# Student Perceptions of Interest, Learning and Engagement from an Informal Traveling Science Museum

## Introduction

Informal science education (ISE) is widely recognized as a way to promote scientific interest, increase scientific knowledge, and enhance scientific literacy (American Association for the Advancement of Science [AAAS], 1993; National Research Council [NRC], 2009). For most Americans, the majority of their science learning occurs outside of a school context (Falk & Dierking, 2010). Informal education encompasses the many activities and programs that involve science learning in a non-school setting. These programs target learners of all ages and range from one-time events to longer programs. The intrinsically varied ISE opportunities include summer camps, after school programs, K-12 field trips, and museums. The motivations behind the development of these programs are equally varied and may include serving the local community, fulfilling grant requirements, and improving the scientific literacy of the general population (AAAS, 1993; Hinko & Finkelstein, 2012).

ISEs are intended to be engaging, enjoyable, and personally relevant encounters that inspire pariticpant interest and further inquiry. Increased interest may also motivate deeper science learning (Covington, 2000; Krapp & Prenzel, 2011; NRC, 2009). ISEs can also help students make connections to and enhance classroom learning (Krapp & Prenzel, 2011; Tran, 2006). For this reason, many teachers plan an ISE-enhanced classroom activity, such as a field trip, for their students. However, with increased financial and accountability constraints, field trips are becoming difficult to incorporate during the school day. Eshach (2007) aserts the need for ISEs to bridge informal and formal learning, especially when complications exist in bringing children to visit informal learning environments. In particular, he describes traveling ISEs as an

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effective way of affording children access to informal environments. He therefore calls for stronger partnerships between informal science programs and schools.

These partnerships also serve a need for scientists as they address the expectation of federal agencies to reach out to the K-12 community. Education and Outreach (E/O) programs, a type of ISE, are an avenue to partner with schools and address this federal requirement. Understanding how to study the effect of E/O programs, particularly those that bridge the informal and formal learning, is timely and necessary. It is imperative to describe and measure students' perceptions of the E/O programs and their interest generated by participating in E/O programs, and also to describe and understand how E/O programs may inspire participating children to continue their intention to explore STEM disciplines. Three research questions that drove this study:

1. To what extent does engaging with small-scale interactive science exhibits increase student science interest?
2. To what extent does this engagement increase self-reported science knowledge gains?
3. How do students perceive their interactions with exhibits and how do these perceptions align with ISE goals?

## Background and Theoretical Framing

### A Framework for Studying Informal Science Education

ISE programs have common goals and attributes despite the variability in environments and motivations. Six interwoven 'strands' of informal science learning reflect the broad goals of informal science education: (1) developing interest in science, (2) understanding science knowledge, (3) engaging in scientific reasoning, (4) reflecting on science, (5) engaging in science practice, and (6) identifying with the scientific enterprise (NRC, 2009, p. 42-45).

Inherent in the strands is the idea that science learning is not relegated to learning content and acquiring process skills, as has been the role of formal science education (NRC, 2007). Rather, inquiry-based learning and understanding the nature of science is emphasized (AAAS, 1993; NRC, 2007). As the NRC recognizes the value and importance of ISE experiences, including E/O programs, we argue that these interwoven strands, operate as a framework to examine E/O program outcomes. Since strands within this framework are interdependent (NRC, 2009), studies must not only examine independent outcomes but also the relationships among outcomes.

**Challenges in Studying Informal Science Education Outcomes**

Studying informal environments presents challenges beyond those encountered with formal education programs. First, the diversity among informal learning environments hinders the development of assessments that might be used to examine learning for participants across various ISEs (Allen, et al. 2007; Falk & Dierking, 2000; Martin, 2004). Second, even when measures align with program goals and structures, these assessments do not allow for the variability of participants or their experiences to be taken into consideration (Allen, et al., 2007). Manipulating or controlling participation to parse out outcomes aligned with the content knowledge assessments can be contradictory to the foundational tenets of ISEs (NRC, 2009). Third, assessments given to individual participants do not allow them to access the knowledge available when working as a group, thus systematically underestimating the learning that has taken place (Schwartz, Bransford, & Sears, 2005; NRC, 2009).

**Impacts of Informal Science Education**

Despite these challenges, many studies have examined impacts of ISEs. The most commonly studied outcomes of ISE programs are affective in nature (Strand 1). Evidence suggests that ISEs can improve interest, confidence, and engagement in science as well as attitudes toward science (Ferreira, 2001; Hofstein & Rosenfeld, 1996; Krapp & Prenzel, 2011; Ramey-Gassert, Walberg & Walberg, 1994; Rennie & McClafferty, 1995; Tran, 2011). Studies of ISE impacts also show interest and enthusiasm are related to learning (Jolly, Campbell, and Perlman, 2004; Renninger, Hidi, & Krapp, 2014; Singh, Granville, & Dika, 2002).

Studies focused on student content knowledge acquisition during ISE experiences (Strand 2) are limited. These studies mostly focus on highly structured programs and involve some form of testing. Findings are varied, generally showing few, if any, knowledge gains (Campbell et al., 1998; Johnson, 2005). Studies of student self-reported learning are typically more positive, showing short-term knowledge gains (Falk, Moussouri & Coulson, 1998; Korn, 2006) and how ISE experiences can help students make connections between formal and informal learning (Bamberger & Tal, 2008). The accuracy of self-reported learning gains is debated (Porter, 2013), but some argue self-reported learning gains are reflections of student attitudes toward their learning experience, which aligns with ISE's student-directed nature (Gonyea & Miller, 2011).

The other strands in the NRC framework consider how participants engage in and identify with science. Outcomes related to these strands can be measured by participant perceptions of the influence of the ISE experience. For example, Rennie and McClafferty (2002) found that interactive exhibits reflective of the idea of "doing science" (Strand 3) led to children's conceptual learning of science. Falk, Scott, Dierking, Rennie and Jones (2004) also found that interactive exhibits led to changes in participants' reflections on science (Strand 4) and the social nature of learning science (Strand 5). Bang and Medin (2010) noted evidence for shifts in student perceptions of the origin of scientific knowledge and their own process of learning science after participating in an ISE. Before the ISE, students believed their own scientific knowledge came from school, books, and teachers. After this program, students views expanded to further include their ancestors, their community, and themselves as sources of science knowledge (Strands 5 and 6). ISE contexts can provide opportunities for learning about the nature of science (Strand 4; Sandoval, 2005), as evidenced by Bang and Medin (2010) when discourse after an ISE shifted from a focus on science as a set of facts toward science as a "set of knowledge making activities" (p. 1022). The various goals of ISE programs necessitate research on motivations and perceptions of the purpose of ISE programs (Packer & Ballantyne, 2010).

## Methodology

### Context

This research study is focused on an E/O program created by a physics professor at a western state public university. The program is a traveling hands-on science museum taken to schools across three western states. Schools do not transport students, an attractive feature to schools, as field trips are often expensive, time consuming, and logistically challenging. These barriers are exacerbated in the case of large-scale field trips for an entire school or for schools in remote locations. The unique traveling nature of this museum allows its influence to be extensive, reaching at least 20,000 PK-12 students each year. As such, it is addressing the need for more ISEs to bridge this formal-informal education gap stressed by Eshach (2007).

According to the program's developer, the aim is not to 'show' students science, but to have them 'do' science and thereby demonstrate that everyone can do science. To this end, the exhibits are designed to be interactive, appealing, and appropriate for PK-12 students. The exhibits are set up in two classrooms, and students spend 45 to 90 minutes interacting with exhibits in a self-guided manner. Although not a requirement of the program, many students engage with the exhibits in small groups. The program's purpose, structure, and student-driven nature identify it as an E/O program (NRC, 2009). This constructivist view of learning is a prevalent approach adopted by science museums (Borun, Massey, & Lutter, 1993; Hein, 1998). Because children learn through direct interaction with objects (Piaget, 1970, Vygotsky, 1978) open investigation of exhibits occurs as students choose their own route, pace, level of engagement, and social group as they explore the traveling museum (Paris & Hapgood, 2002). Furthermore, as students interact with objects, they gain experiences that can be built upon for later learning in formal classroom settings (Diamond, 1996).

The program consists of over one hundred small-scale interactive science exhibits that represent and demonstrate physics concepts (e.g., magnetism, electricity, energy, and kinetics). Each exhibit is designed for students to manipulate components of the exhibit as they explore the physics concept. The exhibit is meant to be an opportunity for students to obtain authentic experiences they can discuss after the program. Many exhibits are created using repurposed everyday objects (e.g., light bulbs, mirrors, hair dryers, and headphones), further reinforcing that students can observe scientific phenomena in their everyday lives. For example, to demonstrate the concept of buoyancy and density as a function of mass and volume, a ketchup packet is placed inside a reused plastic soda bottle full of water. When students squeeze the outside of the capped bottle, the pressure increases inside the bottle, thus decreasing both the volume of gas in the bottle and the size of the air bubble in the ketchup packet. As the bubble in the ketchup packet shrinks, the density of the packet increases. The ketchup packet sinks when it reaches the point that its density is greater than the density of the water. The intent of the E/O developer is that these recognizable objects will encourage students to continue to experiment at home and make further connections to content learned.

The museum visits are overseen by 4-5 undergraduate student interns and program staff. Their roles are not structured, and the facilitation provided varies by student and school.

Interactions may include answering questions or explaining how exhibits operate. However, for interested participants, there are written descriptions accompanying each exhibit describing the concepts (Appendix A). These descriptions are developed by the program's interns and approved by program coordinators. This type of unstructured ISE that encourages exploration is ideal for studying science interest and expectations for learning (Rennie, Feher, Dierking, & Falk, 2003).

**Participants**

The three schools included this study belonged to the same school district and were located in the same mid-sized western city as the university. Schools were chosen based on the willingness of partner teachers to participate in the study. Participants totaled 624 students, which included 96 primary ($2^{nd}$-$3^{rd}$ grade), 110 intermediate ($4^{th}$-$5^{th}$ grade), and 418 middle school students. All participants who completed a survey were included in the study.

**Data Collection**

We collected data through teacher-administered student questionnaires (Appendix B) after students visited the traveling museum at their respective school. The intent of the questionnaire was to elicit student perceptions of the program and its impacts on their learning and interest in science. Insturment items were developed by the research team and were centered on three sub-contructs: interest, knowledge, and perceptions of the program goals. Instrument validity was determined through a two-step process. First, readability of the instrument was determined by an elementary education specialist. Second, content validity was ensured through a review by a panel of experts in education research, the content, and the program (Gliner, Morgan & Leech, 2009). Both closed and open response items were included on the instrument.

**Data Analysis**

We used a concurrent triangulation mixed-methods approach to analyze the quantitative and qualitative data. Data were collected and analyzed simultaneously with equal weight given to each type of data to provide a richer description of student experiences (Hanson, Creswell, Plano Clark, Petska, & Creswell, 2005).

**Qualitative Coding & Analysis.** For each set of open-ended responses, we used an inductive thematic analysis approach to extract emergent themes related to common responses across all students (Braun & Clark, 2006). Two of the authors participated in initial coding of the data as a beginning step in organizing the data. Codes were then categorized into themes and sub-themes in an iterative process (Appendix C). We discussed coding questions amongst the entire research team as they arose until a we came to consensus.

**Quantitative Analysis.** The final themes for each question were transformed into summary variables for descriptive analysis and examination of differences between groups on the outcome variables in SPSS. We calculated differences between grade levels (i.e., primary, intermediate, and middle school) using the Chi-squared statistic. We examined standardized residuals to better understand the nature of the association between the three groups and to identify where significant differences occurred. When we found significant results, we calculated odds ratios to determine the effect size. Quantitative data were analyzed using one-way analyses of variance with appropriate post hoc tests with the independent variable was grade grouping.

## Findings

### Small-Scale Exhibit Impact on Science Interest

The majority of students ($n$=343, 56%) felt the experience increased their interest in science a lot, some students ($n$=200, 32%) thought their interest increased somewhat, and very few students ($n$ =75, 12%) did not feel the experience increased their science interest. We identified themes in student explanations for their degree of interest increase (Table 1). By far, the most prevalent themes concerning reasons for seeing an increased interest in science were that students found the experience *Fun and Interesting* and were *Interested in the Experiments*. These two themes exemplify a connection students made between *enjoyment or excitement* and their perception of *science*, as opposed to fun outside the context of science. Many students felt that, although they already had an interest in science, this program enhanced that interest. Student 126 remarked, “I already loved science, but this made me remember why!” Note that all direct student narratives are drawn from their responses on the questionnaire. Although a much smaller sample, students who reported no increase in interest mainly did so because they had previously participated in the program. The other reasons students gave for a lack of increase in science interest included a disinterest or phobia of science, the experience not being enjoyable, and an already heightened interest in science. Several students ($n$ =13, 2%) who did not perceive that their interest was increased after the program felt that they already had a high level of interest in science, and one experience could not enhance that. Student 234 explained, “My interest in science is really big and I love science and [the program] so I don’t really know how you could increase it very much more.” Still one student failed to see the connection between everyday objects and science, one of the main connections the program tries to make through their exhibits, “It was cool to play with all the different experiments [but] my interest remains the same because we don’t play with gadgets in everyday life,” (Student 79).

<<Table 1 About Here>>

Because the study includes students from early elementary to middle school, a one-way Analysis of Variance (ANOVA) was used to examine whether changes in student interest differed by grade level. The independent variable represented the different grade levels (primary elementary, intermediate elementary, and middle school) while the dependent variable was the average level of increased interest as measured by a four-point scale from "No increase" to "Increased a lot". Data were statistically normal; however, the *Levene's F* test revealed that the assumption of homogeneity of variance was violated ($p < .001$). As such, the *Welch's F* test was used. The one-way ANOVA of student average interest increase revealed statistically significant differences between grade levels, Welch's $F(2, 242.3) = 57.87$, $p < .001$. The estimated effect size ($\omega^2 = .16$) indicated that approximately 16% of the variance in average interest increase is attributable to differences in grade levels.

Games-Howell post hoc comparisons were used to determine which pairs of the three grade levels differed significantly. Results indicate that primary elementary students ($M = 3.86$, $SD = .452$) reported significantly higher average interest increases than intermediate elementary ($M = 3.68$, $SD = .557$) or middle school students ($M = 3.23$, $SD = .798$). Effect sizes (Cohen's d) for these two significant effects were .35 (small, $p < .05$) and .97 (large, $p < .001$), respectively. Additionally, intermediate elementary students reported a significantly higher average interest increase than middle school students, with an effect size of .65 (medium, $p < .001$).

**Small-Scale Exhibit Impact on Science Knowledge**

Some students (*n*=216, 35%) felt that the experience increased their science knowledge, the majority of students (*n*=346, 55%) thought their science knowledge increased somewhat, and a few students (*n*=54, 9%) did not feel the experience increased their science knowledge. There were clear distinctions in the responses of those students who did or did not feel that their knowledge increased (Table 2). Based on the themes identified in their responses, students who perceived an increase in knowledge noted that it was because they *Learned Content* or about *How Things Work* or that the *Resources Were Helpful*. Some students associated their learning with having fun or engaging in science further. For example, Student 256 remarked, “I learned that with science you can do anything that you want.” Another student felt that “The [program] increased my science [knowledge] because it makes me feel like a scientist,” (Student 414).

<<Table 2 About Here>>

Many students felt they did learn some content but not on the same level as they would have in a classroom setting. Others, who perceived no knowledge increase, either felt their knowledge was already high and so there was little to add or they found the resources to be unhelpful, and sometimes confusing. Students who felt the resources were not helpful tended to point out specific aspects of the experience such as the signs being too long or difficult to read or a lack of explanation of the science behind the exhibits.

A one-way ANOVA was also used to examine differences in perceived knowledge increase by grade level. The dependent variable in this case was the average level of perceived increased knowledge as measured by a three-point scale from “No increase” to “Increased a lot.” A *Levene’s F* test again revealed that the assumption of homogeneity of variance was violated ($p < .05$), and the *Welch’s F* test was used. Results indicate that student average knowledge increase differs statistically significantly between grade levels, Welch’s $F(2, 399.0) = 63.02$, $p <.001$. The estimated effect size ($\omega^2 = .17$) indicated that approximately 17% of the variance in average perceived knowledge increase is attributable to differences in grade levels.

Games-Howell post hoc comparisons indicated that primary elementary students ($M = 2.57$, $SD = .577$) reported significantly higher average knowledge increases than middle school students ($M = 2.12$, $SD = .592$), which was a medium effect of .77 ($p < .001$). Additionally, intermediate elementary students ($M = 2.53$, $SD = .502$) reported a significantly higher average knowledge increase than middle school students, with a medium effect size of .75 ($p <.001$).

**Student Perceptions of the Program's Purpose**

To provide context around interest and learning perceptions, 520 out of 624 students responded to the open-ended question, *What is [this ISE program] trying to show you?* Themes identified in these responses are presented in Table 3. One major theme present in student responses was *Explaining Science* (22%). These responses tended to explain aspects of science around us or the exhibits themselves. For example one student said, "It was trying to show all the different types of sciences involved in all the items," (student 376). Student 43 touched on the nature of science, "They were trying to show us how things are done and what the effect is."

<<Table 3 About Here>>

Many students also felt that the program was showing that *Learning/Doing Science is Fun* (21%). A few of these students contrasted the informal experience with more formal classroom learning. For example, Student 105 remarked that the program showed "how science can be creative and fun and not just boring labs." Other students more generally responded that the program was showing that learning science can be fun.

Similarly, 28% of students linked the program to experimentation (i.e., themes *Science Experiments, How to Be a Scientist at Home, Using Ordinary Objects in Science*). One student made the connection between experimentation and interest, "[The program] was trying to show us different science experiments to increase our interest in science," (Student 306). Similarly, student 376 discussed using everyday items to increase science identity, "Simple things can be turned into a science experiment and you can find the scientist inside."

To further contextualize students' perceptions of interest and learning in science, we asked students to describe the program by checking a box in front of the descriptor(s) they felt applied to the program (Table 4). They were given nine choices and were allowed to write in other responses if none of the given descriptors fit their perception of the program. The leading prompt was, *[The program name] exhibit was* ___. Almost all students (98%) responded to the question by checking one or more boxes.

<<Table 4 About Here>>

A large percentage of all students felt that the program was fun and interesting. Overall, the response patterns of students in different grade categories were similar for most descriptors (i.e., the percentage of students checking a particular box was high or low for all groups). Students in the three grade level groups responded differently, however, to the following descriptors: *Time to be with Friends* ($\chi^2$ = 12.912, $p$ = .002, df = 2), *Educational* ($\chi^2$ = 10.490, $p$ = .005, df = 2), and *Doing Science* ($\chi^2$ = 12.252, $p$ = .002, df = 2).

A significantly higher percentage of intermediate elementary and middle school students felt that the program was a *Time To Be With Friends*. In total, 31 students wrote in unprompted responses related to friends. Of these, only four students wrote about "hanging out with my friends" (Student 104). Other students connected the social interaction with learning, such as Student 299 who said the best part of the experience was "Getting to have fun with my friends while still learning." Similarly, another student noted that "It brought me and my friends closer to be able to learn together at the same speed." (student 94).

Interestingly, intermediate elementary students alone had a significantly higher number of responses to the program being *Educational* or *Doing science*. To gauge the strength of the differences between the groups, odds ratios were calculated (Table 5). An odds ratio shows the increase in the odds of a student in one group responding in a particular way versus a student in another group. For example, in Table 5 the odds ratio between intermediate elementary and primary elementary students responding to "[The program name] was *Doing Science*" is 2.57. In other words, intermediate elementary students are 2.57 times as likely as primary elementary students to feel that the program is *Doing Science*. The confidence intervals give a range of valid odds ratios and is considered to be significant if it does not contain the value of 1.

<<Table 5 About Here>>

## Discussion

Through this study we have demonstrated two important findings: (1) that the E/O program we studied was associated with increased student interest in science and (2) that the ISE framework described by the NRC is relevant for studying E/O programs that travel to schools. As is consistent with the literature (Allen, 2002; Falk, et al., 2007), the majority of students in all grades noted an increased interest in science while fewer noted increases in learning. The perception of increased interest was greatest for elementary students, and the mean reported interest increase declined between the earliest elementary grades and middle school. Fewer than a tenth of the students (9%) claimed that the program did not increase their interest in science because they had previously participated in this E/O program. Given these small numbers, it is not plausible that these results are an artifact of students' repeated participation in the program. Rather, we argue that this finding supports other published research that demonstrates that science interest (as well as motivation and engagement) decreases during the transition between elementary and middle school (Osborne, Simon, & Collins, 2003; Vedder-Weiss & Fortus, 2011; Vedder-Weiss & Fortus, 2012). On average, students, egardless of grade level, did note some increase in interest in science after participating in the E/O program, and these increases were more subtle for middle school students than they were for elementary students.

Intermediate elementary students were also much more likely than the other two groups of students to report that the experience was educational. Middle school students might struggle to recognize the exploration of exhibits as educational because of the prevalent attitude that engagement in science is comprised of rote learning and "rigid, dogmatic thinking" (Barton, Tan, & Rivet, 2008; Lunn & Noble, 2008). It is also interesting to note that while intermediate elementary students were more likely to rate the experience as educational, elementary students in general were more likely to report gains in knowledge as a result of the experience.

This study provides further evidence between the positive relationship between science interest and learning (Renninger, Hidi, & Krapp, 2014; Hoffmann, Haeusster, Lehrke, 1998; Singh, Granville, & Dika, 2002). Students who reported that the E/O program led to increased science interest also perceived they were learning. By promoting increased interest in science, programs such as the one in this study could also positively impact student learning (Perry, 1994; Osborne, Simon, & Collins, 2003). Swarat, Ortony, and Revelle (2012) highlight the need for emphasizing the role of students actively engaging as a means of increasing students' interest in science. Experiences such as this E/O ISE could provide such an active hook to keep students interested and engaged in science through the transition between elementary and middle school. Further, programs such as this one have the potential to create personal connections between interest, knowledge, and real-world science (NRC, 2009).

Components of informal programs, such as interpretive materials like exhibit texts, can increase cognitive gains (Allen, 1997; Borun & Miller, 1980; Peart, 1984). However, within our study, only 5% of students noted the textual explanations helped in their learning. Further research is warranted to examine the relationship between specific aspects of these interpretive matierals and increases in cognitive gains.

Our first two research questions intentionally focused on two NRC strands (i.e., interest [Strand 1] and perceptions of cognitive gains [Strand 2]), while our third question explored how broad student perceptions about this program aligned with all six NRC strands. For example, students reported that they were "doing science" (Strand 3) as a part of the program, reflected on science (Strand 4) by considering how their view of science changed, reported that they engaged in scientific activities with friends (Strand 5), and mentioned that they want to do these experiments at home (Strand 6). Not only were they evident, but their intertwined nature was illustrated in individual student responses that were aligned with multiple NRC strands. Future studies should investigate other variables that might affect the connections between strands and how E/O programs such as the one in this study may lead to growth in understanding science and scientific processes along with affective responses.

We do not believe that it is coincidental that the overall odds ratios for *Educational* and *Doing Science* are so similar. If students do not recognize the experience as *Doing Science*, they may not believe the experience to be educational. This relationship may be exacerbated by the structured way science is generally taught at the middle school level, and middle school students preconceived ideas about what *Doing Science* should and should not look like.

Based on our data and supporting literature, it could be beneficial to enhance engagement through scaffolded social interactions of learning.  Our study found that students highly valued "friend" components of the experience. The collaborative nature of learning that ISE programs foster, even in the absence of an adult, has been documented (Guberman & Van Dusen, 2001; Hein, 1998; Tunnicliffe, 1997; Tunnicliffe, 2000). However, Crowley and Callahan (1998) argue that child-adult interactions can provide richer opportunities for scientific learning. For example, E/O program facilitators could model how participants might dialog with one another about the exhibits. Because older students in our study tended to consider the experience to be a social endeavor rather than an educational endeavor, scaffolding the experience with social aspects modeled by E/O program staff could have led to an enhanced experience for the students.

## Limitations

Our study was constrained by two main limitations. First, our analysis relied on student self-reports of learning. Although the validity of self-reported learning gains is mixed (Porter, 2013), we argue that, through the mixed-methods approach in our study, we solicited feedback from student participants on their perceptions of their learning gains situated within the context of students' ideas about the program's goals. We know that student perceptions of their learning gains may predict their goal setting behaviors for future learning (Zimmerman, 1990). Similarly, self-regulation of learning is affected by students' self-efficacy and their perceptions of their own learning outcomes (Schunk, 1991). Therefore, our approach was warranted because of its focus on perceptions of learning. Future research is necessary to examine the relationship between students' perceptions of learning and actual cognitive gains, particularly in traveling E/O programs that bridge the formal and informal learning environment (Eshach, 2007).

Second, our findings are based on the experiences of students in a single traveling E/O program. Our study was not designed to generalize to other settings or programs or to project student learning beyond their participation in the program. We also did not examine the relationships of specific aspects of the E/O program to student perceptions. This was not our intent. We do not view this to be a limitation, but rather an opportunity to build on these findings. Future research is warranted to understand what about traveling E/O programs leads to the outcomes defined by the NRC strands and how these experiences do or do not lead to further participation in science learning after the experience.

## Conclusions

We found that the unique combination of small-scale interactive exhibits constructed from everyday objects in a traveling museum format produced positive results aligned with all six NRC (2009) strands. Like other researchers (e.g., Anderson, Lucas, Ginns, & Dierking, 2000; Falk & Needham, 2011; Turner, 2008 ), we found measuring outcomes to be challenging without interfering with the experience itself. Notable findings emerged, namely the variation in self-reported gains in interest and knowledge for students at different grade levels and the interdependence of how students described their experience. Given our findings and the dearth of literature linking affective and cognitive gains in E/O programs (Rennie, 2007), ISEs such as the E/O program we studied are ideal for exploring participants' learning outcomes to better measure the relationships between interest in science and motivation to learn. Further, since our findings confirm the interconnected nature of the strands, future studies should investigate other variables that might affect the connections between strands and how E/O programs may lead to growth in understanding science and scientific processes along with affective responses.

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Table 1.
*Student explanations for (lack of) increase in science interest due to the program*

| Increased Interest | | | |
|---|---|---|---|
| Theme | # | % | Example Quote |
| Fun and Interesting | 163 | 26 | "The exhibits were really cool, and they made me want to study how they worked and make my own." (Student 508) |
| Interest in Experiments | 146 | 24 | "It made me like science more because it showed me that I can make my own experiments without having to go buy anything." (Student 443) |
| Added to Current Science Interest | 41 | 7 | "I already loved science, but this made me remember why!" (Student 126) |
| Improved Students' Science Phobia | 19 | 3 | "Well I have always got bad grades but whenever I go there I can understand more things." (Student 543) |
| Previous Participation with Increase | 10 | 2 | "I liked it in 5th grade then disliked it in 6th then you made me like it again." (Student 390) |
| No Increased Interest | | | |
| Theme | # | % | Example Quote |
| Previous Participation with No Increase | 53 | 9 | "Well we see the same [program] experiments every year, it gets boring." (Student 92) |
| Disinterest in Science | 15 | 2 | "I have never really liked science but [the program] was really fun." (Student57) |
| Did Not Enjoy the Experience | 14 | 2 | "That type of science might be cool, but if I were to become a scientist, most likely that's not what I would be doing. (Student 90) |
| Already as Interested as Possible | 13 | 2 | "I'm already very very interested in science." (Student47) |

Note: Percentages are calculated based on a total number of question responses N = 618; of these, 141 (23%) of responses were unclear or left blank

Table 2.
*Student explanations for (lack of) increase in science knowledge due to the program*

| Increased Knowledge | | | |
|---|---|---|---|
| Theme | # | % | Example Quote |
| Learned Content/How Things Work | 92 | 15 | "I learned how solar energy works." (Student 218) |
| Resources Helped in Learning | 27 | 5 | "I read all the explanations about how things worked." (Student 295) |
| Fun Added to Learning | 15 | 2 | "Fun things help us to remember." (Student 54) |
| Learned Content to Further Engage | 11 | 2 | "I didn't know many things about science and now I can make my own science." (Student 91) |
| Little or No Increased Knowledge | | | |
| Theme | # | % | Example Quote |
| Learned Some/Little Content | 108 | 18 | "I learned some but not like as much as a class lesson." (Student 237) |
| Current Knowledge Already High | 81 | 13 | "I know a lot about science already and am sort of ready for more advanced stuff but the experiments were still really cool." (Student 143) |
| Little or No Help From Resources | 76 | 12 | "There really wasn't any explanation on the science behind it." (Student 426) |
| Only Fun/No Learning | 31 | 5 | "A little bit, I mean occasionally I would read a sign, but I mostly just played around with the objects." (Student 8) |
| No Learning but Want to Further Engage | 23 | 4 | "I didn't get to see all of the exhibits, so I didn't get to learn a whole lot, but what I did learn has me wanting to study further." (Student 90) |

Note: Percentages are calculated based on a total number of question responses N = 618; of these, 154 (25%) of responses were unclear or left blank

Table 3.
*What is the ISE program trying to show you?*

| Theme | # | % | Example Quote |
|---|---|---|---|
| Explaining Science | 138 | 22 | "I think the [program] was trying to show us how certain stuff worked and it was explained with science." (Student 222) |
| Learning/Doing Science is Fun | 128 | 21 | "It was trying to show me that science is cooler than just a class." (Student 291) |
| Using Ordinary Objects in Science | 74 | 11 | "I think they were trying to show us that science and physics aren't just things in a lab, that they can be made of everyday objects." (Student 254) |
| How to Be a Scientist at Home | 55 | 9 | "I think they were trying to open the door to the scientist inside each of us." (Student 234) |
| A specific Topic/Program Theme | 49 | 8 | "I think it was trying to teach us about more basic principles of light, sound, electricity, and magnetism." (Student 178) |
| Science Experiments | 49 | 8 | "I think they were trying to show us how many different experiments you can do with science." (Student 235) |
| Expanded View of Science | 27 | 4 | "They were trying to show us how everything has a way it connects with physics." (Student 490) |

Note: Percentages are calculated based on a total question responses N = 627.

Table 4.
*Responses to "[The program name] exhibit was …"*

| | Percentage of Student Responses | | | |
|---|---|---|---|---|
| | Primary Elementary (n = 96) | Intermediate Elementary (n = 110) | Middle School (n = 418) | Total (n = 624) |
| Fun | 79 | 91 | 85 | 85 |
| Interesting | 60 | 83 | 75 | 74 |
| Learning with Friends | 47 | 61 | 52 | 53 |
| Time to be with Friends† | 36 | 55 | 56 | 53 |
| Educational† | 36 | 59 | 45 | 46 |
| Doing Science† | 36 | 60 | 44 | 45 |
| Playing Games | 28 | 36 | 47 | 31 |
| Other | 9 | 21 | 11 | 12 |
| Boring | 1 | - | 4 | 3 |
| A Waste of Time | 2 | 3 | 4 | 3 |

Note: Percentages were calculated from group totals as shown in column headers
†Groups differed significantly by grade level on responses.

Table 5.
*Odds ratios for group differences in significantly different responses*

| | Odds Ratio | Confidence Interval |
|---|---|---|
| Time to be with Friends | | |
| Intermediate Elementary vs. Primary Elementary | 2.05 | (1.17, 3.60) |
| Middle School vs. Primary Elementary | 2.29 | (1.45, 3.63) |
| Educational | | |
| Intermediate Elementary vs. Primary Elementary | 2.48 | (1.41, 4.35) |
| Intermediate Elementary vs. Middle School | 1.68 | (1.09, 2.58) |
| Doing Science | | |
| Intermediate Elementary vs. Primary Elementary | 2.57 | (1.46, 4.52) |
| Intermediate Elementary vs. Middle School | 1.87 | (1.22, 2.87) |

Note: Odds ratios show the increase in odds of a student in the first listed group of responding in the indicated way over that of a student in the second listed group. Confidence intervals show the estimated range of the odds ratio.

# Cartesian Diver

## What to Do:

Put your hand on the bottle and push down gently. Do you see the ketchup packets indent? What happens if you push a little harder? Can you make all the ketchup packets sink?

## What is Happening:

This device is known as a Cartesian Diver. There is a small bubble of air inside the sauce packet. When you squeeze the bottle, you increase the pressure in the water. This compresses the small bubble of air in the packet. Since the bubble is smaller, the packet is more dense, and it will sink. When you let go, the pressure goes back, and the packet floats again!

## Appendix B

**[Program Title]**
**Student Questionnaire (Name of School)**

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**What time did you visit the [Program] (please circle)**

7:35-8:10 8:10-5:53 8:57-9:40 9:40-10:21 10:25-11:05 11:40-12:19 12:23-1:00 1:00-1:41

**What do you think the Little Shop of Physics was trying to show you today?**

**Did the Little Shop of Physics increase your <u>interest</u> in science?**

- YES! Definitely!
- Sure, a little.
- My interest is the same.
- No.

**Please explain:**

**Did the Little Shop of Physics increase your <u>knowledge</u> of science?**

- YES. I learned a lot about science.
- Some. I learned a little about science.
- No. I did not learn anything about science

**Please explain:**

**What did you see today which made you think about science in a different way??**

**The Little Shop of Physics exhibit was:** (circle all that apply)

- Interesting
- Fun
- Educational
- Boring
- Playing games
- A waste of time
- Doing science
- Learning with friends
- A time to enjoy being with friends
- Other: ____________________________________

**What helped you to learn?**

- Pictures on the signs
- Reading the signs
- Watching my friends work with the experiments
- Watching the Little Shop of Physics staff work with the experiments
- Talking to Little Shop of Physics staff (in the tye-dyed shirts)
- Talking with my teachers
- Talking with my friends about the experiments
- Playing with the experiments
- Other: _____________________________________

**Did you recognize any objects in the experiments? What did you recognize?**

**Did the Little Shop of Physics give you any ideas for projects or experiments you can do on your own (ex. at home, science fair, etc).**

**What did you like the MOST about the Little Shop of Physics?**

**What could have been done better?**

**THANK YOU!!!**

## Appendix C

Table C1.
*Codes for student explanations for (lack of) increase in science interest due to the program*

| Theme | Sub-Theme |
|---|---|
| Fun and Interesting | Made me enjoy the science around me/Cool or interesting<br>Seeing how everyday objects were used in experiments |
| Interest in Experiment | Interest in how experiments were created/constructed<br>Interest in how things work/Specific experiment |
| Added to Current Science Interest | Learned more about science<br>Made me curious to learn more |
| Improved Students' Science Interest | Changed my opinion about science for the better<br>Made me think about science in a different way |
| Previous Participation | Seen before, but still interested to do more experiments<br>Seen before, but it was the same as always |
| Disinterest in Science | Has a phobia of Science<br>Doesn't Enjoy Science |
| Did Not Enjoy the Experience | Did not connect the experience to science<br>Does not like hands-on science |
| Already as Interested as Possible | Existing Interest in science |

Table C2.
*Codes for student explanations for (lack of) increase in science knowledge due to the program*

| Theme | Sub-Theme |
|---|---|
| Learned A lot or A little Content/How Things Work | General learning about science<br>Named specific concepts |
| Resources Helped in Learning | Signs/interns were helpful<br>Experiments were explained well |
| Resources Not Helpful in Learning | Didn't read the signs/Signs were too long<br>Explanations were confusing |
| Fun Added to Learning | Learned science is cool<br>Learning science is fun |
| (Did not) Learn Content and Wants to Further Engage | Want to know more about how things worked<br>Learned how to make experiments |
| Current Knowledge Already High | Already knew content<br>Had seen content before |
| Only Fun/No Learning | Fun experience, but it was playing<br>Played with "toys" so no learning |

Table C3.
*Codes for responses to, "What do you think the ISE program was trying to show you today?"*

| Theme | Sub-Theme |
|---|---|
| A specific topic/Program Theme | New dimension/3D* |
| | Show science: specific topic |
| Science Experiments | Fun/cool science/physics experiments |
| Using Ordinary Objects in Science | How to use ordinary objects/anything/everything to make experiments/science/physics |
| Learning/Doing Science is Fun | Science is fun and still learn |
| | Science is fun/cool/awesome/interesting/spark interest in science |
| How to Be a Scientist at Home | How to make experiments |
| | Can do science at home/be a scientist/easy to do science yourself/cool things you can do with science |
| Explaining Science | How things work |
| | Show/teach about science/physics in general |
| Expanded View of Science | Science is all around us/ways to use science in life |
| | Different way to look at science/science is creative |

*3D was the theme of the program during the year of the study