Lessons from Observations of Educator Support at an Engineer Design Activity

Research Report

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EXECUTIVE SUMMARY

This study was conducted to document how members of the *Design Challenges* team currently assist visitors as they engage in engineering design activities as a way of informing the practices of informal technology education at the Museum of Science about the types of scaffolds and supports visitors need when engaging in future engineering design labs in exhibitions. To collect data for this study, educators from the *Design Challenges* team were observed as they helped visitors complete the "Solar Cars" activity in *Investigate!* The "Solar Cars" activity was not designed as an engineering design lab but as a constructivist activity that engaged visitors in practicing science thinking skills. Nevertheless, it contains many of the characteristics of an engineering design lab making it possible to use this activity for the study. In order to better understand the supports needed for an engineering design activity, the behaviors and discussion of educators and visitors at the activity were recorded. In addition, twenty visitors were interviewed after they completed the activity, and the educators were debriefed at the end of each data collection session.

Evaluation Questions:
1. When, during the course of the "Solar Cars," do visitors seek the help of the education staff?
2. When, during the course of the "Solar Cars," are the educators most likely to offer the visitors help and assistance?
3. In what ways do the visitors feel that the educators influence/contribute to the learning activity?

Findings:
1. Educators and visitors mentioned a number of supports educators provided to visitors including:
    a. Clarifying the goals and providing sub-goals,
    b. Supplying the visitors with needed instructions, and
    c. Helping the visitors work through activity problems.
2. Educators and visitors did not mention other supports educators provided to visitors including:
    a. Providing encouragement and
    b. Prompting the visitors to try again.
3. When educators provided positive reinforcement by encouraging visitors and telling them to try again, visitors completed significantly more build/test iterations.

Implications for Future Engineering Design Labs:
1. The supports discovered through this study corresponded with visitors moving smoothly through the steps of the engineering design process.
2. The supports are areas that should be investigated further because they may indicate places where scaffolding is needed in engineering design labs.
3. The supports do not necessarily indicate that scaffolding is occurring.
4. The supports should be focused on as areas of concern in the design of engineering design labs because visitors may need support in these areas when they are participating in these activities without facilitation.

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I. INTRODUCTION

In recent years, the museum field has come to understand learning as a social process where visitors learn as they interact other individuals at exhibits (Ash, 2003; Borun et al., 1998; Falk & Dierking, 2000; Leinhardt, Crowley, & Knutson, 2002). This understanding stems from socio-cultural theories of learning, and is grounded in the work of various scholars including Vygotsky (1980), Engestrom, Miettinen, & Punamaki (1999), and others. Scaffolding is a concept derived from socio-cultural theories about learning, which posits that with the support of *scaffolds* (such as a facilitator or programmatic design) a person can accomplish a task which he/she would not be able to complete independently (Larkin, 2002). This theory builds upon Vygotsky's notion of the zone of proximal development which covers the range between the learners' independent abilities and what they can accomplish with help and support.

Through its new vision for informal technology education, the Museum of Science has become committed to teaching visitors about technology and engineering by engaging them in the engineering design process. As the Museum begins to envision the types of activities that engage visitors in this process, there have been discussions about how much of the process visitors will be able to engage in without help as well as what types of scaffolds and supports they will need. *Design Challenges* educators (who run a drop-in program for school and family groups) already work to assist visitors during engineering design experiences as a part of hands-on activities that ask visitors "to design, build, and test a prototype solution to a given problem" (Museum of Science, 2007). Therefore, these educators have become expert in scaffolding visitors' learning during the engineering design process. By observing these expert staff interacting with visitors and documenting the ways in which they guide visitors through engineering activities, lessons can be learned about the types of scaffolds and supports visitors need as they engage in these activities in the museum environment.

In this study, the *Design Challenges* educators were observed as they aided visitors using the permanent Museum of Science exhibit "Solar Cars," which is in the *Investigate!* gallery. This exhibit is a constructivist activity where visitors practice science thinking skills as they come up with their own questions to investigate, and test the answers to these questions using the solar cars. Despite the fact that the activity is not designed to be an engineering activity, the exhibit contains characteristics that make it similar to an engineering activity: a prototype is created which is tested and refined as the visitor attempts to achieve any of a number of activity goals. In order to change the "Solar Cars" into an engineering activity, the educators picked one goal for the "Solar Cars" and asked the visitors to try to achieve it. That goal was to design a solar car that can travel the track in 12 seconds. To achieve this goal, visitors were able to change the wheels, pulley, position of the motor, and the track's light level. To explore educator support at the "Solar Cars," the following research questions were devised:

- When, during the course of the "Solar Cars," do visitors seek the help of the education staff?
- When, during the course of the "Solar Cars," are the educators most likely to offer the visitors help and assistance?
- In what ways do the visitors feel that the educators influence/contribute to the learning activity?

The planning for this evaluation began in March 2006. Educators were observed helping visitors at the "Solar Cars" activity during July and August 2006. The final evaluation report was released in August 2007.

II. METHODOLOGY

Data were collected at the Museum of Science, Boston in the summer of 2006. Multiple methods of data collection were employed including behavior checklists, exit interviews, and educator debriefs. By using multiple data collection methods, the evaluator was able to develop a more complete picture of how educators facilitated the "Solar Cars" for visitors (Table 1).

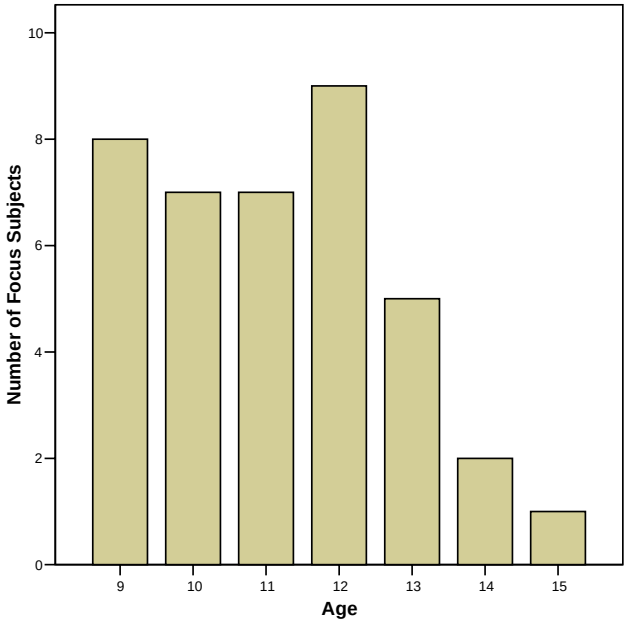
TABLE 1. Methodology Matrix.

Evaluation Questions	Data Collection Methods		
	Behavior Checklist	Exit Interview	Educator Debrief
In what ways do the visitors feel that the educators influence/contribute to the learning activity?		X	
When, during the course of the "Solar Cars," do visitors seek the help of the education staff?	X	X	X
When, during the course of the "Solar Cars," are the educators most likely to offer the visitors help and assistance?	X	X	X

SELECTION OF STUDY PARTICIPANTS

Groups were chosen for participation in the study as they began their interaction with the "Solar Cars" activity based on two factors: the age of the children in the group and the presence of an adult. *Design Challenges* are meant to be used by students between the 4th and 10th grades. Therefore, evaluators did their best to observe groups with children in this age range although sometimes older or younger children were a part of participating groups. Groups without adults were avoided because children cannot be interviewed without adult permission, per the Museum's IRB guidelines. Despite the fact that Museum of Science visitors often participate in activities with a group, one child in each group was chosen as the focus subject for the observation and the exit interview because it is difficult to make observations of multiple members of a group. Using these methods for choosing subjects, 28 of the 39 focus subjects whose genders were recorded were male, and the average age of the focus subjects whose ages were recorded was 10.9 (SD = 2.4). In addition, all the focus subjects were between the ages of nine and fifteen (Graph 1).

GRAPH 1. Ages of Focus Subjects (N=39).



BEHAVIOR CHECKLIST PROTOCOL

Forty groups were observed working on the "Solar Cars" activity in *Investigate!* with *Design Challenges* staff and interns. The evaluator filled out a behavioral checklist for each group, looking for specific behaviors that occurred during the facilitated engineering design activity. While evaluators recorded the demographic information of everyone in the group, they focused on the behaviors of a single individual called the "focus subject." The behaviors that evaluators were looking for included the following:

- Whether the focus subject or educator was building or tinkering with the solar car;
- Whether the focus subject or educator was testing the car on the track;
- Whether the focus subject was talking with other members of their group; and
- Whether the focus subject or educator initiated each discussion/exchange.

In addition, the evaluators recorded any discussion between the educators and the focus subject. Each time the focus subject or an educator changed between building, testing, or discussing without building or testing, evaluators recorded it as a different "behavior unit." Evaluators had an inter-observer reliability rate of 89%. A copy of the behavior checklist can be found in Appendix A.

EXIT INTERVIEW PROTOCOL

Nineteen of the 40 observed groups and one unobserved group were interviewed as they left the "Solar Cars" activity in *Investigate!* Other observed groups were not interviewed for various

reasons. Four groups could not be interviewed because no adults were present. One group was not interviewed because the focus subject was a foreign language speaker. Two groups were not interviewed because they interacted at the activity for a minute or less. Other groups refused to take part in the interview or were not caught by the evaluators before they left the "Solar Cars" area. The exit interview was conducted to gain information from the focus subject, so questions were targeted at this individual. Visitors were asked questions about:

- Times when he/she felt frustrated at the activity and wanted help;
- What he/she found most helpful about speaking with a Museum of Science educator; and
- Ways in which talking with the Museum educator was not helpful.

A copy of the exit interview can be found in Appendix B.

EDUCATOR DEBRIEF PROTOCOL

At the end of each data collection session, educators were debriefed about their experiences with visitors. They were asked questions about:

- Parts of the "Solar Cars" activity they felt visitors had a difficult and easy time with;
- What visitors asked them questions about;
- When they helped visitors even though they did not ask for aid; and
- What they would change about the "Solar Cars" to make it a better learning experience.

A copy of the educator debrief can be found in Appendix C.

DATA ANALYSIS

By collecting data in a variety of ways, the evaluator was able to triangulate the data. The logic behind triangulation is that "no single method ever adequately solves the problem of rival causal factors" (Patton, 2002, p.247). Therefore, if data is collected through many sources, evaluators can avoid the problems of a one-method study, which is "vulnerable to errors linked to that particular method (e.g., loaded interview questions, biased or untrue responses)" (Patton, 2002, p.248). Studies that utilize multiple methods allow "cross-data validity tests" (Patton, 2002, p.248), and thus reduce the likelihood that the evaluator will draw a false conclusion based on the limits of any one instrument. In this case, data from exit interviews, behavior checklists, and educator debriefs were compared to ensure that findings are not susceptible to error, and to allow for an exploration of differences among data. However, because visitors were observed at only one activity, data analysis cannot necessarily predict visitors' needs at every engineering design activity.

Data collected through the instruments were both qualitative and quantitative in nature. Quantitative data were analyzed through descriptive statistics such as percentages and counts. In addition, comparative tests of significance were sometimes conducted. Qualitative data were analyzed using inductive coding. Inductive coding analysis involves "immersion in the details

and specifics of data to discover important patterns, themes, and interrelationships" (Patton, 2002, p.41).

III. RESULTS

Data were collected through behavior checklists, exit interviews, and educator debriefs in order to gain an understanding of the interaction between visitors and educators at the "Solar Cars" activity. The data is split by instrument in this section, and the implications of the data are argued in the Discussion section.

1. BEHAVIOR CHECKLIST

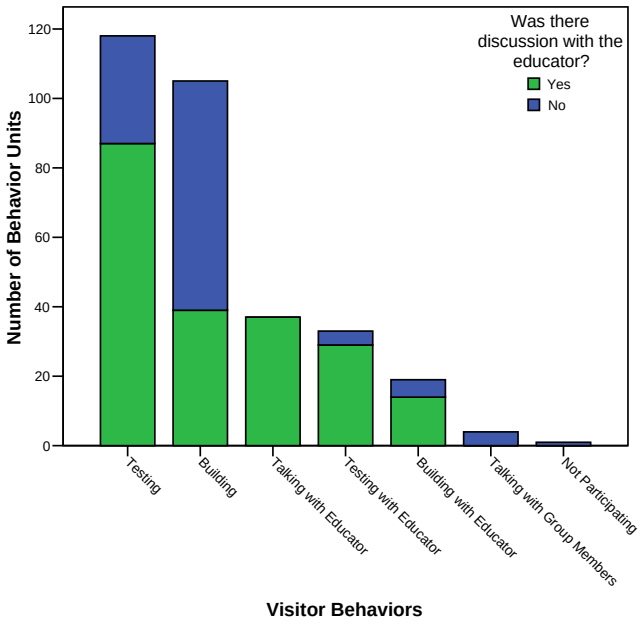
In order to describe the behaviors of visitors and educators at the "Solar Cars" activity, the behavior checklist data were split by these three categories in the sections below:

1. Behaviors visitors displayed at the "Solar Cars" activity.
2. Behaviors educators displayed at the "Solar Cars" activity.
3. Discourse of visitors and educators at the "Solar Cars" activity.

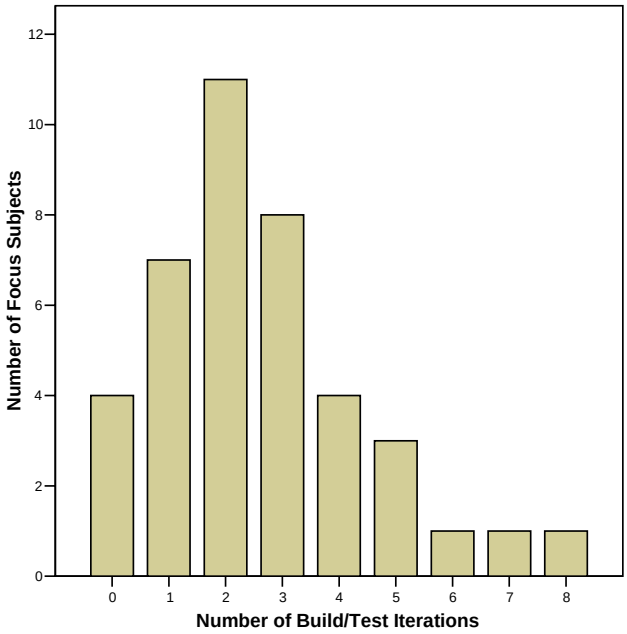
1.1 Behaviors visitors displayed at the "Solar Cars" activity.

The behavior checklist was set up so that each time the focus subject or the educator working with the focus subject engaged in building, testing, or discussion, a new behavior was recorded. Over the course of the 40 observations, 336 of these behavior units took place, and 317 of the behavior units involved actions taken by focus subjects. Sometimes educators were also involved in the behaviors by either talking with the focus subject or helping them with building or testing. The data show that the focus subjects spent 118 of the behavior units testing their solar cars by themselves, and that during 87 of these behavior units the focus subject talked with an educator. The focus subjects spent slightly fewer behavior units building their solar cars alone (105 behavior units), and during 39 of these behavior units they talked with educators. Visitors spent fewer behavior units talking with one of the educators while not building or testing (37 behavior units), testing with the educator's help (29 behavior units with discussion and 4 without discussion), building with the educator's help (14 behavior units with discussion and 5 without discussion), talking with other members of their groups while not building or testing (4 behavior units), and not participating in the "Solar Cars" activity (1 behavior unit) (Graph 2).

GRAPH 2. Number of Behavior Units Focus Subjects Spent on Different Behaviors Split by Whether the Focus Subject Talked with an Educator (N=317).



GRAPH 3. Number of Build/Test Iterations Completed by Focus Subjects.



Another way to understand visitors' interactions at the "Solar Cars" activity is to think about how many times they completed different engineering design cycle steps. In order to complete the engineering design cycle, it is necessary for visitors to go through a series of

steps (ask, imagine, plan, create, test/improve). In the case of the "Solar Cars" activity in *Investigate!*, visitors learn about the activity (ask), think about their solar car design (imagine), build their solar car (create), test their solar car (test), and then re-design, re-build, and re-test their solar car (improve). An important part of successfully completing the "Solar Cars" activity is re-testing the solar car and improving the design (build) multiple times. Evaluators found that the focus subjects completed between zero and eight of these build/test iterations, and that most of the focus subjects (29 of 40) completed two or more build/test iterations (Graph 3).

During the course of the interaction, many of the focus subjects encountered maintenance or design problems with various parts of the solar cars and track including the car motor, the rubber band connecting the car motor to the wheels, and the lights on the solar car track. Activity problems were discussed with the focus subjects between zero and four times while they were at the "Solar Cars" (Graph 4). The data show that educators never had to discuss maintenance problems with 16 of 40 focus subjects, that they had to discuss maintenance problems once with 16 of 40 focus subjects during their interactions, and that they had to discuss maintenance problems between two and four times with eight of the focus subjects. Twenty-five of the problems were discovered during the testing phase, and 10 of the problems occurred during the building phase (Table 2).

GRAPH 4. Number of Problems Encountered by Focus Subjects (N=40).

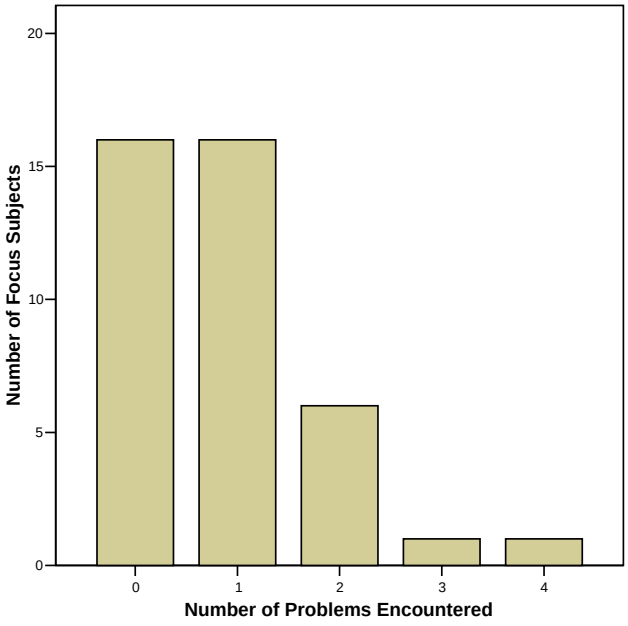
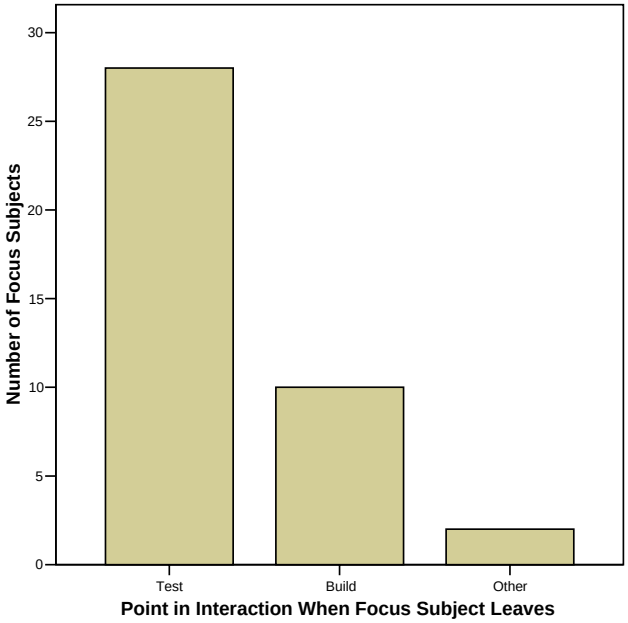


TABLE 2. Number of Times Activity Problems Were Encountered During the Test and Build Phase of the "Solar Cars" (N=35).

	Number of Times
Test Phase	25
Build Phase	10
Total	**35**

Visitors left the "Solar Cars" during different phases of the activity. Of the forty focus subjects, over half (28 focus subjects) left during the test phase of the activity, ten focus subjects left during the build phase of the activity, one left while they were talking with other members of their group, and another one left after talking with one of the educators (Graph 5). When trying to find a reason that the focus subjects left the activity, it was found that seven of the focus subjects left when they encountered a maintenance problem with the activity. Others left because they were finished at the activity, or because their group pulled them away, but these data were not recorded.

GRAPH 5. Point in the Activity when Focus Subjects Left the "Solar Cars" (N=40).



1.2 Behaviors educators displayed at the "Solar Cars" activity.

The data described above focus on the behaviors visitors displayed at the "Solar Cars" activity, but they do not completely describe the behaviors that the educators displayed. Looking at educators' behaviors, it is discovered that educators actively participated in 108 of the 336 total behavior units observed. The most common activity educators participated in with the visitors was talking (37 behavior units). Educators also helped the focus subjects as

they tested their solar cars (33 behavior units), and during 29 of these behavior units, they talked with the visitors. Less often, the educators helped the focus subjects as they built their cars (19 behavior units), and during 14 of these behavior units, they talked to the visitors. Other times, educators were observed to build parts of the solar car without the help of the focus subject (15 behavior units), but this occurred less often than the previous behaviors. During five of the behavior units when educators helped visitors build their cars, the educators talked to the focus subjects. Finally, educators spent the least number of behavior units testing the solar cars without the help of the focus subjects (4 behavior units). Educators talked to the focus subjects during all four of these behavior units (Graph 6).

GRAPH 6. Number of Behavior Units Educators Spent on Different Behaviors Split by Whether the Educator Talked with the Focus Subject (N=108).

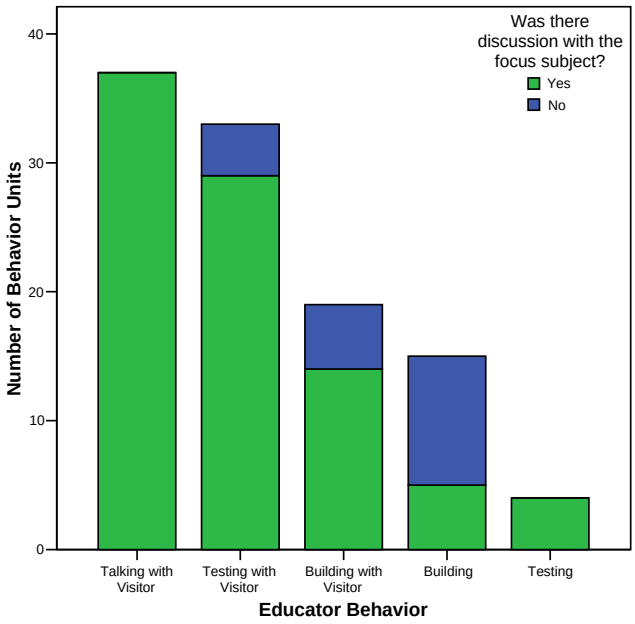


TABLE 3. Number of Behavior Units That Educators and Focus Subjects Initiated Discussion (N=215).

	Number of Behavior Units
Educator	189
Focus Subject	26
Total	**215**

Graphs 2 and 6 indicate that educators often talked to visitors during the course of their interaction at the "Solar Cars." Sometimes these discussions took place when the focus subjects or educators were also building and testing, and sometimes these discussions occurred when no other behavior was taking place. Of the 336 behavior units that were observed, conversation between the focus subject and an educator took place in 215 of them.

Evaluators found that 189 of these discussions were initiated by the educator, and 26 were initiated by the visitors in the group (Table 3).

1.3 Discourse of visitors and educators at the "Solar Cars" activity.

Discussion was a major part of educators' interchanges with visitors at the "Solar Cars" activity. Analysis of this discourse shows that visitors talked to educators about many issues relating to the activity. Visitors were most often observed answering questions posed by educators about the activity (18 occurrences). Visitors also made comments to the educators about what they observed occurring at the activity (6 occurrences). These comments included those such as the following: "I thought [the car] would go faster" (Group #26). Other visitors asked educators questions about the testing process (4 occurrences) like, "Why does [the car] go to the side [on the track]?" (Group #18) Finally, some visitors made social comments to the educators (4 occurrences) such as, "I built my own solar car before" (Group #29) (Table 4).

TABLE 4. Things that Visitors Said to Educators at the "Solar Cars" (N=336).

	Number of Occurrences	Percent of Behavior Units	Quotes
Answer Question for Educator	18	5%	Educator: "See what happened there?" Visitor: "Rubber band came off." (Group #6)
Activity Comment	6	2%	"It's going faster…" (Group #32)
Test Question	4	1%	"Why does it go to the side?..." (Group #18)
Social Comment	4	1%	"I've wanted to do this every time I've been here, but it's been busy…" (Group #28)
Visitor Service Question	3	1%	"What time is it?" (Group #32)
Imagine Question	2	1%	"What are you doing?..." (Group #18)
Create Question	2	1%	"How would you make the rubber band tighter?" (Group #37)
Next Step Question	2	1%	"...Where do you put it?" (Group #2)
Activity Problem	1	0%	"Our rubber band fell off…" (Group #10)
Initiate	1	0%	"What is this?..." (Group #2)
Next Step Comment	1	0%	"We're ready to race..." (Group #38)

TABLE 5. Things that Educators Said to Visitors at the "Solar Cars" (N=336).

	Number of Occurrences	Percent of Behavior Units	Quotes
Test Instruction	47	14%	"Hold it up, make sure these turn..." (Group #1)
Set-Up and Goal	36	11%	"You understand the challenge? Get from that red line to that in 12 seconds. You can change the pulley, wheels on each axel. Put the connectors on like this or the wheels will fall off. " (Group #5)
Try Again	35	10%	"...You can change the wheels or pulley." (Group #5)
Activity Problem	34	10%	"If the rubber band won't stay on this one, you can try this one." (Group #12)
Imagine Question	29	9%	"What do you want to change?..." (Group #2)
Build Instruction	24	7%	"You can use different types of wheels as long as the wheels on the axels match." (Group #7)
Encouragement	20	6%	"Wow, that's really good (12.13 sec)…." (Group #32)
Create Question	16	5%	"... Do you want the wheels closer in or further out?..." (Group #10)
Initiate	15	4%	"Do you want to build a solar car?" (Group #11)
Test Question	14	4%	"Did you want to go and test it?..." (Group #2)
Solar Car Information	9	3%	"...On a real solar car this wouldn't happen because real solar cars use a battery." (Group #12)
Correct Time	8	2%	"...That was just about perfect …" (Group #12)
Goal	8	2%	"...Experiment with ways to change it to make it 12 seconds." (Group #13)
Next Step Question	8	2%	"You ready to test?" (Group #7)
Give Answer to Visitor	8	2%	"It's telling us it took a lot of energy to get the car to start." (Group #1)
Other	5	1%	"Alright, let's see." (Group #7)
Answer Question for Visitor	4	1%	"...Put it on the big pulley to make it go faster." (Group #39)
Next Step Instruction	4	1%	"...Change the pulley. You can change it over there." (Group #18)
Solar Power Info	3	1%	"...It works by the sun…" (Group #24)
Policing	3	1%	"What are you guys doing? Are you in school?" (Group #16)
Social Comment	2	1%	"…I'm glad you got to try it." (Group #28)
Social Question	1	0%	"... Are you the designated timekeeper?" (Group #17)
Visitor Service	1	0%	"...From stores, may be downstairs." (Group #3)

Table 3 indicates that many of the exchanges were initiated by the educators. The educators discussed a number of subjects with the visitors during the course of their interactions at the "Solar Cars" activity. Educators were most likely to give focus subjects test instructions (47 occurrences). Test instruction consisted of comments like: "[The car] might need a tap to get it going [on the track]. Turn the lights on" (Group #4). Educators also explained the set-up and goal for the activity (36 occurrences) by saying things like: "The challenge is to take the car … from that red line to the other in 12 seconds. [In order to do this, you can] change the tires, axel, [and] light [level]" (Group #3). Other times, the educators told the focus subjects to try again and change their design (35 occurrences). An example of this type of comment is: "[Doing] that [to the car] slowed it down. You could adjust [something else to change the speed]" (Group #25). The educators also explained problems with the design and maintenance of the "Solar Cars" (34 occurrences). Educators explained these problems by saying things like, "There's a dark spot where the lights are. That's why [the car] stopped" (Group #2). Educators also asked focus subjects imagine step questions (29 occurrences) like "Did you try any other designs?" (Group #13), or gave the focus subjects build instructions (24 occurrences) such as "I think you want the connector on the outside [of the wheel]" (Group #5) (Table 5).

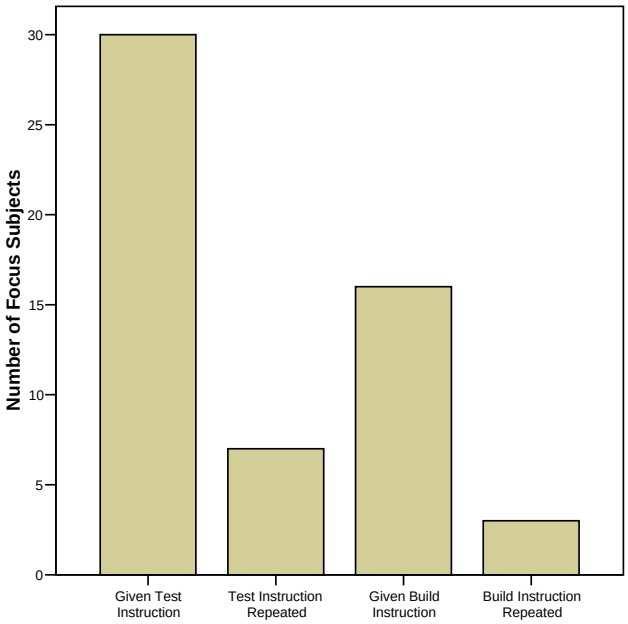
As seen in Table 5, one of the things that educators talked to visitors about was the set-up and goal of the activity. The data show that the educators failed to give only three focus subjects the set-up and goal during their time at the activity (although this information was available in the activity label copy). Of these three focus subjects, one did not complete even a single build/test iteration, one completed one build/test iteration, and one completed three build/test iterations. The number of build/test iterations completed by those who did and did not receive set-up and goal information was compared, and there was no significant difference in the number of build/test iterations completed by those who did and did not receive the set-up and goal.

Educators also commonly gave visitors instructions on how to carry out the test and build steps of the "Solar Cars" activity. Evaluators found that educators gave 30 of 40 focus subjects test instructions during their interaction, and that they repeated the test instructions for seven of the focus subjects (Graph 8). Examples of the testing instructions that educators repeated for the focus subjects are the following:

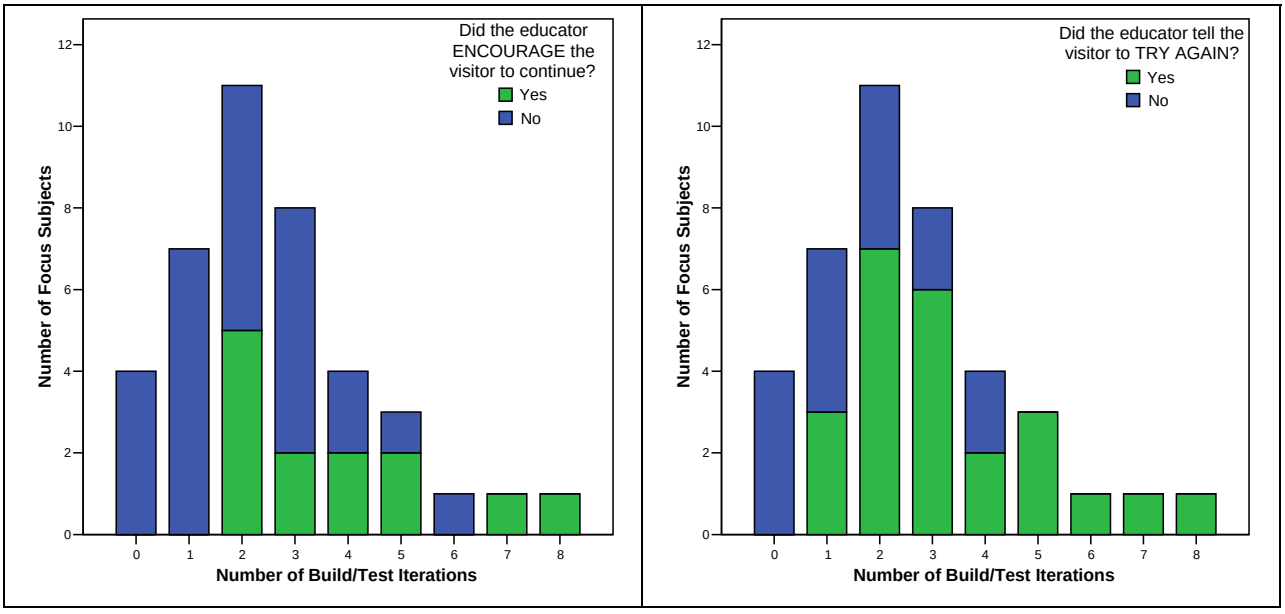
- "…Hold the back wheels up like this to get them [started] turning." (Group #17)
- "Turn [the light] all the way up there." (Group #28)

Evaluators found that educators gave 16 of the 40 focus subjects building instructions, and that they repeated the building instructions for three of these 16 focus subjects (Graph 7). An example of the building instruction that educators repeated for the visitors was: "Put the connectors on [the outside] like this or the wheels will fall off" (Group #5). Significantly fewer focus subjects received building instructions than received testing instructions, χ^2 (1, N=40) = 5.0, p = .025. However, the number of focus subjects who had building instructions repeated was not significantly different than the number of people who had testing instructions repeated.

GRAPH 7. Number of Focus Subjects that Received Test or Build Instructions and Had to Have Those Instructions Repeated (N=40).



GRAPHS 8 & 9. Number of Build/Test Iterations Completed by Focus Subjects Split by Whether the Educator Encouraged the Focus Subject or Told Them to Try Again (N=40).



As seen in Table 5, the educators sometimes encouraged the focus subjects during the time they were at the "Solar Cars." Overall, educators encouraged 13 of the focus subjects by telling them they were doing a good job. An example of this type of comment is: "Oh, so

close! [You need] just a little change" (Group #6). Evaluators found that educators did not give this type of encouragement to any of the 11 focus subjects who completed zero to one build/test iterations. However, educators did give positive encouragement to seven of 19 focus subjects who completed two to three build/test iterations and six of 10 groups who completed at least four build/test iterations (Graph 8). The focus subjects who were not given encouragement (M=2.1, SD=1.5) completed significantly fewer build/test iterations than the focus subjects who were given encouragement (M=3.8, SD=2.0), $t(38) = -2.9$, $p = .005$.

Educators sometimes also told the focus subjects to change their design in order to reach the 12 second goal. If a focus subject's car did not travel the track in 12 seconds, the educator was often heard to make a comment like: "you want to try to make it 6 seconds slower" to encourage the visitor to change their car design until they reached the goal (Group #7). Evaluators found that educators told three of 11 focus subjects who completed zero to one build/test iterations to try again. Educators told 13 of 19 focus subjects who completed two to three build/test iterations to try again, and told eight of 10 focus subjects who completed four of more build/test iterations to try again (Graph 9). The focus subjects who were not told to try again (M=1.6, SD=1.4) completed significantly fewer build/test iterations than the focus subjects who were told to try again (M=3.3, SD=1.9), $t(38) = -3.1$, $p = .004$.

Another thing that educators commonly did was to question visitors to cause them to contemplate the imagine step of the engineering design process. Some examples of imagine questions are:

- "What do you want to change?" (Group #2)
- "Does that [wheel design] make it faster or slower?" (Group #3)
- "You think bigger wheels in the back will work?" (Group #24)

Evaluators found that educators asked imagine questions of 18 of the 40 focus subjects. There was no significant difference in the number of build/test iterations completed by those who were and who were not asked imagine questions.

2. EXIT INTERVIEWS

Evaluators talked to 20 visitors who participated in the "Solar Cars" with educators. Two questions provided the most information to evaluators about when focus subjects needed help with the activity and how the educators helped them navigate the activity. The questions answered the following:

1. Times when visitors felt frustrated or wanted help at the "Solar Cars" activity.
2. Discourse with the Museum educators at the "Solar Cars" activity that visitors found the most helpful.

2.1 Times when visitors felt frustrated or wanted help at the "Solar Cars" activity.

When evaluators asked visitors if there were any times when they were frustrated with the "Solar Cars" activity or wanted help, half (11 of 20 respondents) said "no." Others said that they were frustrated or needed help while they were testing their solar car (3 of 20 respondents) especially when the car kept hitting the wall of the track. Visitors also felt frustrated and needed help with getting started on the activity (2 of 20 respondents) because they did not know what to do. Other visitors wanted help when they had problems getting the activity to work (2 of 20 respondents), or when they were building their solar car (1 of 20 respondents) (Table 6).

TABLE 6. Visitor Responses to the Exit Interview Question "Were There Any Times When You Felt Frustrated or Wanted Help?" (N=20)

	Number of Respondents	Quotes
No	11	"No, not really." (Interview #38)
When I was testing	3	"When it hit the wall because it came close [to making it in 12 seconds]." (Interview #16)
Getting started (set-up)	2	"The first time cause I didn't know what to do." (Interview #40)
Activity Problems	2	"When the rubber band fell off the big one." (Interview #12)
When I was building	1	"Kind of when I was building." (Interview #8)
Other	1	"I asked my grandfather because he was an engineer when it was 15 seconds." (Interview #34)

2.2 Things visitors talked to the Museum educators about at the "Solar Cars" activity that they said they found helpful.

Visitors were also asked to tell the evaluators what they found helpful about talking to the Museum educators while they were working at the "Solar Cars." Exit interview respondents said that they found it helpful talking to the educators about the activity variables they could change (6 respondents) which aided them during the imagine and plan steps of the engineering design process. One respondent said, "[The educator talked to me about] changing the pulleys and wheels on the cars. [They helped me in] thinking about which things to change" (Group not observed). The focus subjects also said the educators helped them by talking to them about maintenance and design problems associated with the solar cars (5 respondents). One focus subject said, "[The educators] said the rubber band was off and that the light wasn't good on that track – to use the other track" (Group #16). In addition, the focus subjects said that the educators helped them by giving them building (4 respondents) and testing (4 respondents) instructions. A smaller number of the 20 respondents (3 respondents) said that the educators helped them by providing the set-up and goal for the activity when "they told me what to do" (Group #9) (Table 7).

TABLE 7. Visitor Responses to the Exit Interview Question "What Did You Find Helpful about Your Discussion with the Educator?" (N=20)

	Number of Respondents	Quotes
Talked about the variables (pulleys, wheels, light) (Imagine/Plan)	6	"I tried the medium wheels and they said the big wheels might make it slower and they were right." (Interview #20)
Talked about activity problems	5	"They said the rubber band was off and that the light wasn't good on that track -- to use the other track." (Interview #16)
Talked about building instructions	4	"Helped us put the thing together with the wheels. I never knew how to put this [holds up clip] on the wheels, so they won't fall off. We are not naturally born mechanics, but we learned it." (Interview #19)
Talked about testing instructions	4	"It can only go if hold wheels up because charges it." (Interview #4)
Talked about set-up and goal (framing the activity)	3	"They told me what to do…" (Interview #9)
Other	2	"They said good job, that's good thinking." (Interview #33)
No	2	"Not really" (Interview #34)

3. EDUCATOR DEBRIEFS

A total of eight debriefs were given over the course of the data collection period. The debriefs gave evaluators information about the following:

1. Parts of the "Solar Cars" that educators felt were easy and difficult for visitors.
2. Points at which educators felt that visitors sought and that they provided help with the "Solar Cars."
3. Changes educators felt needed to be made to the "Solar Cars" to create a better learning experience for visitors.

3.1 Parts of the "Solar Cars" that educators felt were easy and difficult for visitors.

Evaluators found that educators thought that visitors had a good understanding of how to change the variables to make their solar car faster or slower (5 debriefs). Educators also felt that visitors often had an easy time understanding how to build their solar cars (3 debriefs), and that visitors had an easy time navigating the activity once the educators gave them help (3 debriefs). Only after one session at the "Solar Cars" did educators feel that visitors had an easy time understanding how to test their cars (Table 8).

TABLE 8. Responses to the Educator Debrief Question "What Part(s) of the Activity, If Any, Did Visitors Seem to Have A Really Easy Time With Today?" (N=8)

	Number of Educator Debriefs	Quotes
Understood about changing the variables (Imagine/Plan)	5	"They got the idea that you can change the size of the wheels." (Educator Debrief #1-4)[1]
Understood the building phase	3	"Putting the stuff together, assembling the cars…" (Educator Debrief #9-16)
Did okay after some help	3	"Once you give them instruction they're fine. Younger kids have a harder time getting it straight and grasping how to change it." (Educator Debrief #29-33)
Understood the testing phase	1	"...A lot of people knew to get to the testing -- a couple had done it before." (Educator Debrief #5-8)

Evaluators also asked the educators when they felt visitors had a hard time at the "Solar Cars" activity. Educators reported to evaluators that visitors had a hard time fixing and troubleshooting problems with the activity (6 debriefs). They also found that visitors had a hard time understanding the set-up and goal of the activity (4 debriefs). The educators said that only during a few of the sessions at the "Solar Cars" did visitors have a hard time understanding that they could change the variables in order to change the speed of the car (2 debriefs), that they had a difficult time with testing their cars (2 debriefs), or that they had a hard time building their car (1 debrief) (Table 9).

TABLE 9. Responses to the Educator Debrief Question "What Part(s) of the Activity, If Any, Did Visitors Seem to Get Especially Stuck On Today?" (N=8)

	Number of Educator Debriefs	Quotes
Fixing activity problems (broken rubber bands/motors)	6	"The lights and the motor burned out." (Educator Debrief #37-40)
Didn't understand the set-up and goal	4	"...They thought it was interesting and raced but didn't get the 12 second thing. They only wanted to see it go." (Educator Debrief #18-23)
Other	2	"...Don't have enough cars…" (Educator Debrief #29-33)
Didn't understand changing variables (Imagine/Plan)	2	"Getting them to try out different variables…" (Educator Debrief #9-16)
Had problems with testing	2	"Didn't get how to use the timers. Rolling the car back to the start…" (Educator Debrief #34-36)
Had problems with building	1	"...Didn't get how to clip things on." (Educator Debrief #5-8)

[1] One debrief was collected each day, but multiple focus subjects were observed. The educator debrief number refers to the numbers of the focus subjects observed on that day.

3.2 Points at which educators felt that visitors sought help and that they provided it with "Solar Cars."

Evaluators also asked the educators questions about what they recalled visitors asking them and when they provided aid to visitors without them asking. It was important to differentiate between these two types of help because the questions asked by visitors indicate areas where the visitors knew they needed and actively sought help, and the areas where educators provided help without prompting indicate areas where educators knew visitors had the potential of getting frustrated. When educators were asked what questions they remembered visitors asking them at that session, they reported that visitors often asked them how to fix activity problems (4 debriefs) such as when the rubber band slipped off the motor. Visitors also asked them about the set-up and goals of the activity (3 debriefs) and what variables they could change (3 debriefs). In addition, on two debriefs, the educators said the visitors asked them for building instructions such as how to connect the wheels to the car (Table 10).

TABLE 10. Responses to the Educator Debrief Question "What Did Most Visitors Ask You About Today While You Were Working at the 'Solar Cars' Activity?" (N=8)

	Number of Educator Debriefs	Quotes
Asked about how to fix activity problems	4	"Most confused if it didn't work, how to troubleshoot if rubber band came off--had trouble fixing that." (Educator Debrief #9-16)
Asked about the set-up and goals	3	"What do you do here?" (Educator Debrief #1-4)
Asked about changing variables (Imagine/Plan)	3	"Asking about the pulley and didn't seem to get it today." (Educator Debrief #37-40)
Other	2	"...Didn't get the solar car part -- brought cars over from the ramp." (Educator Debrief #5-8)
Asked for building instruction	2	"...How can I out the connectors on?..." (Educator Debrief #18-23)
Not asked	1	--

When asked, educators reported that they were most likely to give aid to the visitors without any request from the visitor when there were problems and troubleshooting issues related to the activity (5 debriefs). The activity problems that the educators helped the visitors included checking to make sure that the rubber band was attached to the motor and learning how to deal with dark spots on the track. The educators said they also helped the visitors by giving them the set-up and goal (2 debriefs) and instructions on how to complete the testing (2 debriefs) (Table 11).

TABLE 11. Responses to the Educator Debrief Question "At What Points Did You Provide Help to the Visitors (Without Them Asking) Because They Seemed Frustrated?" (N=8)

	Number of Educator Debriefs	Quotes
Helped them with activity problems (broken rubber bands/motors)	5	"If the rubber band came off — they didn't figure that out. If the car wasn't working on the track — troubleshooting." (Educator Debrief #9-16)
Other	2	"Just remember saying everything." (Educator Debrief #29-33)
Helped them with the set-up and goals	2	"Kind of went in and explained how to do it. Don't wait for them to ask." (Educator Debrief #24-28)
Helped them with testing instructions	2	"The track—I think us talking to them at the start helped alleviate questions down the road." (Educator Debrief #34-36)

3.3 Changes educators felt needed to be made to the "Solar Cars" to create a better learning experience for visitors.

Educators were asked what changes they would make to the "Solar Cars" to make them a better learning experience for visitors. On all but one debrief, the educators said that the problems with the activity need to be fixed. Those problems included: "lighting on tracks, some rubber bands fall off really easily" (Debrief #9 – 16), and "what seems to damage the motors is if they get pushed" (Debrief #24 – 28). Other times, the educators mentioned that they felt the activity labels needed to be updated (4 debriefs), or that the set-up and goal for the activity needed to be made clearer (3 debriefs) (Table 12).

TABLE 12. Responses to the Educator Debrief Question "After Your Experience Today, What, If Anything, Would You Change About the 'Solar Cars' Activity To Make It a Better Learning Experience for Visitors?" (N=8)

	Number of Educator Debriefs	Quotes
Fix the activity problems (broken rubber bands/motors/lights)	7	"...It has to work. What seems to damage the motors is if they get pushed…" (Educator Debrief #24-28)
Change activity labels/text	4	"...Update panels to what pieces are here, goal of program. Panel on the test track that mentions adding weights inaccurate." (Educator Debrief #5-8)
Make the set-up and goal clearer	3	"The biggest problem is that people don't know what the goal is." (Educator Debrief #1-4)
Other	2	"Not enough variables to change." (Educator Debrief #9-16)
Don't let visitors change variables not changeable on real solar cars	2	"...don't let people change the light level--cheating can't change that in real life…" (Educator Debrief #5-8)
Need more cars	2	"Need more cars (only one worked)…" (Educator Debrief #34-36)

IV. DISCUSSION

This study gave the Museum of Science a chance to look more closely at the types of supports that educators give visitors using engineering design activities. Educators were asked how they helped visitors, and they mentioned many of the aids they provided that they felt were important to the experiences of visitors. The supports that educators mentioned include the following:

- Clarifying the activity goals and providing sub-goals,
- Supplying the visitors with needed instructions, and
- Helping visitors work through activity problems.

There was also one type of interaction that educators had with visitors that they did not mention in their interviews, but that was found to be important by evaluators, which is providing positive reinforcement to the visitors. Although this was not explicitly stated by the educators as a way that they support visitor engagement in engineering design activities, it plays an important role in visitors' continued engagement in an activity.

1. EDUCATORS SUPPORTED VISITORS' USE OF THE "SOLAR CARS" BY PROVIDING CLARIFICATION OF THE GOALS AND BY PROVIDING SUB-GOALS.

The data indicate that one of the actions that the educators often took was to make sure that visitors hear and understand the activity goal and set-up. As stated previously, the goal of the "Solar Cars" activity that the educators presented to visitors is to make a car that can travel the track from start to end in 12 seconds. In order to create a car that can achieve this goal, visitors can change the size of their car's wheels or remove the treads from those wheels. They can also use either a small or large pulley that connects the wheel axel to the motor. The final option that visitors have is changing the light level on the track. Changing the light level allows the visitors to speed up or slow down the car, but some educators downplayed this variable, so it was not often used by the observed visitors. Observations of the "Solar Cars" show that educators almost always gave visitors the set-up and goal of the activity at the beginning of the interaction. The set-up and goal were told to all but three visitor groups, and only once did the educators give the set-up and goal to a group after the first two behavior units.

Even after the educators provided the initial set-up and goals for the activity, they continued to provide sub-goals to the visitors. The conversation analysis shows that one of the things that educators commonly talked to visitors about was how to improve their solar cars by reiterating goals for the activity. Often, the educators achieved this by asking the visitors imagine questions. The types of questions that educators asked of visitors included the following:

- "What can you do to slow [the car] down?" (Group #2)
- "You want to try to make [the car] 6 seconds slower. Are you going to change anything?" (Group #7)
- "Did you try any other designs?" (Group #13)

These questions helped to re-focus the visitors and get them to think about their design and how they would best change their design to achieve the goal. Occasionally, the educators would bring up the goal more directly. During one interaction, an educator said, "So you want [the car] to go in 12 seconds so slow it down. Think about what to do with the wheels or pulleys to slow it" (Group #28).

The educators said during the debriefs that they felt it was important to give visitors the set-up and goals whether they asked for this information or not because this was an area of the activity where visitors often got stuck. One educator said, "All the solar cars were at the stations [placed away from the track. The visitors] wouldn't know what to do [if we didn't talk to them]. We had to tell them what the challenge and variables were" (Debrief #1 – 4).[2] The educators said that without this aid visitors asked them questions. One educator said, "[Visitors would ask] what do you do [here]? The goal isn't explicit [and visitors] thought it was a race" (Debrief # 5 – 8). The educators also said during the debriefs that visitors often had an easy time figuring out that they should try out different variables and test them to achieve the activity goals. One educator said, "I think today [visitors] knew how to change the wheels and customize the vehicles" (Debrief #18 – 23). However, educators found that occasionally they had to encourage the visitors to try out new design ideas. On the same debrief, one educator said, "[Visitors didn't understand] changing the light level and perfecting their time" (Debrief #18 – 23). Of the eight debriefs, educators mentioned that visitors either got stuck on or asked questions about the set-up, goal, and variables on seven of them. The frequency with which educators mentioned this part of the activity indicates that educators felt that it was important for visitors to understand the set-up, goals, and variables of the activity to complete the "Solar Cars."

Some visitors echoed this sentiment. One visitor said that he felt frustrated "when I had no clue what I was doing at the beginning" (Interview #37). However, he continued on to say that the educators and some videos placed around the activity that displayed other visitors' design ideas helped him to understand how to complete the activity. Other visitors did not think that this was an area of frustration during the activity, and that they found it helpful when the educators talked to them about the set-up and goal of the activity. These visitors agreed that it was helpful when they talked with the educators about "how to do the activity" (Interview #5). The visitors also agreed that the educators helped them think through issues with their design. One visitor said, "I tried the medium wheels and they said the big wheels might make it slower, and they were right" (Interview #8). Half of the interviewed visitors (11 of 20) mentioned the set-up, goal, or variables on their exit interview even though almost every visitor heard at least some of this information from educators. This may show that most visitors felt that it was not important for the educators to give them this information. However, it may also indicate that visitors did not remember that educators talked to them about the set-up and goals because this information was given at the beginning of their interaction, that visitors found other discourse with the educators more helpful, or that visitors did not feel frustrated with this part of the activity because educators provided the information so often. In addition, it is possible that the reason that visitors did not say that they talked about the set-up and variables with the educators very often may be the way that evaluators asked this question. Instead of asking visitors to recount

[2] One debrief was collected each day, but multiple focus subjects were observed. The educator debrief number refers to the numbers of the focus subjects observed on that day.

everything they found helpful about talking with educators, only the first answer they gave was taken.

These data show that the educators felt that a critical step in visitors' navigation of the engineering design process was to understand the goals of the "Solar Cars" activity. The educators almost always provided the goals to the visitors at the beginning of their interaction, and they continued to bring up the goals throughout visitors' interactions. The educators expressed that without this information they were afraid that the "goal isn't explicit [and visitors] thought it was a race" (Debrief #5 – 8). Though in the case of a constructivist exhibit like the "Solar Cars" coming up with alternative questions and activities for an exhibit is considered the goal of the activity, if an exhibit is trying to bring visitors to a specific outcome, then it may be more detrimental if visitors do not understand the set-up and goal.

2. EDUCATORS SUPPORTED VISITORS' USE OF THE "SOLAR CARS" BY SUPPLYING THE VISITORS WITH NEEDED INSTRUCTIONS.

Besides giving the visitors the goals during the "Solar Cars," the data show that the educators also made sure that the visitors understood any instructions necessary to help visitors use the activity. The two main phases of the "Solar Cars" activity (testing and building) both required instruction. However, data from across data collection instruments indicate that educators provided visitors with more help during the testing phase than the building stage.

The building stage appears to have been easy for most visitors to understand and navigate. The educators provided less than half the focus subjects (16 of 40) any kind of building instruction, and repeated the building instructions to only a few focus subjects (3 of 16). The educators and visitors agreed in their interviews that the building stage was not very difficult. The educators said that this was a stage of the activity that the visitors had an easy time with. One educator said, "Everyone knows how to use K'Nex" which were used to connect the wheels to the solar cars (Debrief #37 – 40). Only once did the educators indicate that visitors had a difficult time with this step. This educator said, "[The visitors] didn't get how to clip [the wheels] on" (Debrief #5 – 8). The visitors also rarely mentioned that they were frustrated or needed help with the building phase of the activity. Only one visitor said, "[I was] kind of [frustrated] when I was building" (Interview #8).

Educators had to spend much more time helping visitors with the testing phase of the activity. Educators gave almost all the focus subjects (30 of 40) test instructions, and they had to repeat their instructions for seven of the groups. Most often (6 times instructions were repeated) educators had to remind visitors to hold up the back of the solar car so that the wheels could start moving. Educators mentioned on the debrief that they remembered visitors having difficulties with this step. On two debriefs educators said things like: "Sometimes [the visitors] needed help at the track" (Debrief #24 – 28). The educators also found that visitors were less likely to have an easy time with the testing phase than the building phase. During only one debrief did educators say, "A lot of people knew [how] to get to the testing—a couple had done it before" (Debrief #5 – 8). Exit interviews with the visitors concur that visitors had difficulty with the testing phase of the activity. A few visitors (3 of 20) made comments about the difficulty with

the testing phase. One visitor said, "When [the car] hit the wall [it was frustrating] because it came close [to making it down the track in 12 seconds]" (Interview #16).

While the educators and visitors mention the building and testing phase with equal frequency on the interviews and debriefs making it seem that visitors had the same amount of difficulty with both phases of the activity, the behavior checklist tells a different story. Educators provided instruction during the testing phase of the activity significantly more often than the building phase. This may be because the instructions for the testing phase were more complicated. During the building phase, the visitors had a choice of two wheel and pulleys sizes, and the only thing they needed to know how to do correctly was how to connect the K'Nex wheels to the axel. For the testing phase, visitors needed to know that they should reset the timer, turn the lights all the way up, lift the back of the car so that the wheels could start turning, and lift the car off the track to carry it back to the start area to re-test. Because these instructions were more involved, they involved more of the educators' time. The presence of the educators made it possible for the visitors to have an easier time learning the instructions they needed for the "Solar Cars." However, without the presence of an educator, it might be more difficult for visitors to move through the steps of an activity if the instructions are too complex.

3. EDUCATORS SUPPORTED VISITORS' USE OF THE "SOLAR CARS" BY HELPING THE VISITORS WORK THROUGH ACTIVITY PROBLEMS.

Another issue that this study illuminated is the importance of the usability and durability of an activity. The data show that educators spent a lot of time troubleshooting problems related to the "Solar Cars" activity—time that could have been spent working with visitors on their design and testing. Over half the focus subjects (24 of 40) encountered a problem with the "Solar Cars" activity during the interaction. Educators had to discuss these activity problems with visitors only once during most of these interactions (16 focus subjects), but occasionally they had to discuss the activity problems with visitors multiple times (8 focus subjects). These problems ranged from the rubber band being too loose and falling off the motor to the car motor not working to the car getting stuck on dark spots on the track. The problems were sometimes bad enough to cause the visitor to leave the activity (7 focus subjects).

The problems with the activity were so distracting that they were a constant concern for the educators. On most debriefs (6 of 8), educators said that visitors got stuck on the activity problems. The issue was summed up by one educator who said, "The worst part is when [the activity] doesn't work" (Debrief #29 – 33). Educators also said on many of the debriefs that visitors asked them for help with the activity problems (4 of 8 debriefs), or that they helped visitors with activity problems even if they did not ask for help (5 of 8 debriefs). One educator said visitors ask, "Why do [the cars] get stuck on the track? Where is another car? Why isn't this working?" (Debrief #34 – 36). Some visitors agreed that they had problems dealing with troubleshooting issues they encountered at the "Solar Cars" activity. A few of the visitors (2 of 20) said that they were frustrated or needed help with the activity problems. One visitor said, "[I needed help] when the rubber band fell off the big one [pulley]" (Interview #12). Other visitors (5 of 20) said that it was helpful when the educators told them how to troubleshoot the activity problems. One visitor said, "When my car didn't work, they said to check the bottom and we

fixed it" (Interview #6). Another said, "I needed help fixing the car when the rubber band came off" (Interview #35).

The data illustrate the effect that maintenance problems can have on interactions at an activity. The educators were constantly on the alert for activity problems and found these problems were distractions that prevented them from helping visitors in other ways. Evaluators asked the educators what they would change to make the "Solar Cars" a better learning experience for visitors. Again and again, the educators said that they wanted "more solid cars—ones that don't fall apart" (Debrief #18 – 23), and that if this could not happen that there needs to be a "troubleshooting guide [so] if a car doesn't work, [visitors know] what to check" (Debrief #5 – 8). This illustrates that instead of thinking about what supports visitors might need to complete the activity, educators were more concerned about the basic usability of the "Solar Cars." The number of comments given by visitors about activity problems demonstrates the distractions that the activity problems caused for them as well. While maintenance problems are always a concern at interactive exhibits, and while it is inevitable that maintenance issues will sometimes occur, the data emphasize the importance of exhibit designs that are easy for exhibit maintenance staff to maintain and for visitors to use.

4. EDUCATORS SUPPORTED VISITORS' USE OF THE "SOLAR CARS" BY PROVIDING POSITIVE REINFORCEMENT.

The behavioral data show that educators interacted with the visitors in other ways besides providing them with the goals of the activity, giving them instructions, and helping them work through activity problems. Another support educators commonly gave to visitors was providing them with encouragement and telling them to try again. However, despite the fact that receiving this information caused visitors to stay at the activity longer, the educators and visitors rarely mentioned these supports on debriefs or exit interviews.

Educators told over half of the focus subjects (24 of 40) that they should continue working on their car and try again. Sometimes the educators gave visitors general instructions for how they might improve their car. In these cases, the educators told the focus subjects things like: "You want to try to make it 6 seconds slower" (Group #7). Other encouragements to "try again" included specific ways that the visitors might change the car to get a different result. An example of this kind of suggestion was: "Try some different wheels. See if it goes faster or slower" (Group #37). These comments were meant to encourage the visitors to continue with their testing and building processes until they came closer to achieving the goal of creating a car that could travel the track in 12 seconds. Of the focus subjects who were given this encouragement to try again, almost all of them (21 focus subject) completed at least two build/test iterations and very few (3 focus subjects) completed zero to one build/test iteration. Statistics performed on this data indicated that the visitors who were encouraged by the educators to try again completed significantly more build/test iterations than those who did not get this positive reinforcement ($t(38) = -3.1$, $p = .004$).

Even though one of the most common things that educators did when visitors were at the "Solar Cars" was to tell them to try again and continue working on the design, neither the educators nor the visitors mentioned this support on debriefs or exit interviews. It is possible that the educators

did not bring these interactions up because they did not think of encouraging visitors to try again as a behavior that helped visitors. Visitors might not have mentioned that educators told them to try again because they might not have been aware that the educators were doing it. However, this does not mean this type of positive reinforcement was not important to visitor's engagement in the engineering design process. One reason why educators and visitors did not mention the "try again" encouragement may be the questions evaluators asked these groups. Evaluators asked the educators what visitors asked them about and what help they provided to visitors without their asking, which may have caused them not to mention this support. The evaluators asked the visitors what they found helpful about what the educators talked to them about, but evaluators only asked for one answer and perhaps visitors did not think of the encouragement to try again as "helpful."

Fewer focus subjects (13 of 40) were given general encouragement than those who were told to try again. However, the data show that this type of positive reinforcement was also important to the interactions of visitors at the "Solar Cars." The kind of things that educators said to encourage these subjects included: "That [time] was close" (Group #39). They also said things such as: "That's a good time" (Group #14). Of the focus subjects who were encouraged by the educators, all 13 completed at least 2 build/test iterations. Statistical analysis of the data shows that visitors who were given encouragement to continue completed significantly more build/test iterations ($t(38) = -2.9$, $p = .005$).

Despite the importance of educators encouraging visitors to continue their interactions, this topic was rarely mentioned on debriefs or exit interviews. Educators never mentioned that they provided visitors with encouragement at the activity. Once again, this probably has to do with the questions that evaluators asked educators on debriefs. It is also possible that educators did not recognize that giving encouragement helped visitors. Visitors were also not likely to mention that the educators gave them encouragement. However, one visitor did say that he found it helpful when the educators encouraged him. He said, "They said good job, that's good thinking" (Interview #33). This shows that at least one visitor was aware that educators encouraged their work and recognized it as helpful. It is possible that more people did not bring up the encouragement supplied by educators because only a few of them got encouragement or because of the way that evaluators asked the question.

The data described above indicate the importance of receiving positive reinforcement during an engineering design activity. Visitors who were given encouragement or told to try again by the educators were more likely to stick with the "Solar Cars" and re-test and re-build their prototype multiple times.

V. CONCLUSION

This study found that educators were providing visitors with a number of supports throughout their time at the "Solar Cars" activity. At the beginning of the interaction, educators gave support to visitors by making sure that they understood the set-up for the activity and its goals. As the interaction continued, educators made sure to carry on supporting visitors by reframing the goals, providing instructions, and helping with any maintenance problems encountered. In addition, educators provided visitors with positive reinforcements which have pushed the visitors to make more refinements to their prototypes and test them.

Most of the ways that educators supported visitor use of the "Solar Cars" activity helped the interactions of the visitors to go smoothly. By providing visitors with the set-up and goals, educators made it so that visitors did not have to figure out on their own the purpose of the activity. By providing visitors with instructions, educators made it so that visitors did not need to use trial and error to figure out how to put their car together or test it. By understanding possible activity problems and helping visitors navigate them, educators prevented visitors from getting frustrated with troubleshooting or from working with broken cars. These supports prevented visitors from experiencing most of the struggles that they might encounter during the activity and made it easier for visitors to move through the steps of the engineering design cycle. When an activity is trying to reach a certain outcome and has specific goals, these supports can be very helpful. However, there is a potential downside to these supports. If an exhibit has a constructivist goal, then providing supports which do not allow visitors to explore and define their own use of potential activities of the exhibit is negative. Still, in the case of the "Solar Cars," providing these supports may have allowed visitors to spend more time thinking about their design and less time thinking about how to get their car to work.

Because this study did not measure what visitors are capable of doing on their own and compare it to what visitors are capable of doing with the help of educators, it cannot be concluded that the supports mentioned above constitute scaffolding. Still, the supports discovered through this study are important because they can serve as a starting point for thinking about scaffolding of other engineering design labs. This is because they do indicate areas of potential scaffolding and visitor need. Some visitors felt that they did not know what to do at the activity, and so they appreciated receiving the set-up and goals from the educators. Others did not understand how to build or test their cars, so they valued being given instructions by educators. Many visitors were glad that the educators were around to explain to them why the cars were not working. Others benefited from the positive reinforcements given to them by the educators. More study is needed in order to learn areas of scaffolding needed in engineering design labs, but any future studies should begin with these supports in mind.

APPENDIX A: BEHAVIOR CHECKLIST

Group #: _____ Elapsed Time: _____ Data Collector Initials: _____

Time of Week: Weekday or Weekend Time of Day: Morning or Afternoon

Group Composition:	# MA ____	# FA ____	# EdI ____
	Mk 1 Age ____	Fk1 Age ____	# EdV ____
	Mk2 Age ____	Fk2 Age ____	# EdS ____
	Mk3 Age ____	Fk3 Age ____	
	Mk4 Age ____	Fk4 Age ____	

Key

MA = Male Adult EdI = Intern

FA = Female Adult EdV = Volunteer

Mk = Male Kid EdS = Staff Member

Fk = Female Kid

Behaviors and Discussion between Educators and Visitors

Visitor | Educator Behaviors Questions/Discussion between Focus Subject and Educators

- ☐ ☐ Building/Tinkering with Car
- ☐ ☐ Testing Car on Track
- ☐ Discussing with Others in Group

Discussion/Exchange Initiated by: ☐ Focus Subject ☐ Educator

Visitor | Educator Behaviors Questions/Discussion between Focus Subject and Educators

- ☐ ☐ Building/Tinkering with Car
- ☐ ☐ Testing Car on Track
- ☐ Discussing with Others in Group

Discussion/Exchange Initiated by: ☐ Focus Subject ☐ Educator

Visitor | Educator Behaviors Questions/Discussion between Focus Subject and Educators

- ☐ ☐ Building/Tinkering with Car
- ☐ ☐ Testing Car on Track
- ☐ Discussing with Others in Group

Discussion/Exchange Initiated by: ☐ Focus Subject ☐ Educator

APPENDIX B: EXIT INTERVIEW

Group #: _____ Data Collector Initials: _____

Design Challenges Facilitator/Scaffolding Project
Exit Interview

Approach the group and say, "Hi, my name is (blank), and I work at the Museum. We're looking for feedback on the activity you just completed, and I was wondering if I could talk to you for about five minutes about your experiences here. You can stop the interview at any time if you need to."

1. Would you mind describing for me what you did here?

2. Were there any times when you felt frustrated or wanted help?
   [Probe: Can you describe when that was? What did you do so that you were no longer frustrated?]

3. (*If spoke with an educator*) I saw that you spoke with a Museum of Science educator. What did you find the most helpful about that conversation?

4. Was there any way in which speaking with the educator was not helpful?

5. Is there anything else you'd like to add?

Thank you for your help. Have a nice day!

APPENDIX C: EDUCATOR DEBRIEF

Group #s: _____ **Data Collector: _____**
Educator Type(s) and Number(s): ____ Intern ____ Museum staff ____ Volunteer

Design Challenges Facilitator/Scaffolding Project
Educator Debrief

At the top of the page, record the group numbers of the visitors observed that day as well as your initials and the numbers and types of educators present. Record the educators' thoughts as closely as possible. The debrief is a chance for you to think about how things went today… what worked well, what didn't work well, and what you would like to change about your interactions with visitors, or the activity.

1. What part(s) of the activity, if any, did visitors seem to have a really easy time with today?

2. What part(s) of the activity, if any, did visitors seem to get especially stuck on today?

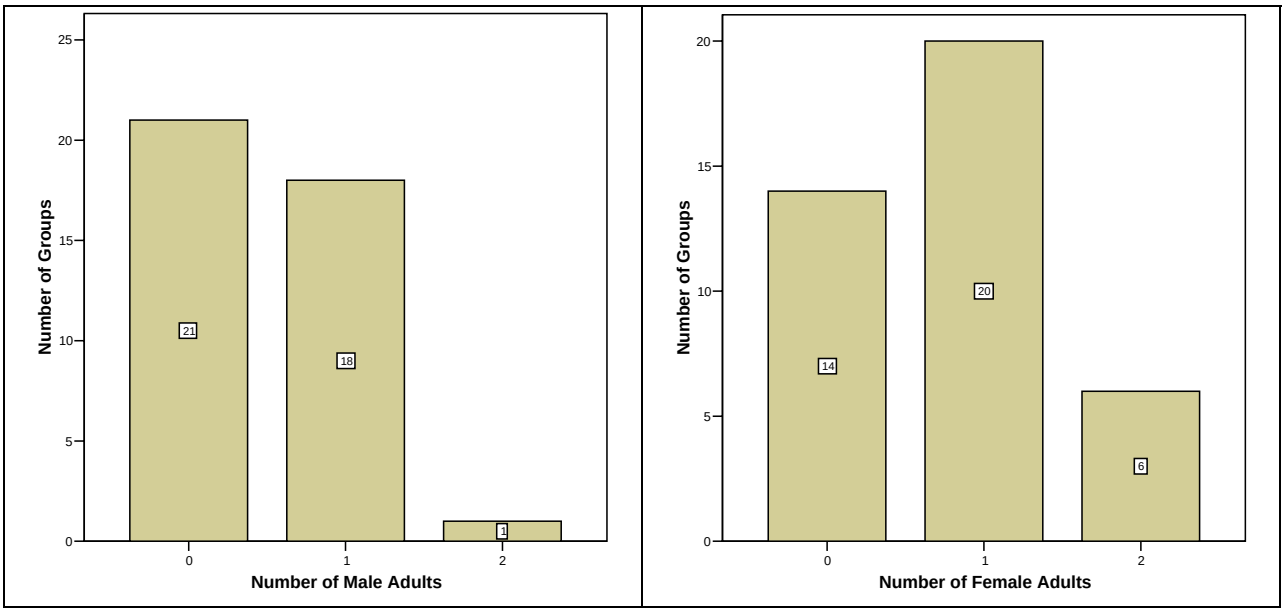
3. What did most visitors ask you about today while you were working at the solar car activity?

4. At what points did you provide help to visitors (without them asking) because they seemed frustrated?

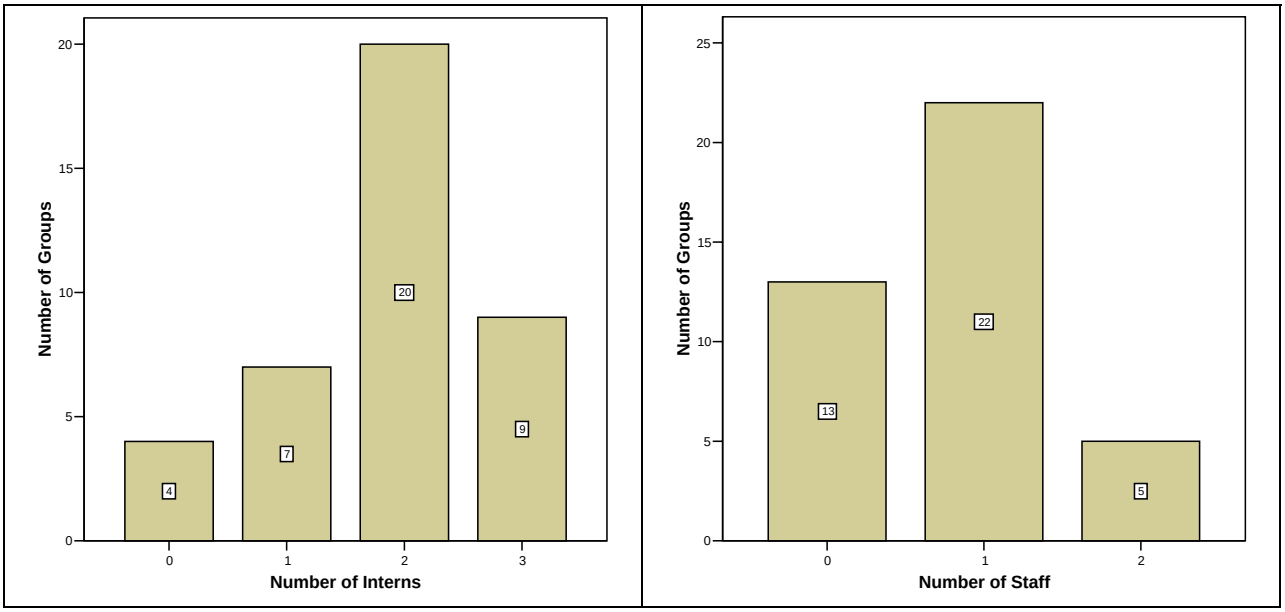
5. After your experience today, what, if anything, would you change about the solar car activity to make it a better learning experience for the visitors?

APPENDIX D: OTHER BEHAVIOR DATA

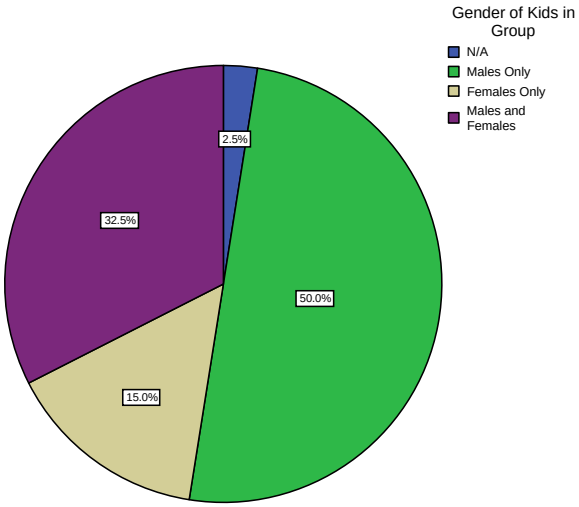
GRAPHS D1 & D2. Number of Adult Males and Females in Observed Groups (N=40).



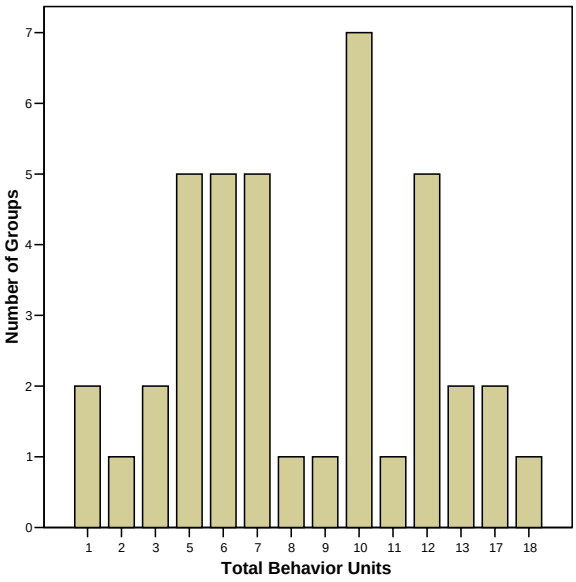
GRAPHS D3 & D4. Number of Intern and Staff Educators Present During Data Collection (N=40).



GRAPH D5. Gender of Children in Observed Groups (N=40).



GRAPH D6. Number of Behavior Units Completed by Focus Subjects at the "Solar Cars" (N=40).



APPENDIX E: OTHER EXIT INTERVIEW DATA

TABLE E1. Responses to the Exit Interview Question "Would You Mind Describing For Me What You Did Here?" (N=20)

	Number of Respondents	Quotes
Changed the variables (pulley, wheels, light) (Test/Improve)	10	"First I did the wheels -- the big wheels and then I put two of the wheels. Adjusted the light to 10." (Interview #5)
Build a car to travel distance in 12 seconds (Build and Goal)	5	"Put together a solar powered car to try to make it go down the track to get to the end at 12 seconds." (Interview #25)
Build a solar car (Build)	5	"I built a solar car." (Interview #8)
Other	2	"Solar cars" (Interview #4)
Travel distance in 12 seconds (Goal)	1	"Try to make the car go in 12 seconds." (Interview #1)

TABLE E2. Responses to the Exit Interview Question "Was There Any Way in Which Speaking to the Educator Was Not Helpful?" (N=20)

	Number of Respondents	Quotes
No	13	"No, everything was helpful." (Interview #26)
Yes	3	"Not really, just one or two big words" (Interview #25)
Other	2	"I don't know." (Interview #8)

TABLE E3. Responses to the Exit Interview Question "Is There Anything Else You'd Like to Add?" (N=20)

	Number of Respondents	Quotes
No	7	"No." (Interview #40)
Positive comment about activity	7	"It was fun!" (Interview #19)
Fix/change the activity	2	"I wish there were more cars so we could race them." (Interview #35)
Task was difficult	2	"It was hard." (Interview #39)
Positive comment about Museum	1	"No, I just thing everything here is really neat." (Interview #No Observation)
Not Asked	1	--

BIBLIOGRAPHY

Ash, D. (2003). Dialogic inquiry in life science conversations of family groups in a museum. *Journal of Research in Science Teaching, 40*, 138-162.

Borun, M., Dristas, J., Johnson, J. I., Peter, N. E., Wagner, K. F., Fadigan, K., et al. (1998). *Family Learning in Museums: The PISEC Perspective*. Philadelphia, PA: The Philadelphia-Camden Informal Science Education Collaborative.

Engestrom, Y., Miettinen, R., & Punamaki, R. L. (Eds.). (1999). *Perspectives on activity theory*. Cambridge, U. K.: Cambridge University Press.

Falk, J. H., & Dierking, L. (2000). *Learning from museums: Visitor experiences and the making of meaning*. Walnut Creek, CA: Altamira.

Larkin, M. (2002). "Using scaffolded instruction to optimize learning." Retrieved on June 27, 2006 from http://www.vtaide.com/png/ERIC/Scaffolding.htm

Leinhardt, G., Crowley, K., & Knutson, K. (Eds.). (2002). *Learning conversations in museums*. Mahwah, NJ: Lawrence Erlbaum Associates.

Museum of Science. (2007). *Design Challenges*. Retrieved March 5, 2007, from http://www.mos.org/exhibits_shows/live_presentations&d=722

Patton, M. Q. (2002). *Qualitative research and evaluation methods*. Thousand Oaks, CA: Sage Publications, Inc.

Vygotsky, L. S. (1980). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.