VISITOR BEHAVIOR AT A CONSTRUCTIVIST EXHIBITION: EVALUATING *INVESTIGATE!!* AT BOSTON'S MUSEUM OF SCIENCE

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INTRODUCTION

Constructivist education theory postulates (Fosnot, 1996; Hein, 1998) that visitors learn actively and create their own meanings as they interact with the world. This raises challenges for visitor studies, since it may be difficult to plan a reasonable evaluation strategy for exhibitions if visitors' actions and outcomes cannot be determined in advance. Constructivist theory also requires an appropriate evaluation approach (Hein, 1997).

This paper illustrates the use of a combination of methodologies that allow visitors' meanings and activities to emerge as they visit an interactive, non-linear exhibition. The Museum's description of *Investigate!* illustrates the constructivist nature of the exhibition.

> *Investigate!* involves visitors in over 30 open-ended activities and experiments. In this 3500 square foot activity center, the Museum provides equipment and materials to do a variety of investigations with some ideas on how to get started. From there, it's up to the visitors to decide where to go. This highly interactive exhibit gives visitors practice thinking like a scientist in activities and experiments that are both fun and educational.
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> The "See-for-yourself" subtitle is the primary message communicated throughout the exhibit, supported by the design and graphic treatment of the exhibit, as well as by specific component activities and through label copy and sidebar texts. It creates a framework that places visitors and their thinking squarely in the center of the exhibit experience. How do you "see-for-yourself" in this exhibit (and in

> general)? By Investigating — that is, by asking questions, searching for evidence and drawing conclusions.

The exhibition actually included 40 different interactive components, arranged in three general areas, *The Lure of Questions, The Search for Evidence, and The Art of Drawing Conclusions.* The exhibition was not linear and visitors could, and did, choose to interact with some of elements and ignore others. About half of the components were small stations where visitors could examine unusual objects, make predictions or engage in limited inquiries. For example, there was a small "probability machine" that dropped ping pong balls, computers where visitors could add data to a survey, or record their own findings. Other components, among the most popular, involved more extensive investigations. In one area, visitors could build and test components for small solar powered cars and then test them on a track. In another, two small elevators could be raised about 3 meters with objects inside them and then dropped with the time they took to reach the base recorded electronically. About 20% of the total area was taken up by a mock archeological site where visitors could examine objects and other data (and record their findings) and explore a midden where objects could be unearthed. They could also examine other aspects of archeologists' work. A table top experimental area allowed visitors to test and compare the insulating qualities of various types of paper and plastic cups by filling them with hot or cold water and inserting temperature probes, whose reading were displayed on a computer screen.

The Museum staff included an ambitious set of questions in their request for a summative evaluation of the exhibition. In addition to basic information concerning visitor behavior in the exhibition, staff were also interested in gathering data to support their goal that visitors should engage in scientific activities and that they recognize that the exhibition provides an opportunity for scientific investigations.

An evaluation design was devised that matched the Museum's issues with appropriate means for obtaining information about them, following a system developed over many years by PERG (Engel and Hein, 1981; Hein, 1995). Our approach centers on developing a matrix that connects the issues to be evaluated and the means employed to do so. This matrix not only connects the two components, but also provides detailed guidance for the questions or foci for each of the means. Before a specific questionnaire or other instrument is developed, we can determine how to shape it so that it provides data to address each individual issue. Alternatively, for means that may have been developed previously or any data collected by others, the list of issues provides a basis for deciding how to use a particular data set to best advantage. The matrix used in the present evaluation is included as Figure 1.

Our own field work consisted of the following activities:

- Tracking Study: One hundred, randomly selected visitor groups that entered the exhibit from the front were tracked, using one member of the group as a focus. Thirty-nine different potential stops at the exhibition were identified, and visitor stops and time (if more than 5 seconds) at each stop recorded.

- Exit Interviews: Seventy-six randomly selected visitor groups were interviewed as they were leaving the front entrance of *Investigate!* Among other questions, visitors were asked to compare *Investigate!* with either two other permanent exhibitions at the Museum of Science.

- Interactive Observations: Ninety three visitor groups at selected exhibit components were observed, recording both their actions and conversations to the extent these could be noted or overheard. In addition, where appropriate, the observer interacted with the groups indicating how they might be able to use equipment, answering procedural questions, or otherwise acting as a facilitator while attempting not to unduly influence the visitors' exploration of the exhibition.

After piloting several approaches to this task, we decided to limit the recording to manual, written observations. This approach provided rich and extensive data, and also allowed the observer to interact or step back easily, without having to worry about cumbersome equipment.

- Post-visit Phone Interviews: During the exit interviews visitors were asked if they would be willing to receive a phone call for an interview some months after their visit. Fifty one phone numbers were obtained from visitors residing in the United States and thirty-eight visitors (75%) were reached in November, 1996, approximately three months after their visits. Some telephone numbers proved to be incorrect, and a few visitors did not return calls after repeated requests.

All data was recorded for visitor *groups*, defined as a collection of individuals who were visiting the exhibition together. Groups varied in size from single visitors to large clusters. Because the evaluation was carried out only during the summer, and because of the nature of the exhibit, almost all visitor groups in this study consisted of families with children.

The tracking study followed the path of one member of the group, either adult or child. The exit interviews were carried out as group interviews, although one member usually answered most of the questions. During the interactive interviews, all participating members of the groups were observed and their verbal and physical behavior noted to the extent possible.

All the data was analyzed using standard, simple methodologies. Quantitative data was tabulated and the results are described in this report. Qualitative data was read and re-read by three different people and coded both for the issues of concern listed above and for any other topics which emerged. Each of these is described below.

TRACKING STUDY FINDINGS

Time in the Exhibition

Visitors stayed a long time in *Investigate!*. The average time spent in the exhibition was 17.1 minutes. This compares very favorably with averages recorded by PERG in other studies, as well as with the kinds of averages usually found in visitor studies and those documented by Serrell (1996). Even more revealing are plots of a visitor decay curve for *Investigate!* compared to similar plots for other exhibitions. Some of this information is provided in Figure 2 which compares *Investigate!* to three other Museum of Science Exhibitions.

Not only is the curve shifted far to the right in comparison with other exhibitions, but the *shape* of the curve is unusual for museum exhibitions; there is not the usual rapid drop off for visitors in the first few minutes. (see Bicknell 1995). Instead, we find an initial period where almost no one leaves. The four exhibits can also be compared in terms of V_{50}, the time when half the visitors have left and half are still in the exhibition. The data is provided in Table 1.

Similar, remarkably long visitor times were found for individual components of *Investigate!* during the interactive observations. For those components where timing data is available, Figure 3 demonstrates the visitor decay curves, many of which are as long as those frequently observed for entire exhibitions. Average times and visitor “half-lives” for the data in Figure 3 are provided in Table 2. The average visitor times at these components are significantly longer than the V_{50} values because a minority of visitors interact with the components for exceptionally long times.

Attracting and Holding Power

A striking characteristic of this exhibit was the wide variation in holding and attracting power of the components. A total of 39 different “stations,” possible stopping points at the exhibit, were identified for the tracking study, (with an additional station, Midden Idea Exchange, added during the course of the study.) The member of the group tracked was followed and times at each stop recorded. Four stations — Drop Stop, Little Tank, Midden Dig, and Introductory Idea Exchange —

appear on all three of the highest ratings lists; they attract more than 30% of the visitors, with more than 20% remaining over a minute, and average times at the station of more than two minutes.

While three different stations attracted over 50% of visitors and 12 stations had average stop times of 2 minutes or more, another 12 stations attracted less than 10 percent of all visitors. With so much to choose from, visitors were selective, but attentive. They stopped and stayed, but did not visit all components during the time available to them.

It is common to measure average visitor time spent at individual exhibit components in seconds. In this exhibition, even components that were relatively less popular still attracted visitors for average times greater than one minute. In addition, there were a striking number of particularly long stops at many different components. Table 3 summarizes this data. All exhibition components held at least one visitor for longer than one minute; 28 components (72% of the components) held at least one visitor for longer than two minutes, and there were 30 separate stops at 14 different components that were longer than 5 minutes. Another way of analyzing the data is to say that over half of all the stops made (469/795, or 59%) were for a duration of at least one minute.

DISCUSSION OF TRACKING DATA

Before we can try to determine what meaning visitors make of their interactions with exhibitions, it is essential to know whether they engaged with the exhibition in the first place. The tracking study used traditional methodology to establish that visitors did engage with the exhibition. The data, with its long average times and high holding power, confirms that the exhibition did accomplish its designers' s most basic objective, to engage visitors.

This exhibition was intended to provide a range of stations, that, in total, would appeal to a wide range of audience. The relatively long total time spent in the entire exhibition by visitors as well as the many individual stops that were of long duration indicate that the aims of the developers to create an interactive exhibit that attracts visitors has been achieved. Serrell's (1995) "51% solution," suggesting that in a "successful" exhibition visitors will stop and become engaged at 51% of the components, does not appear to apply to this exhibition. Since the exhibit is not linear and since many of the interactive components function totally independently of each other, there is no reason why visitors should stop at a great number of components. What was desired (and accomplished) is that the visitors become engaged with *some* components, spending sufficient time at them to investigate.

INTERVIEW FINDINGS

Powerful evidence towards answering the questions of interest to the exhibition developers was obtained from the various interviews conducted at the exhibition. All three types — exit, interactive and delayed interviews — provided information on visitor meaning making. The combination of the three was particularly useful in allowing grounded conclusions from the data. Examples are provided in the discussion below.

Visitor Engagement

The tracking data is augmented by the interview data which demonstrates powerfully that visitors did focus on the exhibition components as they stopped at them. They reported that the visit was a positive experience, they talked with each other about what they were doing, and they used the equipment, instruments and content of the exhibits. In the delayed phone interviews many visitors recalled and talked about their involvement with the exhibit components.

> Yes, the fact that the air from the fans on the water were affecting the way it would flow. [He explained that he was noticing how the water flowed when he poured in front of the air] (Exit interview, adult male)

> A man (60) approaches me “Do you work here? I tell him that I am doing a job for the Museum. “Well then,” he explains, do you know the Penny Scale is not working properly?” I tell him I wasn’t aware of it, but would report the problem. He takes me over to the scale. “See, it runs continuously”, he says. I look at the scale, onto which he has placed a penny. The scale’s read-out keeps changing. “I figured out how to stop it,” he says. “If you put a quarter on the scale it will weigh the penny and the quarter. I was able to determine the penny’s weight by keeping the quarter on the scale.” (Excerpt, Interactive Observation)

> 5:16:45 — 5:21:30 PM, 1F (35)
> A woman sits at a Balancing Teeter Station. She is carefully threading nuts on the device. She tries to add several to one side. She removes them all and adds them to the center. She gets up. I ask her if she was working on a specific problem. She tells me that she was trying to do as the sign suggested. I ask her to share her thinking process with me. She says she was “working with side to side balancing. I noticed that in order to get it to tip, I needed to work with the sides as well as the top.”
>
> (Interactive Observation)

Scientific Inquiry

The Museum of Science staff defined scientific inquiry in terms of the categories covered in the subsequent sections — they wanted visitors to ask questions and form hypotheses, gather and record evidence, use instruments, and draw conclusions. We will discuss each of these

components separately below. The quotations above and those in the following sections usually illustrate more than one issue of interest for the evaluation.

There is overwhelming evidence that visitors asked questions and considerable circumstantial evidence that they formed hypotheses. They were repeatedly observed trying to find something out. They also said that they wanted to know how something worked, why it happened, or that they had questions answered. In many instances, we have to presume that they had some idea they were testing, or that they made predictions or educated guesses about what would happen, since their behavior suggested it.

> The kids were mixing hot and cold to get warm and looking. They were trying to guess how much water would make the water a particular temperature. (Exit interview)

> We tried to fix [the solar cars] because they were broken, we held them up to the light. (Exit interview)

> A boy, J— (10), boy (5) and Mother (35) are at the Roll Down Station. J— tests the car. It falls off the ramp. He makes adjustments to the underside of the car. Mom is sitting on a stool, right next to the ramp. She asks "What does it do? The boy (5) [younger brother?] "Hey Mom I did that." M (5) says to his brother "You can make your own cars over there." He points toward the workshop. Mom reads the direction sign about wheels on the exhibit aloud to the boys. The boy (5) appears very engaged. He readjusts the rubber band on his car. Mom asks "What kind of a wheel are you putting on?" (Excerpt, interactive observation)

> She holds the cup up to the fan letting the fan blow onto the cup. I ask her if she could tell me something about what she's doing. She says, "I'm trying to make it cooler." "How can you tell if it's cooler," I ask. "I can put my hand in it," she says. She lets it blow for a minute or so. She says to me, "I don't think it is going to work." She gives an audible sigh. "If it's gonna work," she continues " . . . but not yet." I mentioned that I'd seen her using that other thermometer. She picks it up in her hand. "Maybe I can check with it now", she says. She places the thermometer in the cup. She says, "It's down a little. I suggest she might try using the thermometer in the hot and cold water. She does and gets very animated as she observes the thermometer's red band, dropping from the hot to the cold. (Interactive observation)

> Boy (13) changes wheels, changes rubber band, puts power in large wheels from small wheels. "It can't turn because there's not enough power, you need more tension on the rubber band." "I don't think the rubber band is strong enough." These comments are made more or less to grandmother (60) as he works. (Excerpt, interactive observation)

> The part where we were standing — all the hands-on stuff the archeological dig stuff and the questions you could ask about the items you picked up — what type of person used this, what was this tool used for- the way it made them [the children] think about what was going on with the article they found whether it was an animal track or a piece of something worn or used.
> (Telephone interview, response to, "What do you remember most?")

Visitors gathered evidence constantly. This is another way of confirming that they interacted with the exhibit components. Comments about gathering and recording evidence and/or

manipulating variables were noted in 18 different exit interviews. Additional comments were provided in some of the telephone interviews.

> They loved [the Midden area]. They think they're really finding things. My daughter was filling out sheets. It's good on two levels, for each age. It still challenges. They do need more plastic envelopes. My daughter couldn't find one to put her card in.
> (Exit Interview, mother with 7-10 year-old daughter)

> Computer measures changes in your skin temperature . . .I was filling glasses with hot and cold water. I held one. I watched the temperature of my skin. I plunged it into cold water. It dramatically dropped.
> (Exit interview)

> 1:55:47 -1:58:54, 1M (10); 1F (35)
> The boy goes to Table #2. He looks up and calls "Mom I need help!" He begins to brush. He reads the sign above the table. He continues to brush and read. He picks up a magnifier. He studies a shell with the magnifier. He calls out "Mom." He continues to brush. He calls to his Mom, "You can look like this." He demonstrates looking through the magnifier. "You can write it down too," he says. His mother moves from the Big Dig, where she's with a younger child and comes over to the boy. "O.K.," says Mom, "Let's do it." The woman asks the questions on the card aloud and together they decide what to write on the card. They play together with the magnifier, laughing. The mother says, as she looks at her son's face through the magnifier, "That's the biggest picture I ever saw."
> (Interactive Observation)

> That things where you lift up the weights and they go down -and you measure how fast — gravitational forces — everything affected no matter how much it weighs — gravity affects them all the same.
> (Description of what they did, Phone Interview)

The evidence that visitors use instruments is, of course, related to the data illustrating the previous section on gathering evidence; the instruments available are the tools used for gathering evidence. The observations, tracking, exit and phone interviews all reinforced the view that the visitors *used* the exhibits; they measured, uncovered fossils, entered items on touch screens, cranked and released weights, handled the objects, etc.

The extent to which they used the specific instruments available — magnifiers, microscopes, computers, temperature probes, scales, electric volt meter, timers — can be gauged from the holding power of the components. In general, where instruments were available, they were used to the extent that the component was used.

When asked what they found most memorable from their visit (Exit interview, Question #2) visitors often referred to instruments they had used.

> The fish, I used to think sharks were the best designed, but I see the little fish have much more maneuverability. (Adult, Exit Interview)

> They recall the motion detector sensor…The black disks, figuring out what was the shape inside…How the computer measures changes in your skin temperature…The balance, I was on that for a half hour…The Dig thing, the midden, the survey thing, the computer. (Exit Interviews)

> We poured the hot and cold water into the cups. We put these long things into the cups. Then it showed us on the screen [she described this and pointed to the equipment in the photo]. (Exit interview, girl, 8-year-old)

Some of the previous quotations have already demonstrated that visitors did draw conclusions from their interactions with the exhibit components. They talked about what they had learned or concluded in their conversations, and they noted conclusions in responses to some of the questions in both exit and phone interviews. Many of the observations indicate that visitors come to some closure as a result of their interaction with the exhibit component. They used the instruments and often stopped when they had come to some kind of conclusion.

> A family. 1F 40-45; 1M 40-45; 1 M 17; 1 F 15; 1 M12
> Mom looks at racetrack. She walks around it slowly. She read the signs on the exhibit. Father and kids sit down at the Idea Station. They listen to the comments. They briefly discuss what they want to record. In unison they say, “We all agree that light makes a difference but we don’t know why.” They laugh. The father turns to the group and says, “Now let’s get out of here before anyone notices us.” The group walks out of the exhibit, with several of them repeating the chant that they’d just recorded.
>
> (Interactive observation)

> The motors were not working, the motor connectivity is improper…the tension prevents the motor from turning. It needs a gear. (Exit interview)

> The reason the temperature probe was such a hit, was we figured out what we were supposed to do. When you read it you understand and I could explain to my daughter what was going on. (Phone interview)

“Scientific habits of mind” are defined by Museum of Science staff as curiosity, respect for evidence, skepticism and open-mindedness (American Association for the Advancement of Science, 1989). Previous quotations illustrate these qualities since “habits of mind” are not separate from actions. Our observations suggest that they are present, but mostly need to be inferred.

> 3:27:45 — 3:32:01, M (11).
> This boy had been watching the previous group. He sits down. Carefully he places all the items in the container. He watches the read-out when allowing the items to drop from the height. He thoughtfully removes all the items considering and observing each one as he removes it. He replaces the items. He raises the device and lets the items drop. He seriously watches the read out when dropping the items. He repeats this procedure three more times, each time replacing all the items. The next time he does this he strokes his chin. As the items are dropped his expression changes and apparently he is pleased and satisfied. He makes a comment [inaudible to me to a younger boy (6) [brother?]. He get up and leaves.

> 5:15:09 — 5:26:11 PM, 1F (6); 1E (11) 1M, 1F (30)
> The group is at the Pulley Pit Station. They sit on the stools and begin winding. The mother sits down along side the younger girl and says "You need to set the timer." After they've done it a couple of times I suggest that the older one (who's been winning by working with the smaller gear belt) try the other side and see if there is any difference. She does so and tells me the wheel is the same to turn. I ask if there is any way to make her sled take less time. At first she says, no and then says, "Less weight." She tries moving the weights to the other sled. The girls continue to try it repeatedly, shifting the weights, and shifting who turns the wheels. Their attention span for this activity is longer than their parents' who suggest they try something else. The girls finally agree to do it "one last time." Then the whole family leaves.

Exit interviews also contain references to these qualities of the exhibition. Visitors indicated that the exhibition allowed them to figure out how and why "things" worked, that they were motivated to examine, hunt, find and do, and at least six used the word "curious" in their answers. Others mentioned that the exhibition allows you to learn for yourself through experimentation.

> In *Mathematica* [another exhibition] you sit and read. Everything is done for you. This is discovering it for yourself. I do love that. (Exit interview)

> Imagination, trial and error things, visual things. It either works or it doesn't work for them. Discovery. Curiosity.
> (Exit interview, response to Question #4-describe the exhibit.)

> They don't tell you how to do things. You must figure them out.
> (Exit interview)

Metacognition

The answers to a collective set of questions concerning visitors' understanding of the *kind* of exhibit they have visited are almost totally affirmative: visitors see *Investigate!* as an exhibit that is different from "traditional" museum exhibitions, as a place to experiment and investigate, and they do recognize that it has similarities to *Seeing The Unseen*. The exit and phone interviews provide the primary evidence for these conclusions, since these specifically give us visitors' conscious responses to the exhibition, their verbalization of what they believe.

- Visitors' response to the exhibit is almost unanimously positive. In response to the first interview question, where they were asked if they felt positive or negative about the exhibit, all but four of 87 responses were unqualified "positive."

- Another question asked visitors to compare *Investigate!* with two other permanent museum exhibitions, *Mathematica* (a more traditional exhibition) and *Seeing The Unseen* (the first component of the Museum of Science's new interactive exhibition strategy.) The responses both confirmed that visitors viewed *Investigate!* as about investigation, and that they viewed the two other exhibitions as different from each other.

A summary of answers to this question shows that 40% of the responses indicated a preference for *Investigate!* when compared to *Mathematica*, while only 24% of responses preferred it to *Seeing the Unseen*. More important, a significant number of responses indicated that visitors viewed both *Investigate!* and *STU* as interactive ("hands-on") while none recognized *Mathematica* as such.

- The delayed phone interviews supported the conclusion that, even after a three month interval, visitors recognized the exhibition as hands-on (mentioned by 37% of phone respondents) and that it was "different" from other exhibitions.

Social Interaction

The evidence that *Investigate!* fosters social interaction which leads to socially mediated learning is, again, overwhelming. All members of the evaluation team were struck by the wealth of exhibit related talk among the family groups and by the percentage of that conversation devoted to their interactions with exhibits; most people engaged with the exhibit and talked about their work. Visitors talked to other members of family groups, to strangers and to themselves.

> A family. 1M (9); 1F (11); 1F (13); 1F (36); 1M (37)
> The group enters the Midden. The girl [S—] and the boy [N—] go into the Big Dig. The mother goes over to the entrance sign and reads it. She goes over to the Big Dig and quotes the sign [about this being an ancient "garbage dump"] aloud to the children. The kids get focused on the idea presented by the sign. The mother sits on the edge of the Big Dig, leaning in and observing. The boy says "I uncovered a jaw bone." Mom asks, "Is it human?" A younger girl, also working in the Midden says "I discovered a beaver skull." The mother looks through the guide next to the Big Dig. She reads some of those statistics to the kids. The boy leaves the Big Dig and goes over to Table Dig #3. He calls his Mom over. She responds immediately. The boy says, "Look I found a fossil." S— comes over to the two at Table Dig #3. "What is this stuff?," she says pointing to the walnut shells. "Walnut shells," says Mom. S— comments, "They get in your shoes." N— is still fossil hunting, he says, "Wow, look at those teeth, Mom." S— leaves the table and comes right back with Dad. Dad says to N—, "You going to be an archeologist?" Mom sits down at Table Dig #2. S— is led away to the Computer Station by her Dad. "What do you think you've got there?" the mother asks to N—. "That's the way archeologists work. You've got to get the whole bone, you've got just the tip. "Dad comes back with the boy's hat which had apparently been lost. They discuss the hat momentarily, then Mom leaves and tells Dad to stay with N—. Dad does so, looks down at N—'s activity and says "Cool." Dad begins to sift also. "I'm going to work away at this, Dad," says N—. They continue to both brush and sift, without conversation.
>
> (Interactive observation)

> 1F (7); 1F (11), 1F (15), 1M (40)
> The group arrives at the station. The younger girl (7) and the man (40) sit on the stools. The other girls (11,15) are standing. The man gives instructions telling them to hold the probes. All are looking intently at the screen. The Father gets up and watches the screen. He says to the youngest "Your hand is like 90 degrees. It only

> goes to 77 degrees." They all walk away, the youngest remaining a moment longer than the rest.
>
> (Interactive observation)

> 2:15:30 — 2:21:18, 3F (<6); 1 F (7); 1F (9); 1F37
> The 5 girls are around the tank, each working a fish on a stick. [As I observe it becomes clear that two of the girls are sisters and the older woman is their Mom.] The woman reads the sign out loud, "check it out, try swimming..." The group seems to respond to her suggestion. The F (9) says, "this one's easier out in the ocean." The mother says, "I think you need to hold it up straight. Feel it swim." She steps back and watches. She moves back toward the tank again. "Why don't you trade [fish]. Twist it like this." [She demonstrates with one of the girl's fish.] "Does it feel different from the shark? Let your sister try the clown fish." She continues to read the sign aloud, "Not all fish live in open water." She points to the pictures. "See that's like the one you have, of course it's much bigger." The F (7) leaves the area. The two sisters remain. "We need another clown fish," says the woman. "Let's try the other clown fish." Another woman and a M (9) come over to the tank. The first woman says, "Give these other people a chance." The girls put down their sticks. The mother of the two girls assists her youngest girl in drying her wet hands with the electric hand dryer which is hanging on a nearby wall. The first woman says as they walk away, "I think this is the coolest thing we've seen all day." (Interactive Observation)

One notable aspect of the conversations, evident in the quotations above, was a great deal of "parenting" talk; parents educating their children. In the exit interviews many commented that the exhibit was educational, and parents appeared to be taking their parental roles as teachers of children seriously. This talk also covers an enormous range of different *types* of parenting/teaching methods. Although some parents are extremely patient with their offspring, guiding, suggesting and helping them to investigate, others make the characteristic "naming" or "announcing" statements that tend to curtail inquiry.

> Man [to child] "One fell faster, the tennis ball fell faster, why do you think it fell faster? (He points to the two timer numbers, one of which is .001 second lower than the other. Boy (11) "Because it's heavier?" Man, "Right."
>
> (Interactive Observation)

It would be too much to expect that a single exhibit at one Museum of Science should change a whole society's parenting practices!

Perseverance

A striking feature of visitor response to the exhibit was their perseverance in various tasks. Visitors spent long periods of time working at various stations with full concentration on the activities. The most obvious and simplest data in support of this conclusion is the tracking and other timing data that demonstrates the relatively long times they spent in the exhibit. Especially striking are the long "tails" on the visitor decay curves that show some visitors remaining for particularly extended periods. But there was also much additional evidence for this conclusion. One example is

the solar car area, one of the most popular in the exhibit and one where visitors spent relatively long periods of time. During most of the evaluation period, this component was not working as intended, the solar cars did not work. Yet, visitors spent minute after minute, fiddling with the cars, trying to make them work, adjusting wheels, rubber bands and positioning the motors.

The constant comments by parents that they could not pull one or another of their children away from the exhibits also attests to the perseverance. It was not uncommon for a visitor engaged with one of the components (Drop Stop particularly) simply not to hear what was said by a parent or companion.

> Woman (30) mother of little boy comes over, to end table, boy is in middle one). "What have we got here?" man (father, 30) comes over, that's a piece of jaw bone, He digs, she looks at reading and at notes. Man goes to child, she settles down, looks through magnifier, sweeps and observes. Man, "What are you finding, what have you got?" She reads, sweeps, he goes back to the boy, reads then comes back to her, they talk, "I've found walnut shells. What I've found is walnut shells." 3y old sweeps, woman goes to other table and sweeps on earth, then turns on light, studies objects, boy continues to play. Man and woman talk, man walks away to zoo field station, she reads, boy fills sieve, uses scoop, plays with walnut shells, he is absorbed. She reads, man reads zoo feed station. They start to go, she says softly to child, "Let's try something else." He responds, "I want to stay," also softly. Man goes off, woman stays at another station, more forceful "Let's do other stuff now." Child, "I want to do this!" also more forceful. Other couple arrives with child, they know each other, begin to talk. Other man goes to boy, moves light, "let's see your teeth." Child, "No." Boy continues to sweep and scoop, mothers talk…Man "All right, ready to go home." Child continues to sweep and dig. Mother goes away, other couple stays with boy. Boy continues to dig and sweep, looks around briefly, then back to "work." Other man, "The ambulance there turns its light on . . ." Boy ignores this but moves to big midden dig. He stumbles on way in, falls over, picks himself up, returns sieve to where it had been (he had clutched it in his hand) starts to dig in big pit with scoop digs, starts to play with slightly older boy from other family, mother and father come back, parents talk, kids dig. "Come on K—," he ignores this. Parents walk away, "OK, we'll see you sometime." Parent comes back and gets K— who leaves reluctantly. (Interactive observation)

Some of the visitors exhibited an extremely long focus on the investigation at hand. In several instances we observed a particular narrowing, or funneling, of focus by a long-engaged visitor. An example of this was a 15 year old male at one of the Table Digs in the Midden. Initially he began with general, typical "brushing." However, as he continued with his activity he became more and more specific in his investigation. Eventually, he had developed a particular interest in searching out and retrieving the tiny seashell fragments that were mixed in with the walnut shells and collected them in one location. He continued intently with his activity for close to a half hour.

> Two boys who are together, are working independently, at the solar cars. They are both 11 (I ask them). One (J—) shows me what he is doing, "Look, the rubber band is too heavy." He shows that the car wheels will spin if held in the air, but not if put down on the table. 13 minutes later, as we leave, J— is still working on his car, as

> is the other boy, over near the tables where parts are kept. 35 minutes after the first observation, the other boy finds us in another part of the exhibit. “Come look, I made it work!” He takes us back to the track. Shows us that his car will move slowly down the track. “The rubber band has to be loose to make it work.” He demonstrates that there is more motion if band is loose than if stretched tight. (Interactive observation)

> The M (10) moves back to his original position at the Station. He murmurs [what sounds to me like] “I got to try..., I got to try...” as he put items in, raises them and then drops them, he watches the screen, not the device. He verbalizes the numbers on the screen aloud. A woman comes up behind him. She asks, “You know what you’re doing?” “Yeah,” he says, still facing the Drop. “What’s your objective?” says the woman. He doesn’t respond. “See,” she says, pointing to the screen, “There’s your drop time.” He say, “I know.” He continues his activity, watching the screen and quietly mouthing the read out. I ask him if he’s working on something special. He says, “No.” and seems reticent to speak with me. He reads the last numbers on the screen and then leaves.
>
> (Interactive observation)

Staff Assistance

Although visitors spent a long time at the exhibition and clearly engaged with many of the components, there was a strong sense that at least some visitors, and some components of the exhibit, would benefit greatly from the continual presence of staff who could serve two role, as “explainers” or guides to assist the visitors’ investigations and experimentation, and as monitors for early indications of any problems with components not working properly.

A particularly striking example of the impact of an intervening “staff” member was found in the results from our interactive observations of the temperature station. On the whole, visitors did not understand the experimental situation that was intended, and did not find any other investigation to carry out with those materials that interested them. Thus the time spent at this station was low in comparison to other exhibitions, and there is little evidence of engagement. But an intervention by the observer allowed visitors intellectual access to the inquiry, and greatly enhanced interaction with the component. The following two excerpts from observation notes indicate typical, qualitative differences between the two types of interaction.

> 2:15:02 – 2:16:00, 2F (8); 1M (9); 2F (16)
> One of the F (8) reaches the Station first and grabs hold of one of the probes. “What are you doing J—?” says one of the F (16). The same F (16) begins to read the sign aloud. The boy comes over and says, “What are you supposed to do here?” No one answers. They all walk off.
>
> (Interactive Observation)

> 2:19: 03 – 2:26:58, 1M (11)
> A boy (11) comes over to the station. He pokes at the cups. He begins to walk off. I ask him if he knows how to work it? He says, “I don’t know what to do.” I suggest to him that he read the sign. He does. He begins to walk away again. I ask him if he’s got a friend with him with whom to shake hands. “If not,” I say, “you can shake

> my hand." "Or," I say, "you could just check out how warm your own hand is with the probe." He grips the yellow probe and I press the start button. He watches the monitor. He squeezes the probe harder and continues to watch the screen. He lets go of the probe. I ask him if he wants to test the temperature of the water. He immediately fills the cups with hot and cold water. He places the probes in the water and watches the read out. His eyes get big as he sees the graph change. I say, "I wonder if you could get the green and yellow lines at the same level?" He says, "It will be tricky, but I'll try." He mixes the waters back and forth between the cups. He places the probes into the cups. He watches the read out. He adds hot water and then cold water to the cups, checking the graph as he goes. Ultimately after several minutes of adjusting the water, he has matched the lines up. He is quite animated. A young man (22) [apparently unknown to the boy, but interested in what's happening] is looking over the boy's shoulder. We share what he's been doing with the young man. The young man leaves. The boy tells me he is going into fifth grade. I ask him if he studies science in school and he says they did last year. He leaves. (Observation, 8/18/96)

The time differences recorded for the two types of interaction provide dramatic quantitative support for the powerful impact of an interpreter on visitor behavior at the exhibit component. Comparative visitor decay curves and times are illustrated in Figure 3 and Table 4.

Because many visitor groups by themselves were either not interested in or could not understand the investigation proposed by the temperature station, the effect of an intervening staff member was particularly striking at this component. At other stations, where visitors designed their own investigations, or used the instruments in personal ways, the consequence of intervention was more qualitative than quantitative, resulting in different types of interaction rather than replacing non-interaction with engagement.

DISCUSSION

The sections above illustrate the application of qualitative methods to evaluating an exhibition and the power of such methods to illuminate visitor interaction in a way that can be useful to exhibition designers. Another necessary aspect of such methods is for them to allow insights into visitor activities that were not necessarily anticipated by exhibition designers. We were able to develop several such themes from the data. The following selections illustrates our conclusions.

These methods were particularly appropriate for a study of this exhibition, because the Museum attempted to present a complex picture of what "doing science involves." the content of the exhibition could not be gathered by studying the text, it required that visitors interact with exhibit components. And just as "doing science" is an ongoing activity, so the intention was to develop an exhibition that could be visited repeatedly and provide opportunities for visitors to investigate.

The style of this exhibition brings with it both strengths and issues that need to be considered by all who are interested in interactive science exhibitions. Some of these issues, as they were illustrated by our data are discussed below.

Doing Science

The Museum of Science has accepted a definition of "doing" science that, although widely recognized among scientists as describing inquiry, problem solving, and other characteristics of science, differs markedly from some textbook descriptions of *the* scientific method, that stipulate an ordered sequence of observation, hypothesis, testing, and reformulation of hypothesis. These components were often present in the visitors' actions, but not as isolated recognized actions, illustrating the difficulty of separating out the "steps" of actual scientific activity.

Some visitors and other observers, who may have had a more formal concept of scientific inquiry in mind, categorized visitors' behavior differently. The exhibition did not meet their standard of didactic pedagogy.

> In terms of kids, [it would be good if there were] simpler explanations for parents. They should tell what the end results will be, such as 'it will topple with three,' and then it could be a great learning experience. In a museum experience there is a short attention span as opposed to a classroom experience. Because of the time factor they should have the answer." (Phone interview)

> We thought it was too disorganized, chaotic really — you couldn't learn there, there was no structure to learning. Typically American, a flash but no substance, nothing to stay with you. (Marketing exit interview)

> I was critical. It's a couple of months ago. . .what I found difficult about the exhibit is that I thought for the youngsters, while you were looking for them to give a result, they didn't know what they were supposed to find out. [I] think the kids should have been given the answers. I think that other kids we saw should not just play. (Phone interview)

Unintended Use of the Exhibition

There can be no doubt that visitors *use* the exhibition. A more subtle question is whether they use the exhibit as intended. The exhibition consists of interactive elements; hands-on stations where people can do things. And they do, according to their own interests. This visitor activity may or may not be the one designed, and it may or may not be scientific experimentation, depending on the interpretation of the observer. This characteristic of visitors to invent their own modes of interaction was captured in one of the newspaper articles published at the time of the exhibition's opening.

> This is what the exhibit is designed to do: recreate Galileo's famous experiment of dropping different weights from the top of the Leaning Tower of Pisa, proving that objects of differing weights fall at the same speed…Here's what the kid was doing instead: Figuring out the mechanism that stopped the buckets from rising whenever he opened the little doors that let users put weights in the buckets. Having figured that out, he was testing his reaction time by seeing if he could open the door fast enough, after the weights started falling, to catch them before they hit the bottom.(Chandler, 1996)

Similarly, we have seen many instances of visitors doing something different from the intended activity. A striking instance is afforded by the solar cars, where the intended activity — racing solar powered cars with different wheels and varied configurations down a raceway — was not possible during most of our observation period because the cars didn't work very well. But the visitors turned the exhibit into a problem solving exercise and, even though most who tried didn't get the cars to work very well, it was an active, popular stop with visitors hard at work at a respectable scientific investigation.

The midden presented a different sort of variation from the intended activity. There was considerable repetitive activity, just brushing walnut shells off fossils, or, especially on the part of younger children, pouring, sifting and "playing with" the walnut shells; the shells themselves became a focus of inquiry! Much of this observed activity reminded us of the kind of repetitive play typically seen with young children interacting with the natural world. It is not problem solving scientific inquiry as usually carried out by adults; but the phenomenological exploration of the world necessary for future scientific inquiry. Both children and adults explored the unusual medium of walnut shells with interest.

In contrast, temperature probe was a station that was difficult for visitors to engage with in a rich and rewarding way without the intervention of a staff member. Here the activities were often not what was intended, and they tended to be short for those visitors who could not create investigations that provided them with enough interaction and reward to continue.

Other components provided similar instances of intended and unintended activities, some of which were rich and rewarding investigations, others of which were less satisfying and engaging for the visitors.

We did not observe much random, unengaged action, that is, "hands-on" without "minds-on." The push-the-button-and-leave-before-anything-happens syndrome fostered by some types of exhibits was not a common occurrence during our observations. On the whole, either people did not "engage" with a component and left after a short time to investigate something else, or they became absorbed and made a significant time commitment.

Races or Competition

Several of the exhibit components — drop stop, solar cars, pulleys, for example — set up scientific experiments in the form of races or competitions so that the visitors can see which goes/drops faster, etc. This style of developing exhibits is common, especially in ones designed to illustrate various aspects of gravity. It hearkens back to experiments by Galileo and others who demonstrated that, for example, acceleration due to gravity is *independent of* mass.

Unfortunately, the race analogy, although appealing to visitors and especially to children, (see Hein, 1968) is perhaps not the best model to use in all situations. The “race” mode of thinking includes having a winner, no matter how close two results are. In horse racing, we resort to taking photographs to avoid a tie; in baseball, after a season of 162 games, one team wins even if its winning percentage is only a fraction of a decimal; in soccer elaborate tie breaking procedures are followed in world cup matches. The point of a race is, if necessary, to focus on very small differences in order to decide on a winner. Thus, once a situation is set up as a race, the visitors try to find the small differences that would permit declaring one trial to win out over another.

For example, they focus on the minute differences in timing recorded by the accurate timers at the Drop Stop. But the point of these experiments is that the differences found are much smaller than could be accounted for by the different properties of the objects used in the trials. Thus, the issue is not which one won, but whether a large enough difference is observed so that it can be attributed to the different characteristics. The model for such situations should not be races, but other types of uses of numbers where only large differences are important and small ones are ignored. (For example, School grades awarded in a class are such a use of numbers; students who get approximately the same grades on individual quizzes and tests end up with the same overall grade; boxing or wrestling weight classifications are another, although the cut off weights are exact, a 195 lb. and a 200 lb. boxer fight in the same class, the difference in weight (at least within a class) is usually not the contributing factor as to which one wins.)

The challenge of a race may be beneficial at some stations — the effort to make the solar car go faster may lead visitors to understand more about the mechanics of friction and the relationship of gears — but it is not a universally fruitful metaphor for scientific inquiry and should be considered carefully in each instance.

Complex Messages

Investigate! includes an overall theme and design that differentiates between "asking questions," "designing experiments" and "drawing conclusions." Various sections of the floor space are intended to highlight each of these processes. In addition, there are themes within areas. For example, the set of components in the midden section present a story about a particular archeological dig and the final video station provides two different interpretations based on all the evidence presented.

We have little evidence that visitors understood this complex set of messages about the exhibit. It involves a rather sophisticated engagement with the entire exhibit over a long time before some of these themes emerge. The field observers did not note these themes until they had watched for several days, spending much more time each day than any visitor group.

Since the open, interactive nature of the exhibit allows visitors to sample the elements and since there is little evidence that they visit a majority of components, it is not likely that these larger themes will become clear to first (or even second) time visitors. The advantage of this complexity is that there will be new depths of meaning at the exhibit for visitors to explore at subsequent visits.

Return Visits

We encountered a number of visitors who were making return visits to the exhibition, and our delayed phone interviews indicated that visitors did or intended to come back.

CONCLUSION

Investigate! is definitely an interactive exhibition and is thoroughly used by visitors. It provides a rich opportunity to study visitors and illustrates the many ways in which visitors make personal meanings in exhibitions when provided with an opportunity to so.

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Figure 1

LESLEY

Evaluation Matrix

Museum of Science
Investigate!

	Tracking study	Exit Interview	Interactive Observation	Grad. Exhibit class report	Undergrad. psych. studies	MOS small studies	Market Survey Quest.	Delayed phone int's.
Ed Goals—visitors engage	X	X	X	X	X	X	X	X
visitors ask q's and form h's.			X		?	X		
gather, record evidence		X	X		?	X		
use instruments	X	X	X	X	?			
draw conclusions			X				X	X
use thinking skills (habits)			X		X	X		
Metacog—how do they describe it?		X	X				X	X
Metacog—recognize difference?		X					X	x
Behavior—what do they do?	X		X	X			X	
Behavior—social interaction			X					
Connections to outside		X	X					X

Figure 2

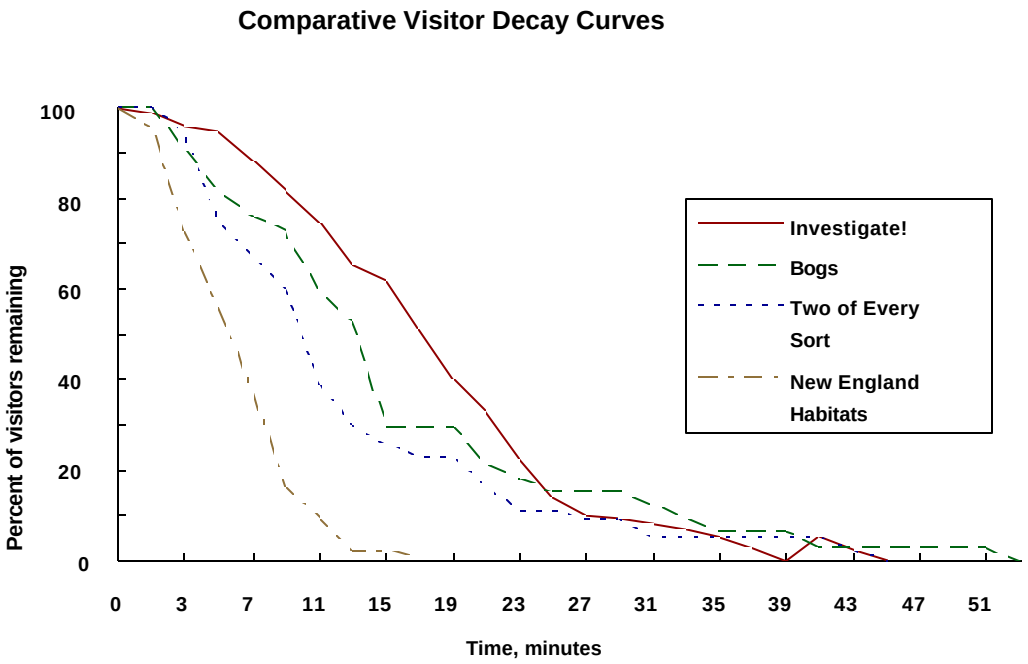

Table 1

Visitor Times for Four Exhibitions

	New England Habitats	*Two of Every Sort*	*Bogs*	*Investigate!*
V_{50} value, in minutes	5.6	9.7	13.2	17.3

Figure 3

Visitor Decay Curves,
Exhibition Components

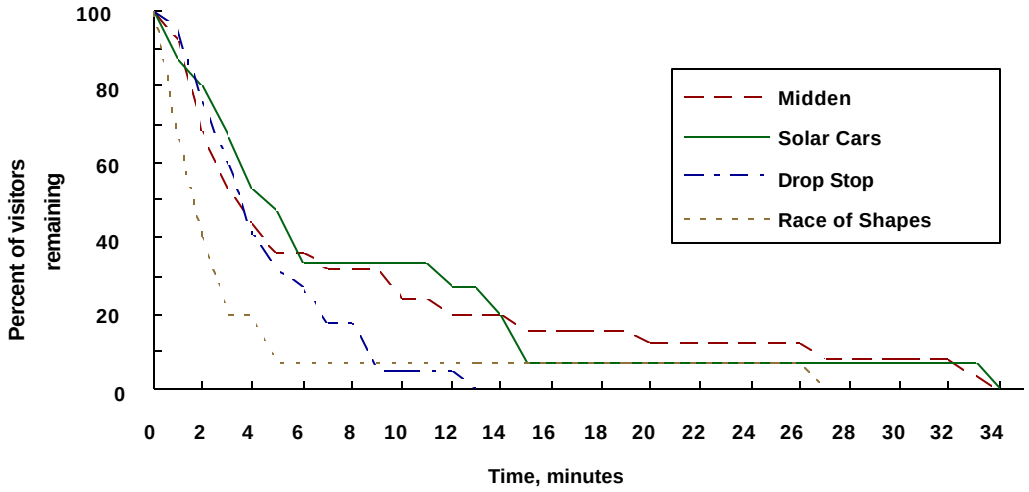

Table 2

Average Visitor Times and V_{50} times for Selected *Investigate!* Components

Component	*Average Time*	*V_{50} Time*
Midden	9.0	3.2
Nails	8.3	4.7
Solar Cars	7.8	4.6
Drop Stop	4.3	3.5
Race of Shapes	3.6	1.6
Temperature Probe	1.5	1.0

Table 3

Holding Power: Visitor Stops of Long Duration

Stops longer than:	Number	Number of components represented
5 seconds or more (Total stops recorded)	795	39
1 minute	469	39
2 minutes	269	28
3 minutes	139	26
5 minutes	30	14

Figure 4

Visitor Decay Curves,

Temperature Station

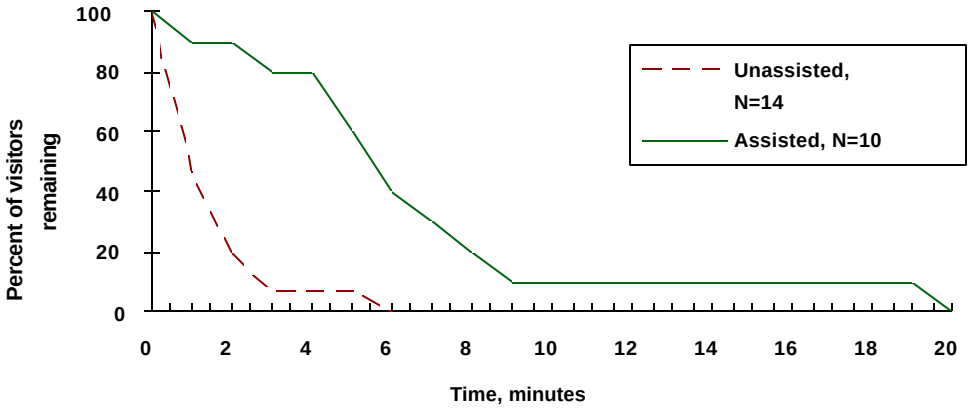

Table 4

Times at Temperature Probe Station Unassisted and Assisted

Time (min:sec)	*Unassisted, N=14*	*Assisted, N=10*
Range of time	0:10-5:51	0:10-20:00
Average time	1.4	6.3
V_{50} half life	1.0	5.5