardless of whether the unit was a lab or an exhibit—although visitors articulated this much less frequently about their visit to the Spectrum Window. This is likely due to the "less scientific" nature of the Spectrum Window. Visitors tended to comment more about observing the beautiful colors, and perceived the exhibit as primarily an aesthetic experience.

Most of the experimenting behaviors visitors described were playing, observing, and making comparisons.

> *It's interesting to move the lenses and change the lenses...especially that first one with your fingers and [it all comes] into view. That was neat. (O406)*

> *I was just trying to figure out...what would happen if I did this. Okay, what if I tried this? [I was trying] to see what would happen. (E177)*

I like watching the different wavelengths and how the amplitude and the time changes as you change pitches and change the intensity of the sound. (W386)

I was trying to get the capacitor to work. I don't know exactly what you're supposed to do with it. (E156)

At the Spectrum Window it was much more likely that a visitor would state they were just enjoying the beautiful colors, although the data collectors' comments from their observations revealed that they did in fact engage in some experimenting behavior.

I was just thinking that it was really, really pretty, that I would like to paint something like that. (S5017)

It's just fascinating to watch the colors move, either with wind or basically on their own. [It was also interesting to see] how the light affects the colors. (S5004)

While there was a large amount of data indicating visitors participated in certain experimenting behaviors—noticing cause and effect relationships, making comparisons, and observing results—there was less indication of more sophisticated experimenting behavior such as developing and testing hypotheses, and designing and setting up experiments. The units at which this more sophisticated experimenting behavior occurred were almost exclusively labs.

I was thinking that if I changed the position of the weight, that it would change maybe the speed that the pendulum swang at, or the degrees that it swang at...I didn't stay at the exhibit long enough to figure out what those changes were. (P710)

I thought the amps would go all the way up, except instead of that it went all the way down, to minus five. (E162)

I kinda knew what I should see...if I change[d] the lengths of the pendulums and where the weights are positioned and where the starting angles are. I still liked doing it anyway, even though I knew what the results were supposed to be...Basically it fell out the way I expected. (P297)

The picture was showing it towards the back, so I had it toward the back, but then it wasn't focusing. We weren't seeing anything on the screen. So then we thought well maybe if we turn the light we'll get a different projection. (O462)

Although specific data were not collected on how many different experimenting behaviors were exhibited by a particular group, or how many experiments were designed and set up

at each of the units, given the greater times visitors spent at the labs combined with the observation notes and interview comments, it appears that visitors attempted a greater number of experiments at the labs than at the exhibits. In addition, these experiments appeared to be more sophisticated in nature, including a greater number of variables, and more thoughtful design. This was particularly noticeable at the Electricity Bench.

Visitor Outcomes

Learning

Learning at museum exhibits is evidenced in many different ways. Some visitors make personal connections to the scientific concepts. Many articulate thoughtful questions they are thinking about as they leave the unit. Others clearly state things that they feel they have learned.

In this study, it appears that visitors learned things at all five units regardless of whether or not they were labs or exhibits. A summary of visitors' recollections of what they learned at each unit is included in Appendix H.

An analysis of the interview data suggests that the visitors to the labs may have had more meaningful learning outcomes than visitors to the exhibits. Some of the learning outcomes described by visitors to the exhibits included such things as learning that there are colors in bubbles, or that bubbles can be big.

> *[I learned] how strong [soap] film can be. (S5039)*

> *[I learned] that when you pluck it, it makes different vibrations from the bow to the plucking. (W311)*

Visitors to the labs on the other hand tended to describe their learning in more scientific terms, for example stating that they learned how to make a telescope, or that they learned about light projection.

> *[I learned that] the weights balance each other so that it goes on for a long time. (P230)*

> *[I learned] that if you connected almost every kind of thing that it would still work. Of course you only really needed like one resistor, and a copper wire. (E156)*

A few visitors in particular appeared to have especially meaningful experiences at the labs. Following are excerpted versions of interviews with two individuals who spent time at the Optics Bench and the Electricity Bench respectively.

I liked [the Optics lab] because I was planning on making my own pin-hole camera. I was experimenting with this to see if the focal length made any difference. Apparently it doesn't. I think the most important thing is the size of the hole itself. [At this point the respondent took the interviewer over to the bench and explained how he figured this out. Then he started talking about the lab again.] Everything is right here. You have a complete assortment of lenses, lights, screens...[When I walked away from the lab I was thinking about] how I'm going to make this camera. I have some unanswered questions. They regard the interference patterns that might be created in a pin hole. I had interference patterns on this device. [I had thought about interference before, but the lab didn't help me figure it out. Maybe the lab could include] a little demonstration on interference patterns, why they occur. (O484)

[These are notes from the data collector's notes. There is no transcript due to a malfunctioning tape recorder.] Fifth grade student. He was very interested, trying everything, hypothesizing out loud, explaining, looking for the right pieces. He obviously grasped the point of the exhibit—he knew why it worked and why it didn't, he knew what each piece was called and what part it played. He understood how to arrange things to achieve the desired result, and he could explain to others. He used every piece. I think he felt very empowered. He encountered some difficulties but you could hear him reason things out. During the interview he said that he had learned how to set up a circuit and that he had "made a lot of things go." He also learned that in order for things to work, "both ends have to touch." He said he liked it because it "really helps you learn." This was at least his second time to the lab. (E129)

Enjoyment

A review of the interviews reveals that visitors were overwhelmingly positive about all five units. Comments included it was fun, it was neat, I liked it, it's cool, it was good, etc. This type of response is very typical among museum-goers and yet indicates overall feelings of satisfaction.

One specific comment visitors frequently made was how much they liked being able to see something that they had previously only read about in text books.

That's one reason that I like it so much...I do like just seeing these theories actually work in front of me. (P297)

[This unit] had a very cool way of showing how the different waves went through. (W395)

[At this unit we can] see some practical applications of what we've been getting out of the book. You know, you can tell someone what a wavelength is, but to be able to see it...It's interesting to see it in action, that's for sure. (W802)

I see it in the book of science, in the physics book, but seeing my eyes, very interesting...Best way to understand science is by seeing. (O452)

Positive comments about a museum experience is very typical among museum-goers. Although nice to hear, these comments often provide little useful information to exhibit developers about what visitors really enjoyed. Research data suggests that in order to enjoy a museum visit, visitors need to experience six affective variables: curiosity, challenge, confidence, control, playfulness, and communication (Perry, 1989).

A more thorough analysis of the interview data revealed visitor comments specifically relating to control, curiosity, play, and confidence.

Control

Visitors to the labs in particular commented on how they liked being able to do a variety of activities, and to be in control of the experience.

[This unit] is funner than the other ones. [At this unit you can make] what you want instead of doing [something that's been] all set up before...You could just keep doing whatever you wanted with it. (E148)

It's really neat because it has the computer, and you can change anything, and you pretty much have all the control. (P284)

People can actually go at their own pace, and control what's going on. [It] makes it...a little more meaningful. (O439)

There were no similar comments made by visitors to the exhibits.

Play

Another important component of successful museum units is that visitors experience a sense of playfulness. A number of visitors described that they enjoyed playing at the labs.

İ liked the way it's hands-on. You can move it around and change it...It was very self-explanatory...It's easy to switch stuff around and play with it. (E177)

I like playing with science things. (E156)

Curiosity

Visitors to all units commented on how much they enjoyed the unit because something at the unit was surprising, or new.

It did things I didn't expect it to do. (S5034)

It's something you don't see anywhere else. (S5039)

I thought it was interesting that the picture gets turned upside down. (O406)

Although most visitors indicated that they felt the units were really interesting, some stated that they were bored.

I don't know. A lot of the exhibits, they're sort of the same...I guess it's boring. (P230)

It wasn't all that exciting for me. (S5017)

Safety

A few visitors also specifically commented on how they appreciated being able to use components that won't break, and to be in a safe environment.

It's the hands on experience that I think is really important in being able to see how things work; something that has good solidity, that's not breakable. (O465)

You could touch stuff without getting electrocuted, so if someone doesn't know anything about it they're not so afraid to try it out. (E185)

Frustration and Intimidation

Some visitors also expressed feelings of intimidation or frustration. Although this occurred at all units, it appeared to be more prevalent at the labs compared to the exhibits. Most of these feelings seemed to stem from one of three causes, a) the visitor was unable to figure out what they were supposed to do, b) they were unable to successfully complete a task or c) the unit did not answer some basic questions the visitor had.

I didn't really know how to work it. (P254)

[That unit was] a little over the head. [I was wondering] how come you can get some things to work good and other things you can't get to work. (E181)

I was trying to get the capacitor to work. I don't know exactly how you're supposed to use it. I can't figure out why it's not working. (E156)

Why is the hand projected upside-down? Why isn't there an answer? (O462)

How does the fan spin? And how does the power saver save power? (E140)

I didn't see anything that used a diode...One of the parts there is a diode, and it didn't show how to use it. But the other ones all had it. (E185)

Only one person expressed frustration at the Spectrum Window, and that was because the solution was old and they could not make a bubble. A few visitors to Waves on a String expressed frustration because they felt it was difficult to understand.

It's hard to figure out at first. My mom came over and showed me how to do it. (W395)

You could sit there forever and try to figure out what it is. (W802)

A number of visitors either mentioned or were observed having trouble with the information/activity cards in the labs.

It was a little difficult...It took...too long to figure out. If I had my own time, it might be interesting...It's a good thing [the cards are] here to explain what's going on. Not that I figured it out... (P235)

Older visitors

We did not collect data specifically on older visitors (grandparents, senior citizens) but the data collectors' comments and an analysis of the interview transcripts indicated that as a group older visitors tended to be somewhat more intimidated than younger visitors. Generally speaking, it was more difficult to get them to answer questions during interviews, and they tended to be much more passive in their interactions. This might be an interesting phenomenon for further study by the Science Museum of Minnesota.

Effect of Fences and Sign-up sheets

Again, specific data was not collected about the effect of the fences or sign-up sheets. However, during the final data collector's debriefing session, they had a lot to say. The general consensus was that both the sign-up sheet and the fences created a barrier to the use of the labs.

> *I think people were really intimidated by [the sign-up sheet]. I think they would look in the Pendulum lab and be like, do we want to commit ourselves to 20 minutes playing with that? No. (data collectors' debrief)*

> *I also think that the little enclosure is kind of a commitment in itself. To actually have to enter that space was kind of intimidating. (data collectors' debrief)*

> *[Ten or maybe 20 percent of the people who didn't go in, didn't go in because of the sign-up sheet.] I overheard a number of people say "oh look, a sign-up sheet. I don't know if we're supposed to..." (data collectors' debrief)*

One visitor talked about the confusion created by the sign-up sheet.

> *I read...that it was a twenty minute experiment that you could do. I wonder how a person would go about doing that experiment?...I wasn't sure what that was all about. Is somebody supposed to sit at that for twenty minutes and just change the weights in increments? (P710)*

At the same time, at least one data collector stated that the sign-up sheet was a good idea. They made a few specific suggestions such as putting a smaller time limit on it, perhaps ten minutes.

Effectiveness of the Labs

In looking carefully over all the data, and reviewing the data collectors' debrief session, it appears that the Electricity Bench was the most successful of the labs, then the Optics Bench, followed by the Pendulum Bench.

Visitors stayed longer at the Electricity Bench than either of the other two, and were observed engaging in more thoughtful experimenting behavior. They appeared able to complete more experiments. In addition, the data collectors appeared to feel strongly that the Electricity Bench was the most effective of the three.

On the other hand, the Pendulum Bench appeared to be the least well-liked or understood. Many visitors expressed frustration at not being able to understand what the unit was

about. It was sometimes described as very abstract. The two groups for whom the Pendulum Bench worked very well turned out to be a pair of college mechanical engineering majors (P235) and an individual with "a couple of degrees in science" (P297).

One way of thinking about a particular unit is that the visitor has to overcome two primary obstacles in order to be successful. The first is figuring out what they are supposed to do, and the second is successfully doing that.

It appears that at the Electricity Bench, visitors readily understood what they were supposed to do—follow the instruction card and build a complete circuit—and it was relatively easy to do so. It was also very clear when they had succeeded—the light came on.

At the Optics lab, many visitors understood they were supposed to follow the instructions and to project the image of their hand, but it was more difficult for them to be successful. The directions appeared more difficult to follow, and it was easier to have something "not quite right." The indicator of success—seeing the image projected—was relatively clear, and very impressive. At the same time however, a number of visitors expressed feelings of frustration because they did not understand why the image of the hand appeared upside down. In addition, even if they completed the first demonstration, visitors were often unable to complete any subsequent experiments.

At the Pendulum Bench, it appeared that a number of visitors could not figure out what they were supposed to do. When they did try some different things, they were not clear if they had been successful or what they were supposed to be noticing. Many liked the computer, but a number did not appear to understand how to use it, and/or they could not interpret the graphs.

One way of describing the success of the labs is to think in terms of three levels of success:

1. I get what I am supposed to do and I am successful.
2. I get what I am supposed to do, but I am not successful.
3. I don't get what I'm supposed to do. I may or may not be successful at doing something.

Although there were many individual exceptions, it appears that the first statement characterized many visitors to the Electricity Bench, the second statement described visitors to the Optics Bench, and the third, visitors to the Pendulum Bench.

SUMMARY

Visitors spent substantially longer periods of time at the labs than they did at exhibits, and while in the labs, appeared to engage in more thoughtful and purposive experimenting behavior. At the exhibits, experimenting behavior tended to consist of playing, observing, and making some comparisons; at the labs visitors engaged in those experimenting behaviors as well as making hypotheses, manipulating variables, designing and setting up experiments, and forming conclusions. No visitors described or were observed to engage in a systematic, step-by-step, progression through all the stages of experimentation.

There appeared to be a wider range of social interactions at the labs than at the exhibits. Data collectors recorded more instances of meaningful social interactions at the labs than at the exhibits and fewer instances of mediocre social interactions. There was evidence of visitors working together on problems, or one visitor taking on a teaching or guidance role. Surprisingly however, in spite of the labs being specifically designed to enhance social interactions, more than one in ten visitor groups to the labs engaged in no social interaction whatsoever. This implies that some members of the group were watching the activity of another, or perhaps individuals were working side by side but not talking. This lack of social interaction might be due to the highly personal nature of "experimenting". It could also result from visitors feeling less capable of engaging in a cooperative scientific process.

Many visitors chose to remain in the labs after some initial baseline success and set up their own experiments, sometimes hypothesizing out loud about what they were doing. They frequently talked about the sense of control that they felt and that they appreciated that they could go at their own pace and "do their own thing".

At the same time, many visitors also indicated feelings of intimidation and frustration. They appeared to want to pursue further activity, but could not, either because they got stuck on an unanswered question, they weren't sure what they were supposed to do, or they felt the concepts were beyond them.

While learning is difficult to measure directly in a museum environment, there were many indications that visitors learned at and enjoyed the labs. Visitors repeatedly praised the labs in terms of how much fun they were, and described many and varied learning outcomes, some very personal and of significant importance.

CONCLUSIONS

The detailed data collected in this study allowed us to get a glimpse into the visitor experience at the Experiment Benches. In particular we saw that the labs were effective at engaging visitors for longer periods of time than other successful museum exhibits and in ways that often resulted in more experimenting behavior. Learning at the labs was often idiosyncratic and personal, and visitors were able to socially interact in meaningful ways. While some visitors expressed frustration at not being able to figure out what they were supposed to do, or not being able to do it, visitors on the whole overwhelmingly indicated that they enjoyed themselves and had a good time. Many visitors perceived that these were labs where they were in control, could go at their own pace, and explore what they wanted.

As the museum profession struggles with serving the needs of our audiences, promoting the public understanding of science, and encouraging positive attitudes towards science, we are repeatedly faced with developing creative ways to motivate, challenge, and engage our visitors.

The Science Museum of Minnesota has taken interactive exhibitry a step further by creating a series of labs that are quite successful at engaging museum visitors in more thoughtful and meaningful multiple-outcome experiences. While opportunities to engage with scientific apparatus and phenomena in a safe environment are unfortunately not that abundant, the Experiment Benches allow visitors to have in-depth experiences with the stuff of science.

RECOMMENDATIONS

1. *Have a senior citizen's lab day or evening.* Many of the older visitors demonstrated that they felt particularly intimidated by all the science and technology. They often didn't appear to feel comfortable about just playing with the lab components. A "Get Serious About Playing" evening program targeted at senior citizens with many staff available, might encourage them to feel comfortable enough to bring their grandchildren back. This might also ultimately help to reduce the numbers of visitors who stand back and watch others experiment without getting involved themselves.

2. *Remove sign-up sheets to the labs.* There was strong evidence to suggest that the sign-up sheets created more of a barrier to the labs than an effective means of traffic control. As we are constantly seeking ways to make science less intimidating, it would be worth it to remove the sign-up sheets and observe visitors to see if they more readily enter the labs.

3. *Provide answers to visitors' unanswered questions.* Some visitors were particularly frustrated because they had questions that were not answered, for example why their hand appears upside down at the Optics Bench, or why the fan goes at different speeds at the Electricity Bench. Providing answers to these more frequently asked visitor questions will reduce levels of frustration and increase experimenting behavior.

4. *Try to increase social interaction.* On the whole, the labs elicited better social interactions than did the exhibits. While this is encouraging, it was also noted that one in ten visitor groups to the labs engaged in no social interactions at all. The reason for this is not clear, but could be because people aren't sure how to engage in cooperative learning and experimentation. Some guidance on the activity cards might be useful, such as "Talk to each other to figure out a different way to do this" etc.

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APPENDIXES

APPENDIX A

Observation Form

Observation Form

Exhibit: _____ Page _____ of _____

Observer: _____ Date: _____ Time Start: _____ Time End: _____

How many people/groups stop but don't stay for more than 15 seconds ("Window shoppers")? _____

Baseline criteria: the person stands in front of the Bench or interacts with the exhibit for more than 15 seconds.

Group #	# People	People: Gender, Age	Time Entered	Time Exited	Total Time	Physical Interactions (0-5)	Intellectual Interactions (0-5)	Social Interactions (0-5, na)	Comments

APPENDIX B

Guidelines for Scoring Interactions

Guidelines for Scoring Interactions

This set of guidelines will assist the observer to score visitors' interactions with exhibits.

This framework is based on the work of Deborah Perry. It is Perry's theory that visitors in museums interact with exhibits in these three ways. They touch, see, listen and walk over exhibits; this constitutes the **physical interaction**. Visitors also interact with an exhibit mentally--they think, they try to answer questions, they compare their models of phenomena with the museum's--this is their **intellectual interaction**. Finally, people intearct with each other in significant ways in museums. They compare notes, they point things out to each other, they strike up conversations with strangers; this constitutes their **social interaction**.

The task of the data collector is to score visitors to the exhibits in these three areas. On a scale of 1-5, how did the visitor interact with the exhibit? These interactions are difficult to observe, especially the intellectual interactions. To guide the evaluator, we have developed a set of guidelines. These guidelines will help you resolve questions about people you observe who are between scorings; it will also help us calibrate one observer to another. Please take a few quiet moments to read the guidelines, which appear on page 2.

Notes:

- Base your scores on the degree to which the visitor demonstrates a variety of the desirable behaviors, over some extended period of time, with some degree of persistence. The scores should *not* be based on whether or not a visitor exhausts the potential of that exhibit. The scores should be based on whether the visitor exhausts her or his potential at any exhibit. That's why you'll notice that a score of "5" always includes some comment about the visitor "bringing something of themselves to the activity." It's their potential we're interested in, not the exhibit's.

- Rate a group as if they were one person, as long as the people are paying attention to what the others in the group are doing. For example, if the two people in the group, combined, do all the physical interactions mentioned, give them a "5". The only exception to this is if the people are completely ignoring each other's actions; then rate only the main person.

- These three kinds of interactions are relatively independent. Someone can be a "5" in physical interactions, and not appear to learn or think about it at all; many young children will do this, in fact. But, it is more likely that if they interact significantly on a physical level, they will probably be interacting significantly intellectually, as well.

Guidelines for Scoring Interactions

Physical Interactions

Look for visitors that are....manipulating objects, pushing buttons, playing with objects, touching things, reading.

Score	Guideline
0	No interaction. Visitor stands and watches.
1	Only minimal interaction. Touches or does one or maybe two things; shows little interest.
2	Some but still inadequate interaction. Does a couple of things, but doesn't complete a task.
3	Minimally successful interaction. Spends minimum amount of time and completes one task.
4	Good, solid interaction. Spends a signficant amount of time and successfully completes more than one task.
5	Exceptional interaction. Uses multiple objects, in multiple times in multiple combinations. Visitors clearly bring something of themselves to the activity.

Social Interactions

Look for visitors that are....explaining things; directing attention; asking questions; pointing; reassuring; encouraging; guiding discovery; cooperating on a task; adapting interactions to age, interest level, or experience level of group.

Score	Guideline
na	not applicable. Only one person!
0	No interaction.
1	Minimal interaction. Very brief conversation.
2	Some but still inadequate interaction. Talks some, but doesn't help each other much. Maybe asks or answers one question, and ignores others. Misses opportunities. Talks down to, gives negative feedback. Explanations at too high a level.
3	Minimally successful interaction. Some good conversation, or working together. Maybe more one-way (teaching) kind of behavior than would be ideal...
4	Good, solid interaction. Both one-way and two-way communication. Some sense of physically working together, sharing duties (i.e., parent reading, child doing and listening).
5	Exceptional interaction. Everything in #4, just more of it. Good patience, good listening, sharing ideas, getting excited by each others' interest. Visitors clearly bring something of themselves to the activity.

Experimenting Behavior (Intellectual Interactions)

Look for visitors that are....thinking; manipulating objects systematically and purposefully; playing with objects; making hypotheses; setting up experiments; making comparisons (of one test piece or phenomena with another); observing results; developing theories.

Score Guideline:

0 No interaction. Stood there, hardly looked, Seemed to have other things on their mind.

1 Minimal interaction. Pushed a button, looked for reaction; when nothing happened, just left.

2 Some but still inadequate interaction. More persistence than 1, but still not much cognitive engagement. Was mindless about it; tried, but wasn't really thinking.

3 Minimally successful interaction. Does a cognitive task. Appears to notice cause and effect .

4 Good solid engagement. Compares different things, or searches for the "right" or a specific object. Sets up and tests a couple of experiments.

5 Exceptional interaction. Stays a long time. Is actively engaged in hypothesizing, setting up experiments, comparing, observing results, and drawing conclusions. Visitors clearly bring something of themselves to the activity.

APPENDIX C

Interview Form

Interview Form

Page _____ of _____

Date: _____ Time: _____ Interviewer: _____ Group #: _____

"We're trying to find out about this exhibit. Would you mind giving us your opinion by answering a few questions? It will take about five minutes. I will be taking some notes so I can remember what you tell me. May I also tape record it?" [If they ask, only Deborah Perry, the evaluator, will hear them, and no one will ever know their name.]

1. Is this your first visit to the Museum? Have you ever seen this particular exhibit before?

2. What do you think of this exhibit?

3. Rate this exhibit from 1 to 5 compared to other exhibits in this gallery. (1 = bad, 5 = excellent)
   Why did you give it that rating?

4. I noticed that you were doing _____. Can you tell me what you were thinking about while you were doing that?

5. Image you were telling a friend what this exhibit is about. What would you tell them, in one sentence?

6. What did you find out at this exhibit that you didn't know before?

7. When you walked away from this exhibit, what things were going through your mind?

8. What unanswered questions did you have?

9. That's all the questions I have. Do you have any questions or comments for me?

10. Thank you very much for your time!!!

APPENDIX D

Debriefing Form

Interview Debrief Form

Date: _____ Time: _____ Interviewer: _____ Group #: _____

This is the place to put **your impressions** of the group and your interaction with them.

A. Describe the visitor(s): Composition of group, age/gender/ethnicity, basic dynamics, etc.

B. What do you think they learned? (Include things that may not be related to the exhibit itself.)

C. How much did they appear to enjoy themselves?

Interview Debrief Form (con't)

D. How do you think they felt about being here? Specifically, did they feel either intimidated or empowered? Was there a balance between feeling confident and being challenged?

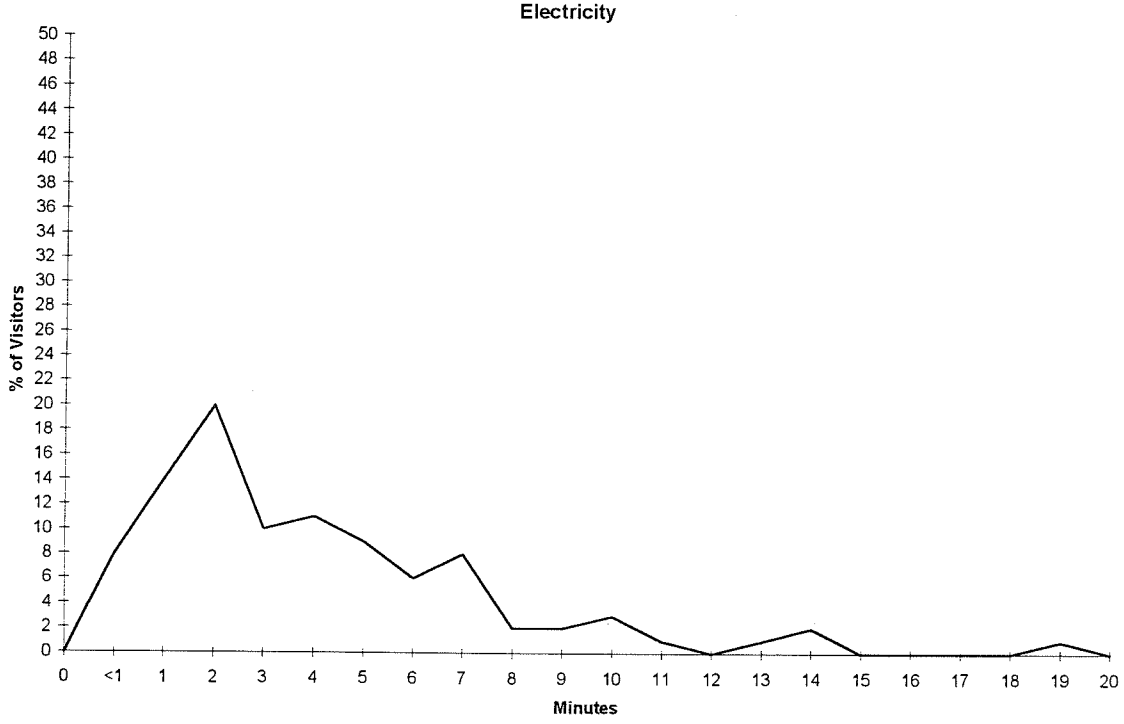
E. How engaged do you think they were in the scientific process: trying stuff out, comparing things, being curious, looking for causes and effects?

F. Other comments.....

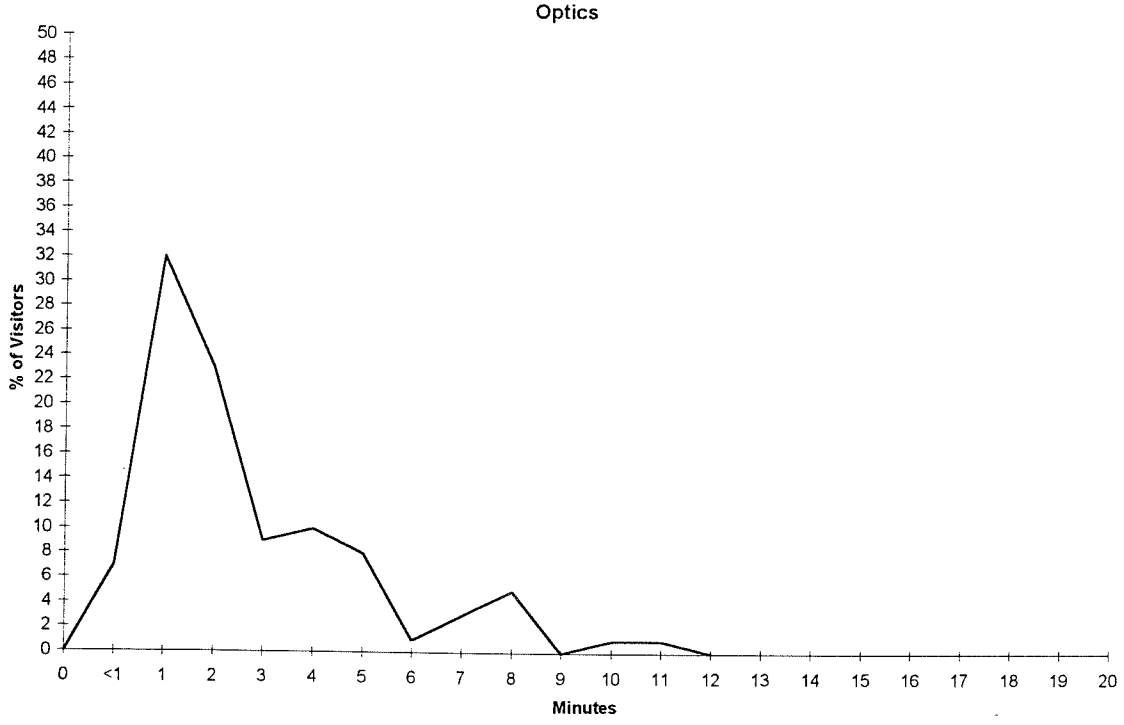
APPENDIX E

Time-at-Unit Frequency Distribution Graphs

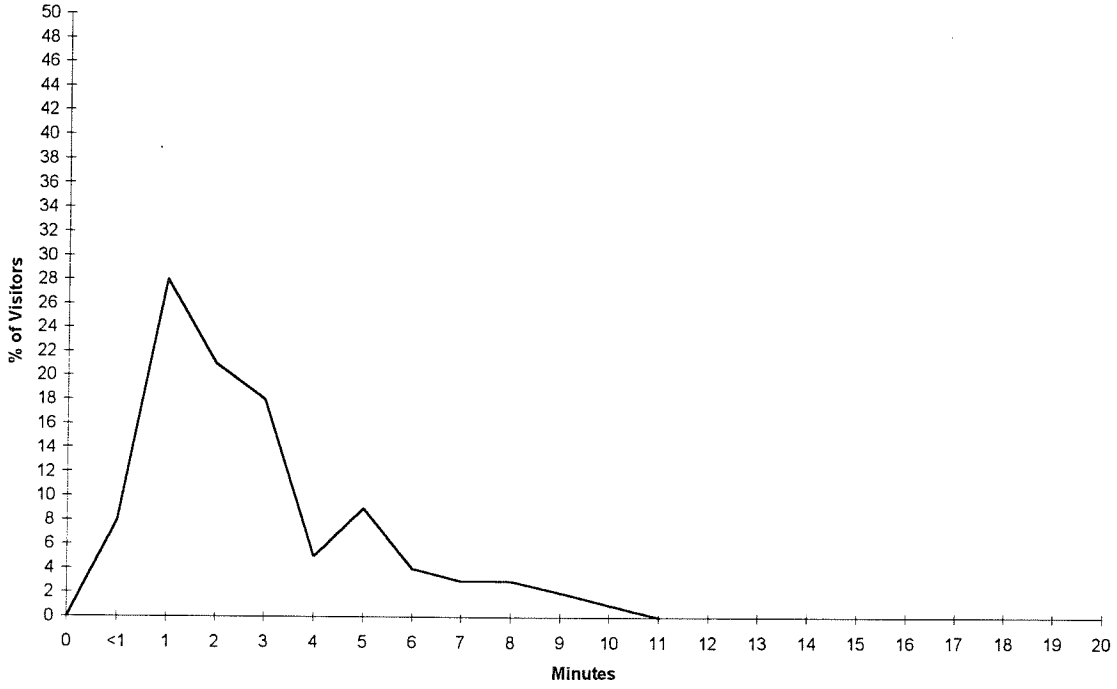
Time-at-Unit
Electricity



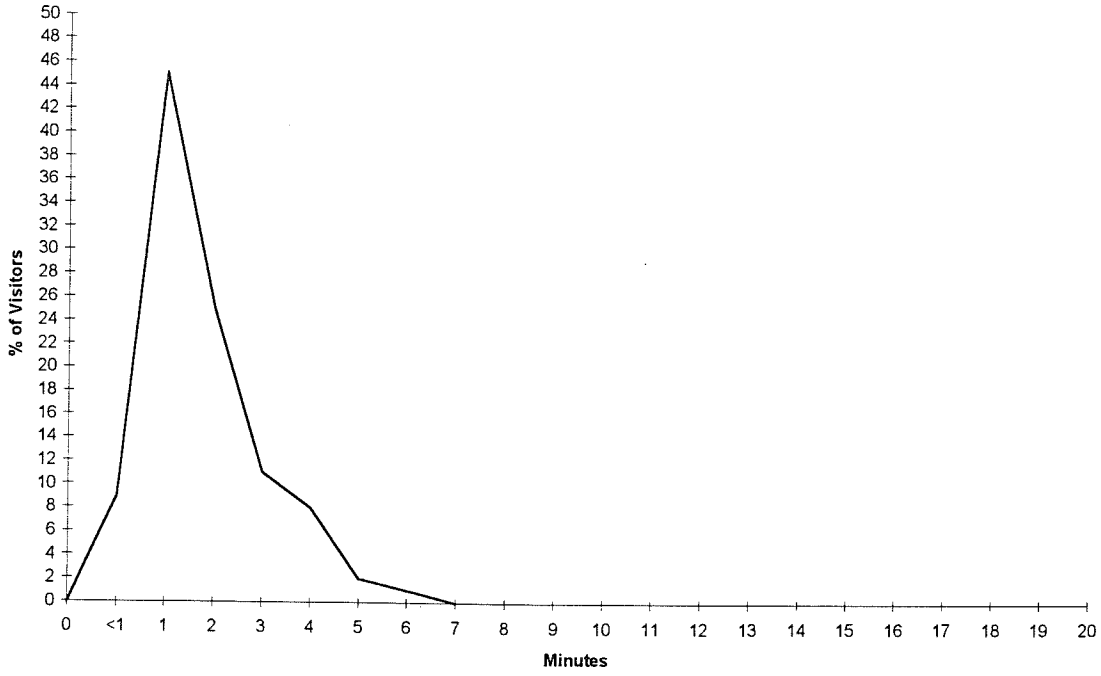
Time-at-Unit
Optics

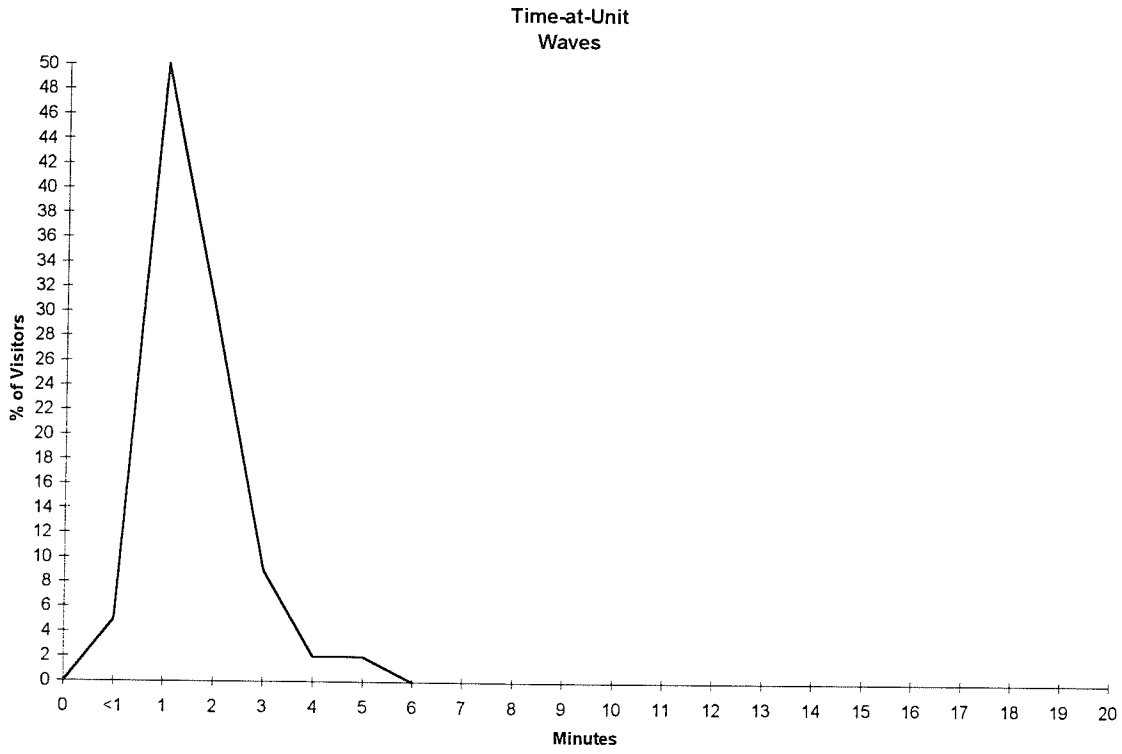


Time-at-Unit
Pendulum



Time-at-Unit
Spectrum




Time-at-Unit
Waves
% of Visitors
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44
42
40
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36
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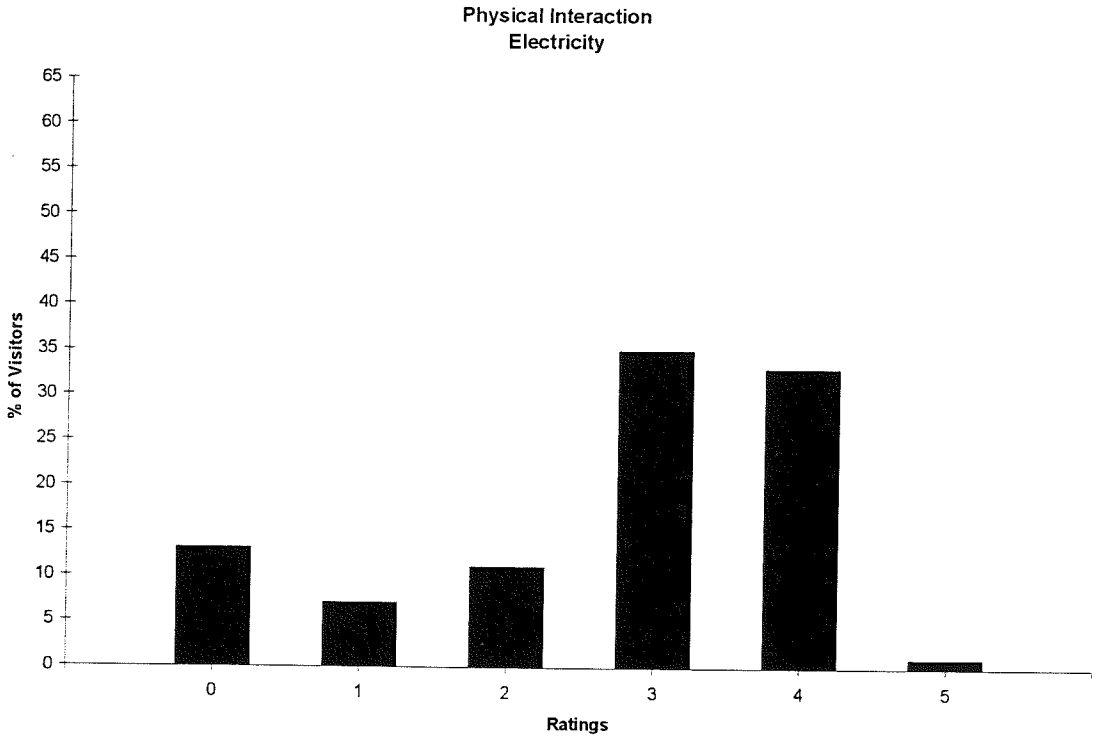
20
Minutes

APPENDIX F

Visitor Interactions—Unit by Unit


Physical Interaction
Electricity
% of Visitors
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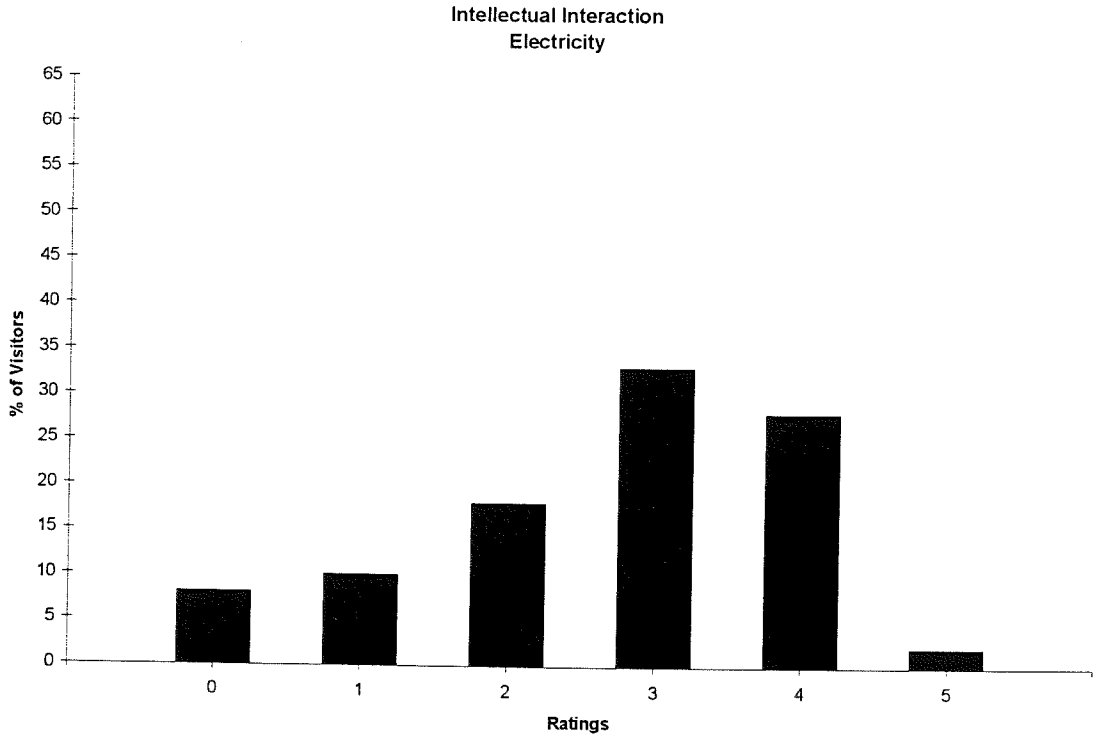
Ratings


Intellectual Interaction
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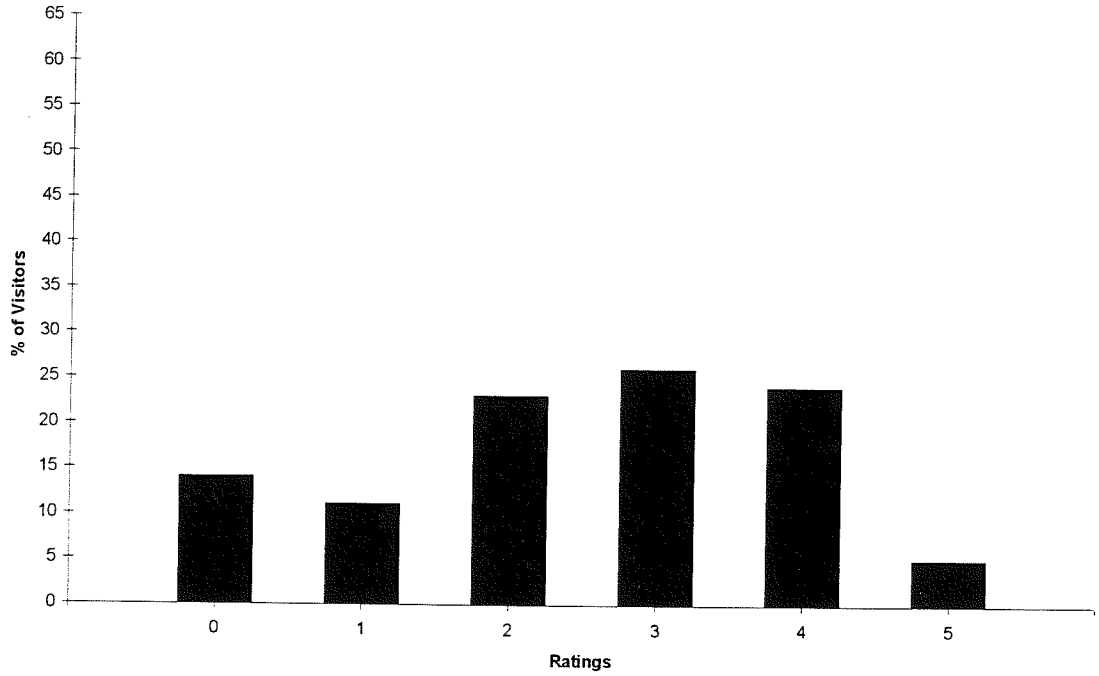
Social Interaction
Electricity



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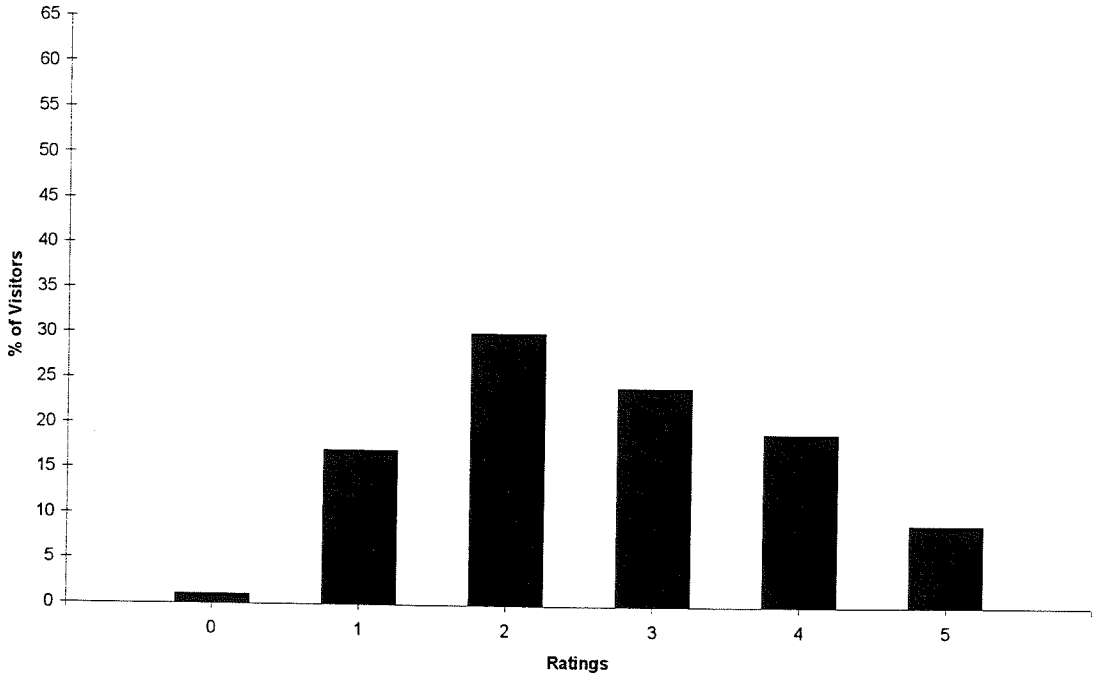
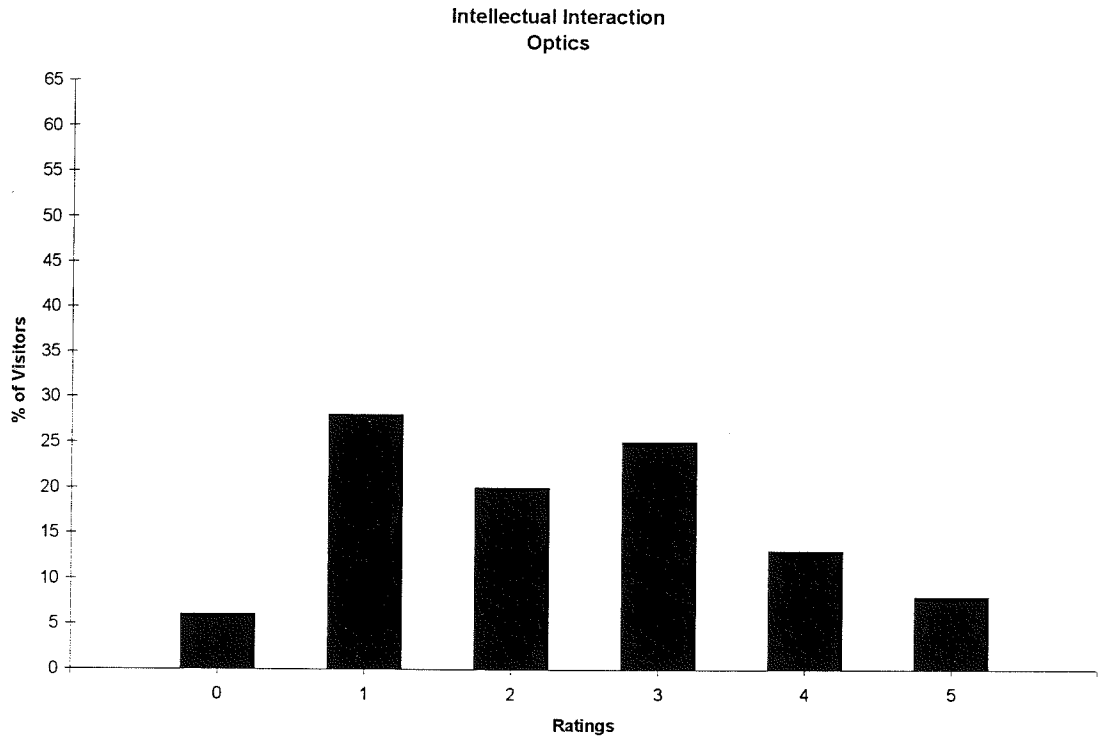
Optics




Intellectual Interaction
Optics
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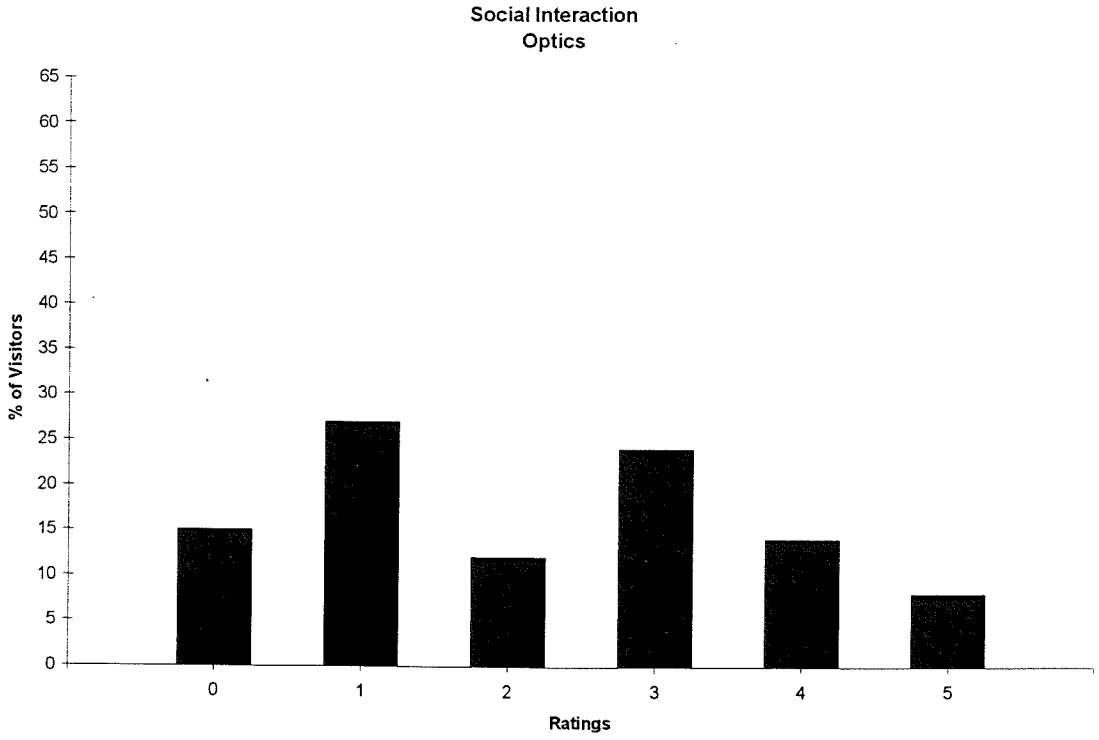
Social Interaction
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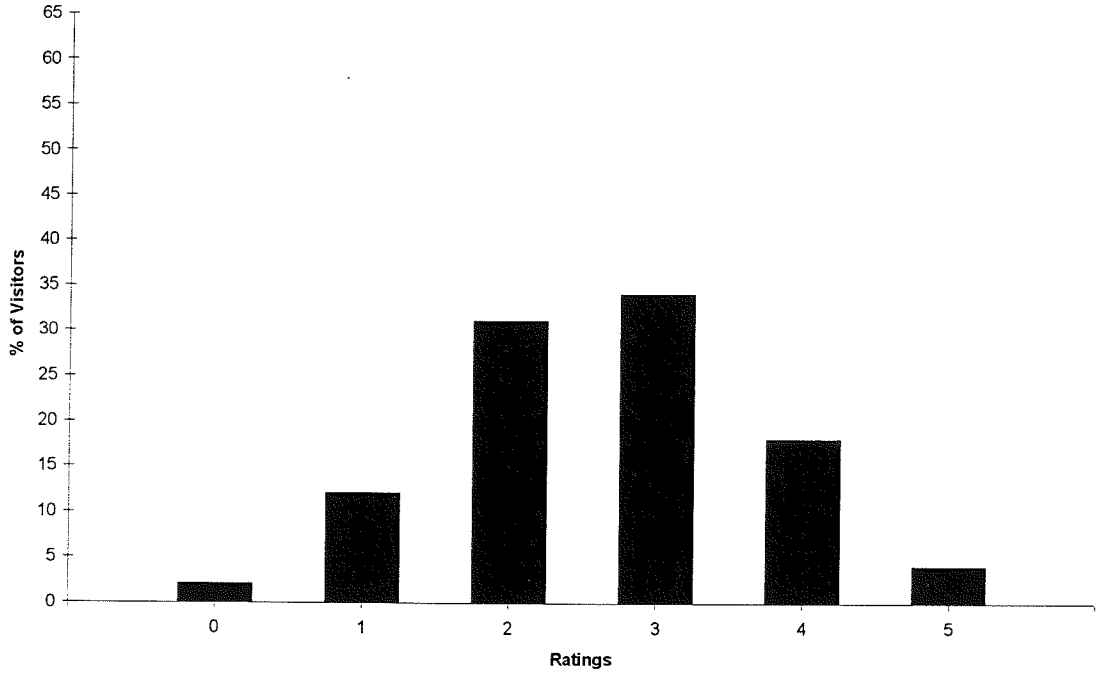
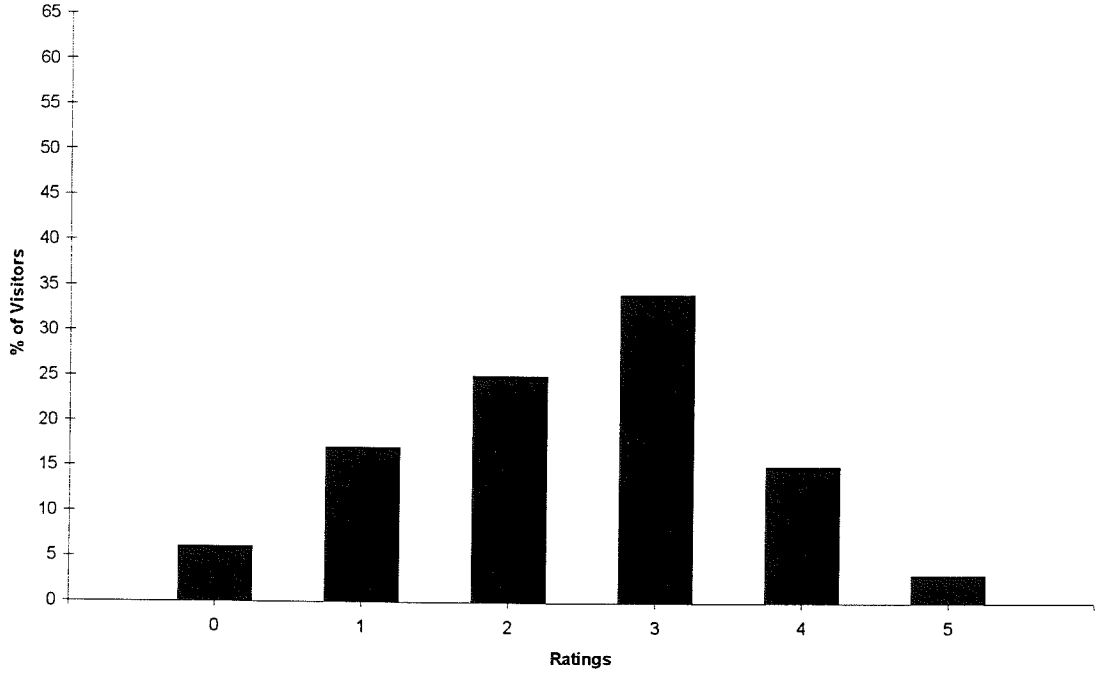
Ratings

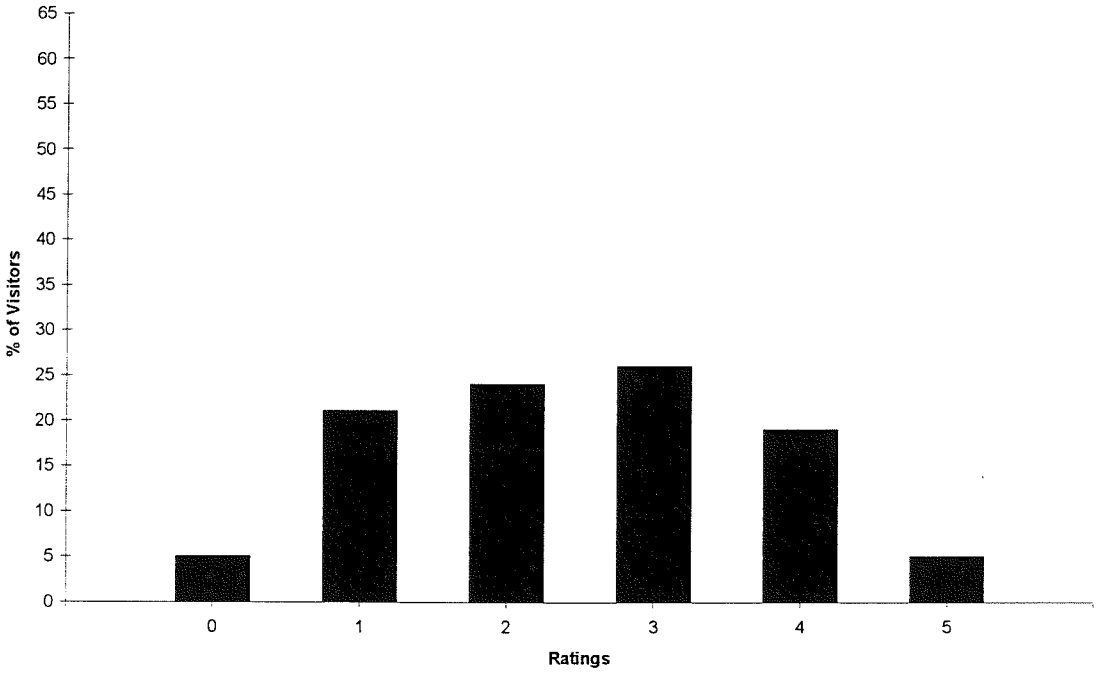
Physical Interaction
Pendulum



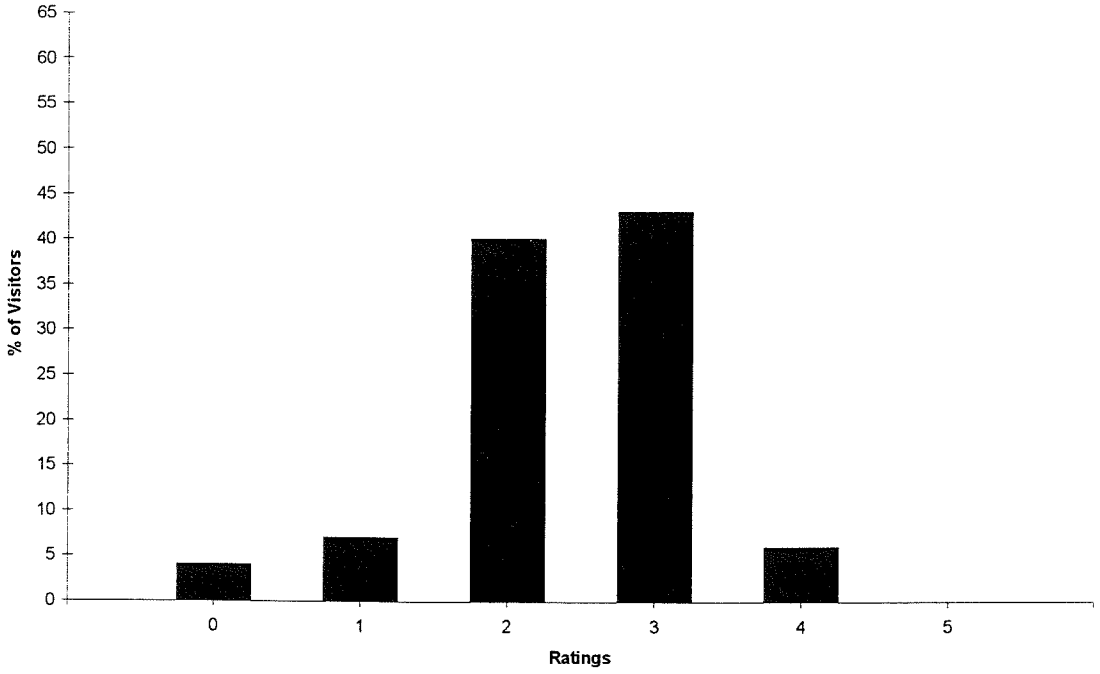
Intellectual Interaction
Pendulum

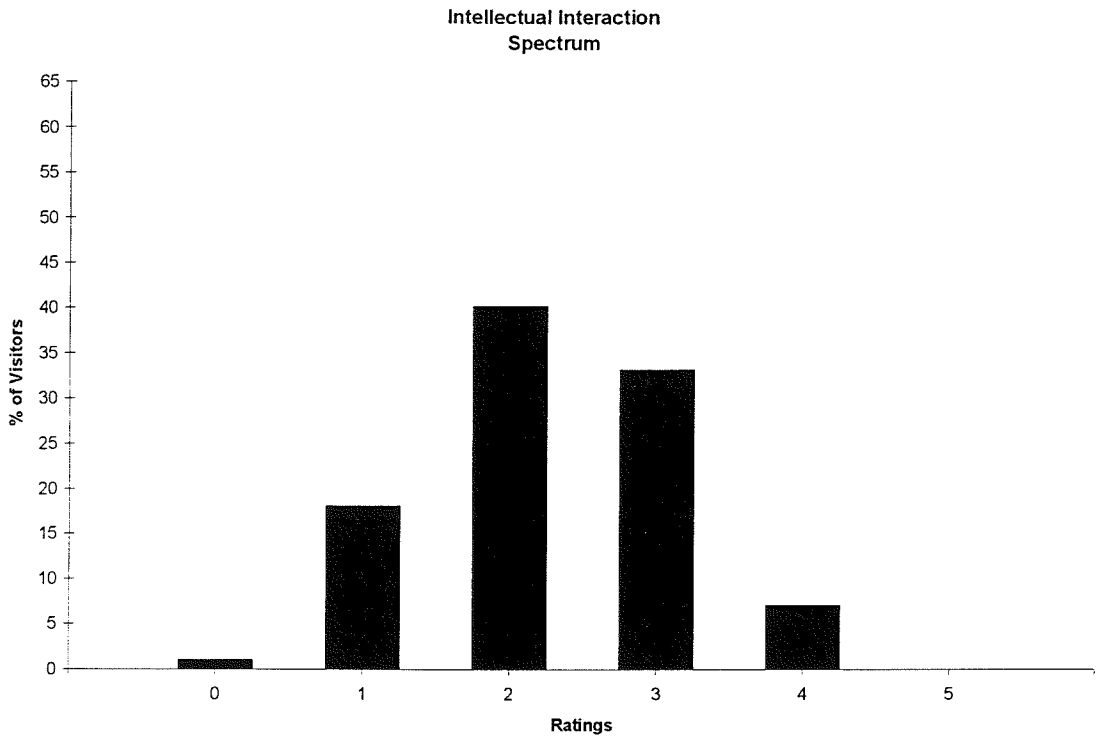


Social Interaction
Pendulum



Physical Interaction
Spectrum




Intellectual Interaction Spectrum
% of Visitors
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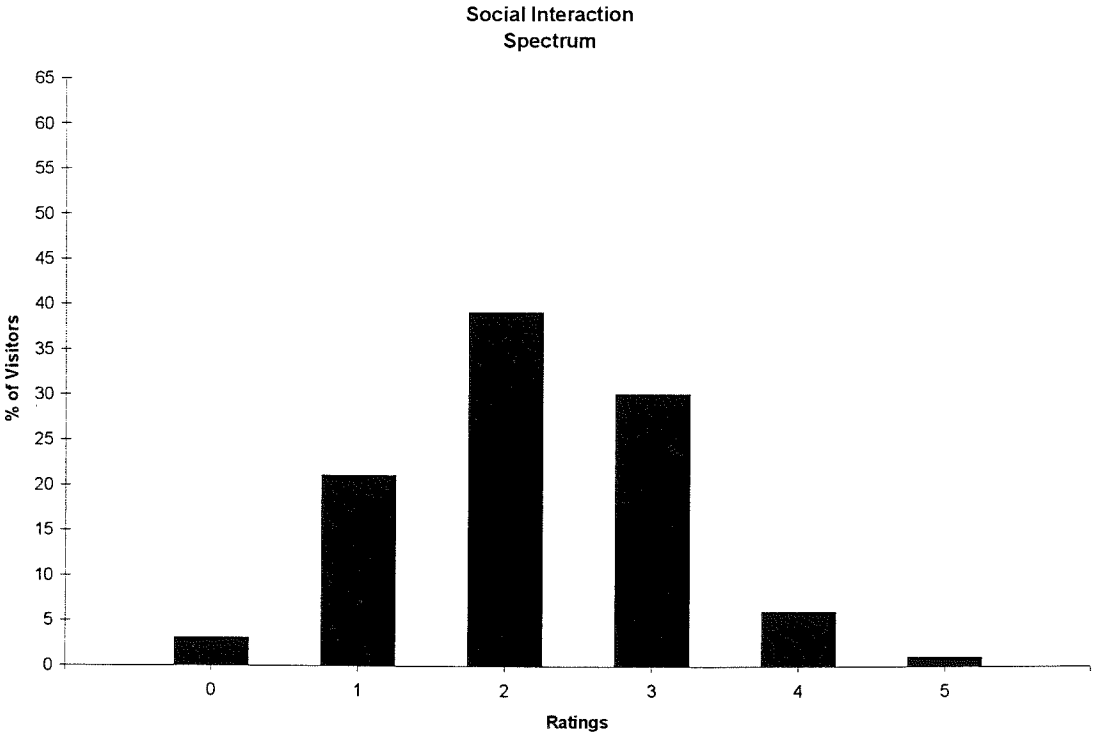
Ratings


Social Interaction Spectrum
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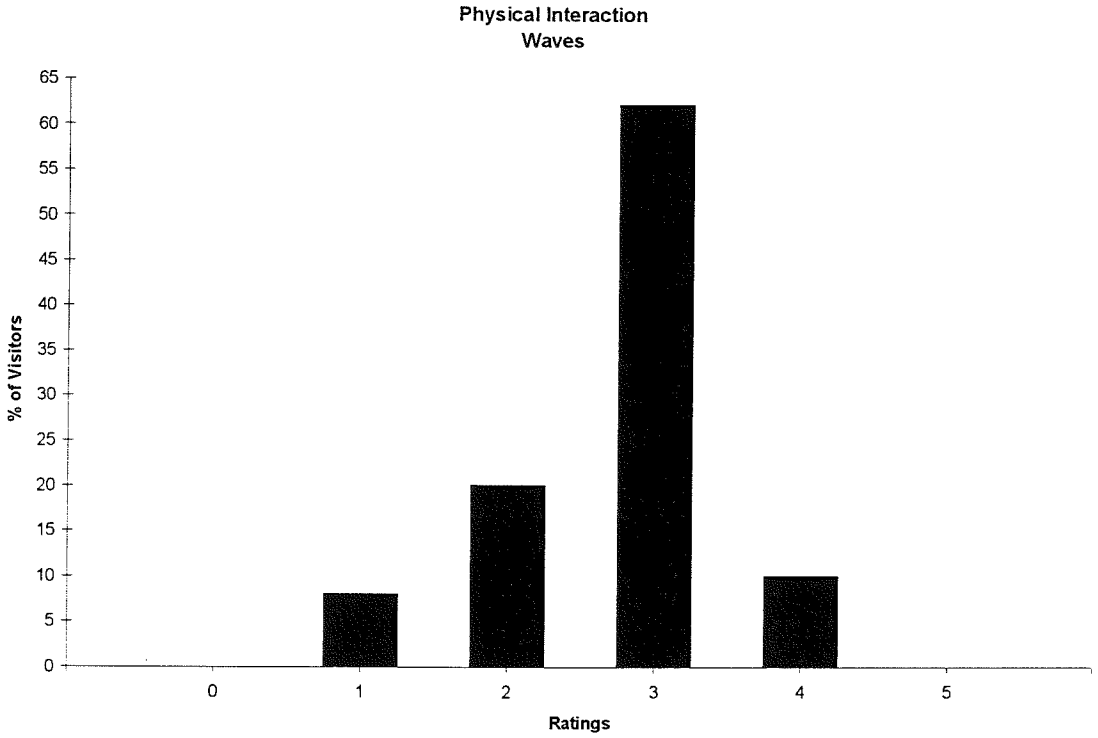
Physical Interaction
Waves
% of Visitors
65
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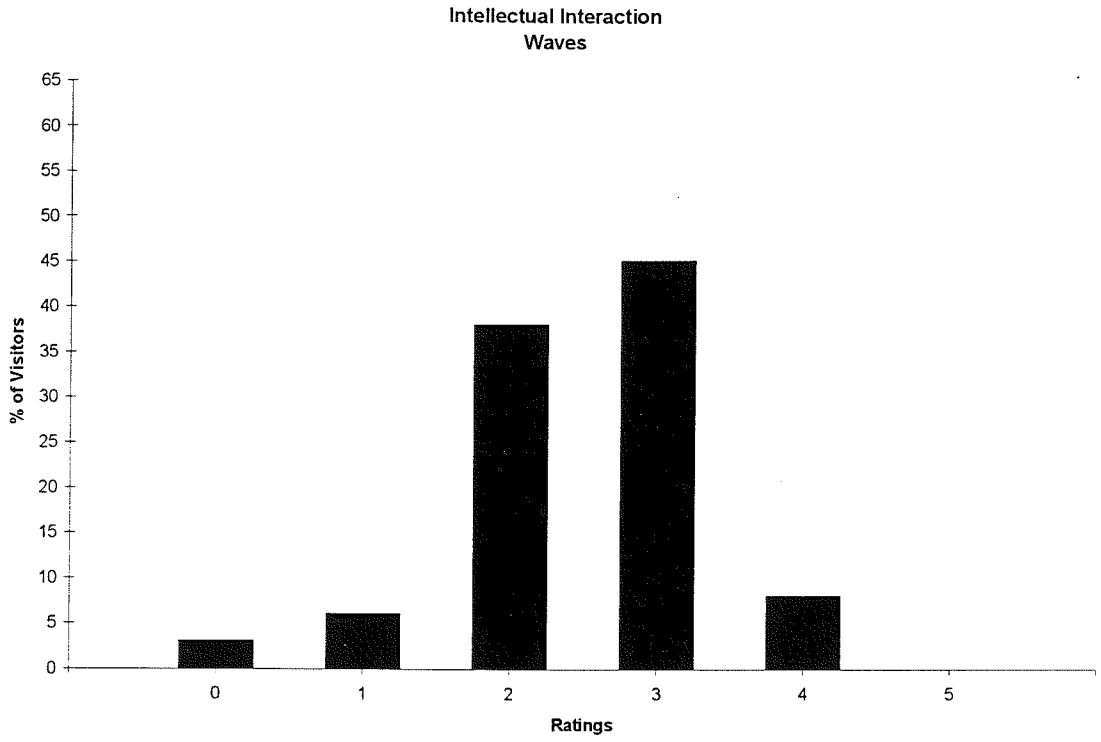
Ratings


Intellectual Interaction
Waves
% of Visitors
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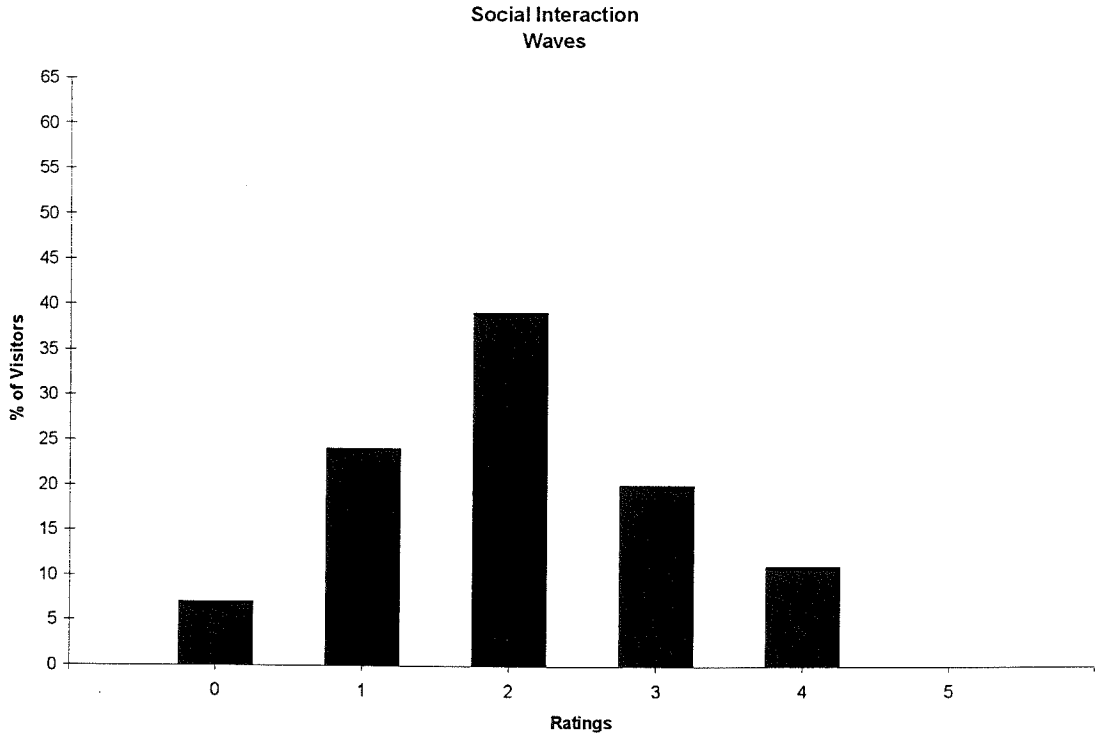
Ratings


Social Interaction
Waves
% of Visitors
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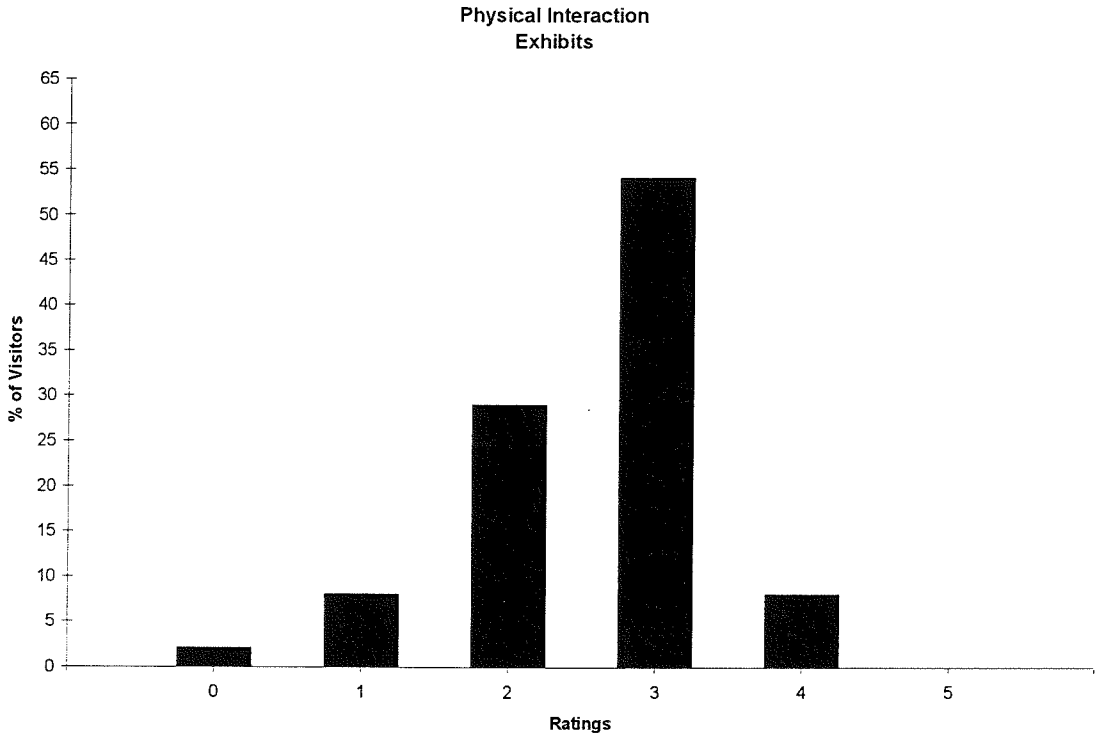
Ratings

APPENDIX G

Visitor Interactions—Lab vs. Exhibit


Physical Interaction
Exhibits
% of Visitors
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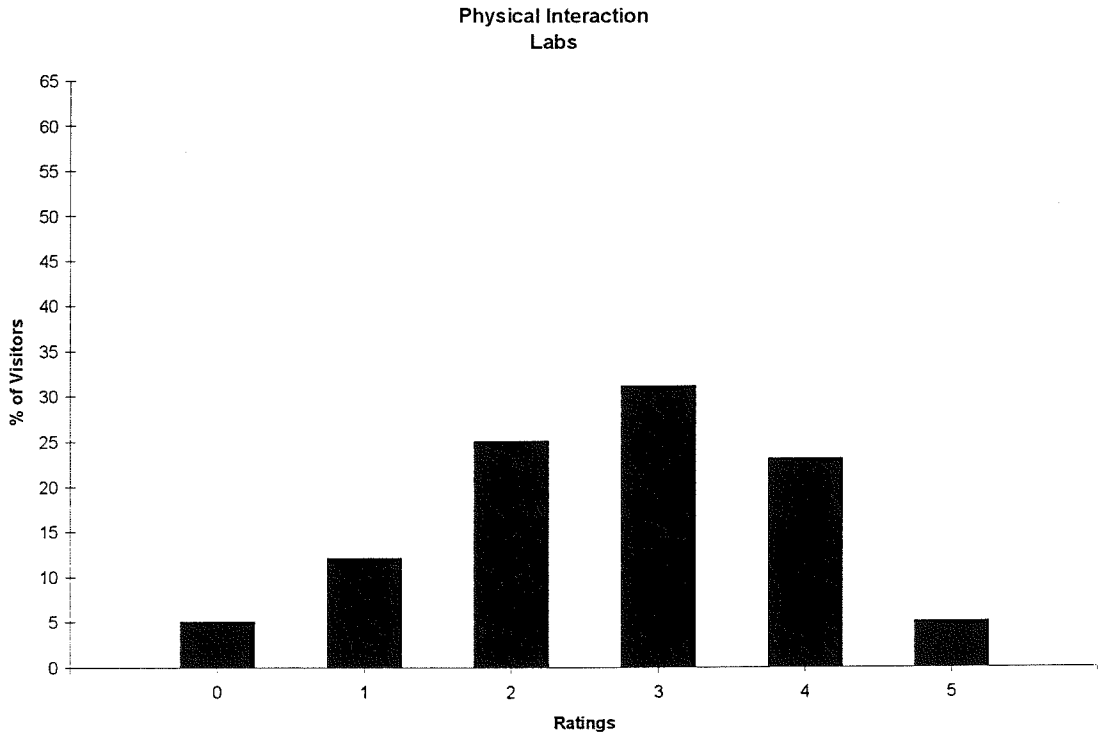
Ratings


Physical Interaction
Labs
% of Visitors
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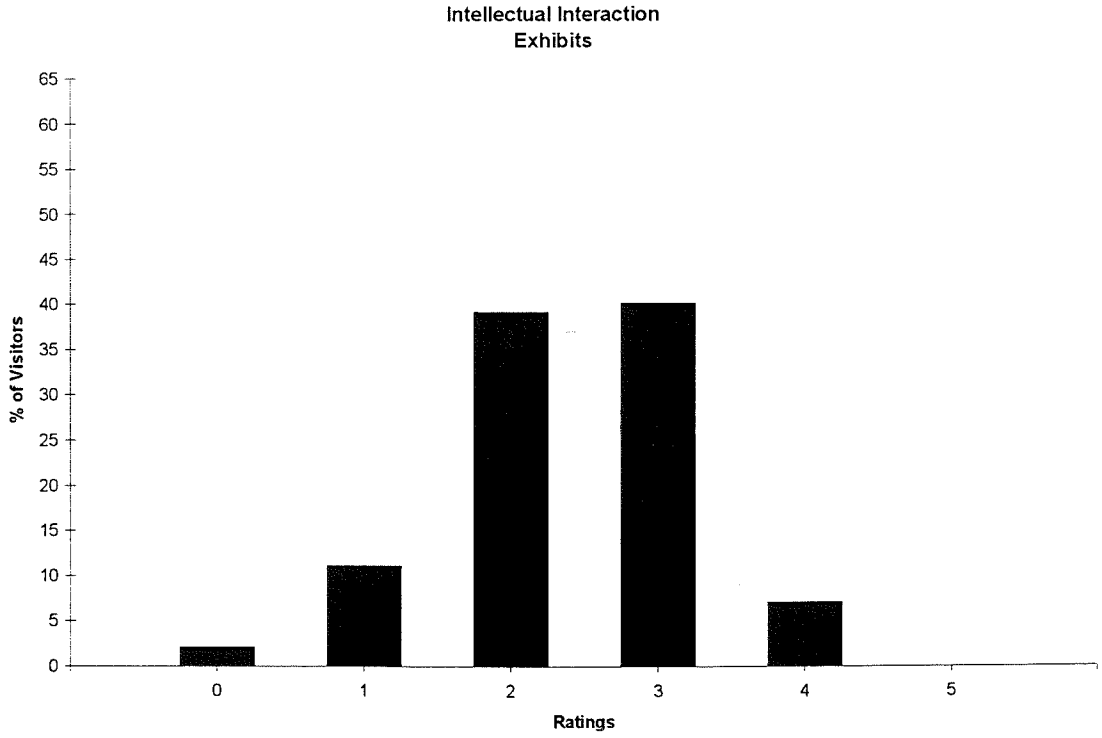
Ratings


Intellectual Interaction
Exhibits
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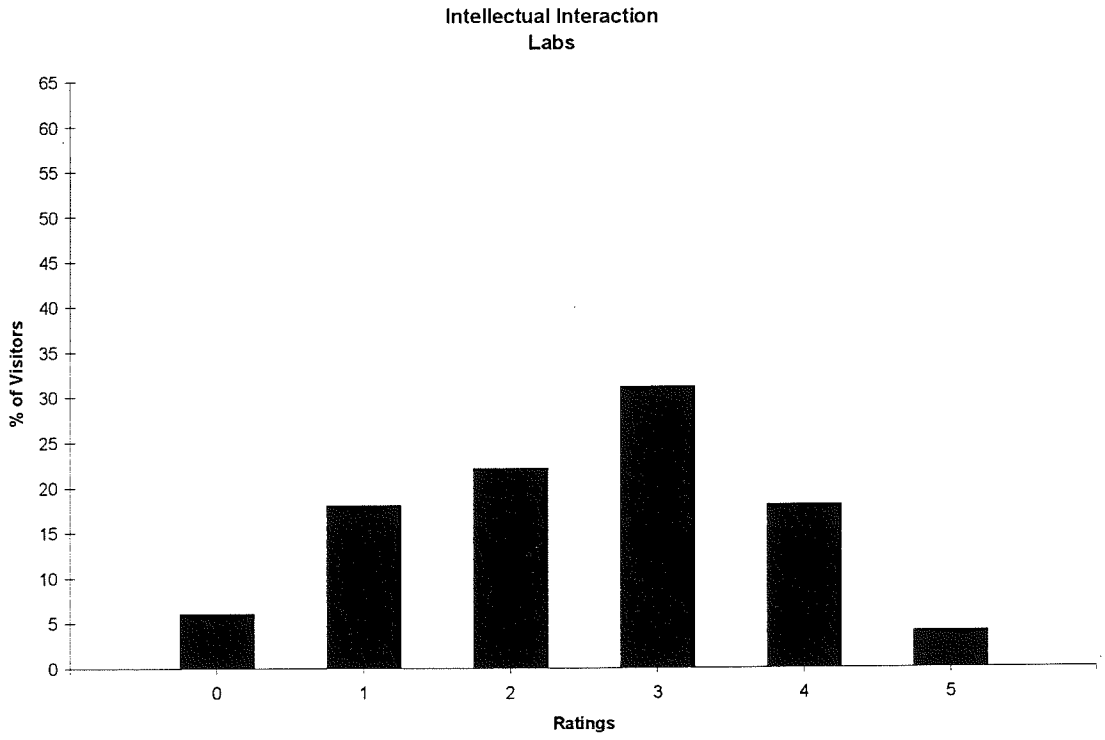
Ratings


Intellectual Interaction
Labs
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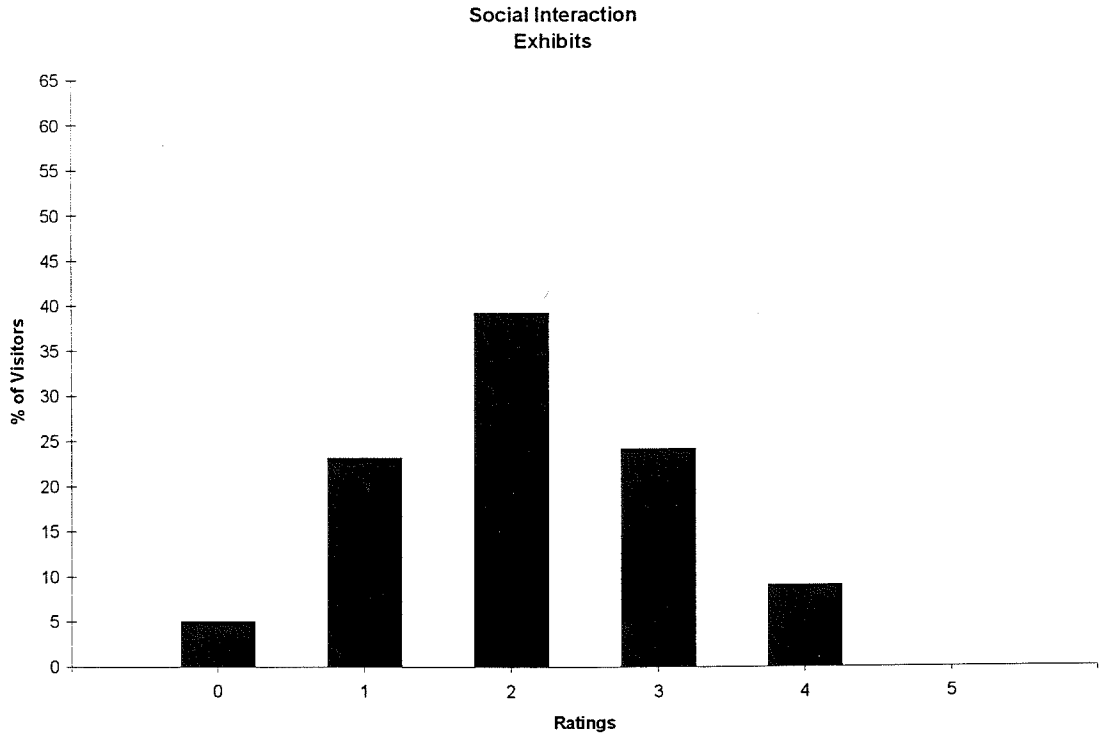
Ratings


Social Interaction
Exhibits
% of Visitors
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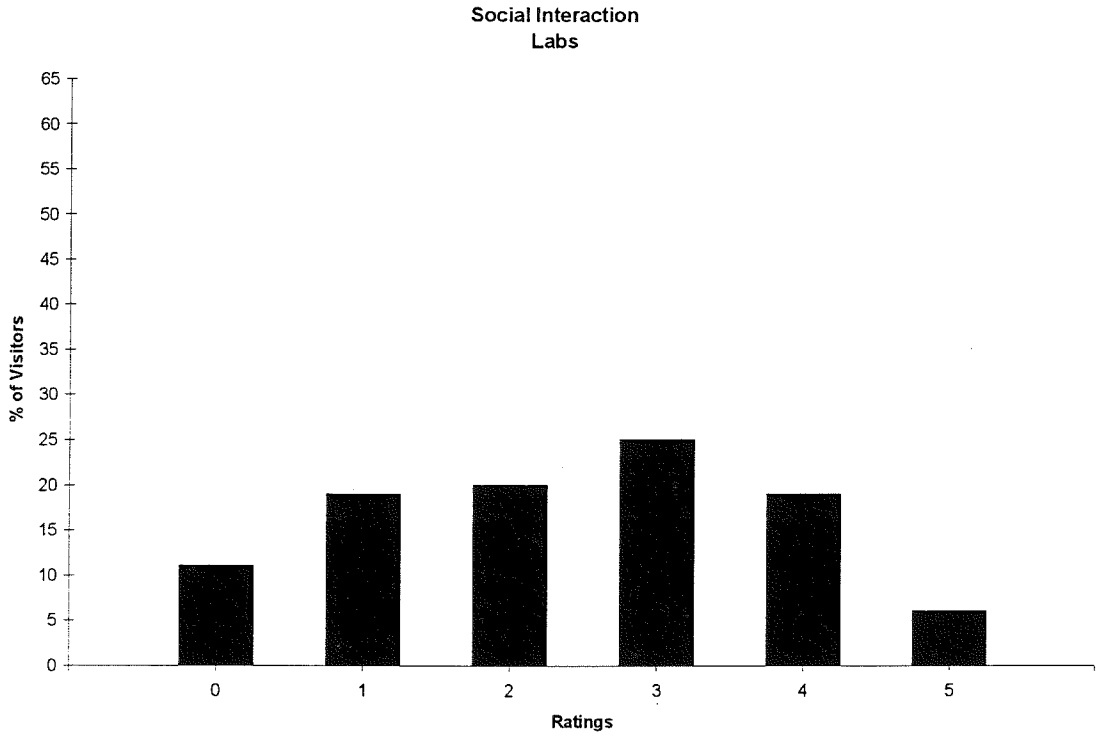
Ratings


Social Interaction
Labs
% of Visitors
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Ratings

APPENDIX H

Unit by Unit Data Summary

Electricity Bench Data Summary

Common limits to success were:

- not understanding what a component was for or how to use it, especially the capacitor, and volt meter.

At the Electricity Bench visitors were observed and/or reported doing the following:

- trying different combinations of components
- following the instructions on the cards
- comparing effects of different combinations of components
- comparing what they built to other appliances
- replacing different components
- "trial and error."

Visitors expressed frustration, boredom, intimidation about:

- having unanswered questions
- not knowing what a component was for or how it worked
- none of the cards had you use a diode
- there was only one power source so only one experiment could be conducted at a time

The unit was particularly successful for:

- someone who wanted to work by themselves or a small group who wanted to work on the same experiments

Visitors particularly enjoyed:

- having all the components there
- the creative design of the lab
- being able to work with electricity and not worry about being shocked

Visitors had unanswered questions about:

- why the fan would go at different speeds
- how does the fan spin
- how does the power saver save power
- why some didn't make a complete circuit

Visitors learned that:

- about the tester deal
- that it'd still work if you connected everything
- there is such a thing as resistance
- how a dimmer switch and a capacitor work

Visitors made personal connections about:

- working with a motor at home

Spectrum Window Data Summary

Common limits to success were:

- did not find or notice the rod and/or the handles for the rod
- soap solution was not always working i.e. it was old, or used up
- rod was raised, but there was no bubble
- did not find or notice button
- pushed the button when there was no bubble

At the Spectrum Window visitors were observed and/or reported doing the following:

- blowing to see the colors
- comparing the effects of blowing hard and soft
- raising and lowering the rod at different speeds
- observing the colors and movement of colors
- putting hands in the bubble
- putting hair in the bubble
- waving hands at the bubble.

Visitors expressed frustration, boredom, intimidation about:

- not enough science in it
- could not get it to make a bubble because solution was old

The unit was most successful for:

- enjoyable aesthetic experience
- oh wow!

Visitors particularly enjoyed:

- the colors and movement
- simple enough they could do it at home

Visitors had unanswered questions about:

- how you make the solution
- does it do the same colors all the time?

Visitors learned that:

- there are colors in bubbles
- bubbles can be big
- they can stay a long time
- how strong bubbles are
- how spectrum theory relates to bubbles
- how bubbles reflect light

Visitors made personal connections about:

- wanting to paint a picture like that
- the movement is like sand and wind
- I want to make it at home

Optics Bench Data Summary

Common limits to success were:

- not recognizing zones
- screen too far back
- too dark for reading
- not noticing the instruction cards

At the Optics Bench visitors were observed and/or reported doing the following:

- moving lenses
- changing lenses
- setting up experiments
- observing the effects of different lenses
- following instructions on the cards
- hypothesizing about what would happen
- using different combination of lenses
- using different angles.

Visitors expressed frustration, boredom, intimidation about:

- why it doesn't explain why my hand is upside down
- how to use all the stuff

The unit was most successful for:

- an enjoyable aesthetic experience

Visitors particularly enjoyed:

- seeing their hand upside down
- that their hand is projected but it's not in a direct line with the screen
- making pretty designs

Visitors had unanswered questions about:

- why the image of their hand is upside down
- how did the museum figure out an exhibit like that
- what is the purpose of the exhibit
- why if they cover half of the lens it shows a whole picture
- interference patterns

Visitors learned that:

- you can project an image by shining light on it
- how to make a telescope
- how to use exhibit
- about light projection
- information to help me build my pinhole camera

Visitors made personal connections about:

- when I was a kid and used a microscope
- lenses in overhead projectors
- making a pinhole camera

Waves on a String Data Summary

Common limits to success were:

- didn't see the waves
- couldn't see the differences
- did not use or couldn't find the resin
- didn't know what they were supposed to look for

At Waves on a String visitors were observed and/or reported doing the following:

- plucking
- bowing
- comparing the effects of bowing up vs. down, fast vs. slow, hard vs. soft
- shortening the string
- trying to make the waves appear while holding the mirror still
- making noise
- "making the thing spin faster and slower"

Visitors expressed frustration, boredom, intimidation about:

- the resin and bow were in bad shape
- hard to figure out what you're supposed to do
- directing kid's attention away from speeding up and down the spinner to the wave

The unit was most successful for:

- visitors who had someone with them who could explain it

Visitors particularly enjoyed:

- seeing a visual image of something abstract

Visitors had unanswered questions about:

- how it works
- why it's saw-toothed when it's bowed
- how it relates to electronic sound waves

Visitors learned that:

- there's a difference in sound waves when you pluck it compared to bow it
- sound moves differently through water and through air
- wavelengths change as intensity changes
- damped harmonic motion

Visitors made personal connections about:

- playing a string instrument
- something they read in a text book
- music

Pendulum Bench Data Summary

Common limits to success were:

- did not get point of exhibit
- did not see the connection between computer and pendulum
- the computer crashed

At the Pendulum visitors were observed and/or reported doing the following:

- measuring
- changing the lengths of rods and the weights
- playing with it
- speeding up and slowing down the metronome
- comparing the different graph results

Visitors expressed frustration, boredom, intimidation about:

- not understanding the point of the lab
- the activity/explanation cards
- didn't understand how to work it

The unit was most successful for:

- people with a background in physics

Visitors particularly enjoyed:

- the computer

Visitors had unanswered questions about:

- how long will the pendulum keep spinning
- should I leave it while it's still spinning

Visitors learned that:

- it goes for a long time because the weights balance each other
- the weight and length change things
- you can use gravity to keep the pendulum swinging at the same rate

Visitors made personal connections about:

- makes me think about how things work
- music
- physics class
- I'll tell my teacher about this