Engaging Youth in Exhibition Development and Evaluation
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Abstract. Incorporating youth in exhibition development and evaluation can support powerful learning opportunities for participants and critical insights for informal learning professionals about how best to design learning experiences for this audience. This article will describe how an exhibition design team from the National Center for Interactive Learning at the Space Science Institute used this strategy to connect youth to STEM as a part of the *Asteroids* project. During the design development phase of the *Great Balls of Fire* exhibition three teams of middle school youth were recruited to form Student Advisory Teams (SATs). Youth in Colorado, New Mexico, and North Carolina participated in a variety of experiences related to space science, scientific practice, the design-development process, and the evaluation of exhibit components. Quantitative analysis of pre-post questionnaires investigated changes in knowledge, attitudes, and level of engagement with science topics. Qualitative analysis of post program interview responses provided elaboration of these patterns of change. The results provided evidence of improvement across impact categories. These findings will be discussed in terms of their implications for the value of active inclusion of youth in authentic design-development experiences.

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Introduction

The NSF-funded *Asteroids* project was a multi-faceted informal education initiative led by the National Center for Interactive Learning at the Space Science Institute. This project supported public engagement and understanding of the dynamic structure of the solar system through investigations of asteroids, comets, and meteors and their relationship to Earth. PI Paul Dusenbery directed the project and coordinated the contributions of project partners that included: Sunset Middle School, CO; New Mexico Museum of Natural History and Science, NM; and Catawba Science Center, NC as well as the exhibition planning and design firm Jeff Kennedy Associates, Inc., and a research and evaluation team from the Institute for Learning Innovation. The centerpiece of this project was the development of the traveling exhibition *Great Balls of Fire: Comets, Asteroids, and Meteors*. The GBoF tour began in May 2011.

In coordination with the design development phase of the exhibition, three teams of middle school students were recruited to form Student Advisory Teams (SATs). Teams were established in three locations: Sunset Middle School, CO; New Mexico Museum of Natural History and Science, NM; and Catawba Science Center, NC. The design and implementation of the SAT program was grounded in existing research and best practices for successful youth programs in out of school settings (NRC, 2002; Koke & Dierking, 2007; Bell et.al., 2009; Dussault, 2009). The structure of the program was informed by elements of positive youth development, an asset based theoretical framework that encourages youth centered, knowledge centered, and community centered experiences (McLaughlin, 2000). In addition, the project was committed to achieving target outcomes that reflect successful positive youth development efforts including competence, confidence, connection and contribution (Lerner, 2005; Luke et. al., 2007). Project advisors familiar with the challenges of authentic youth engagement in exhibition design and development provided critical guidance for the SAT program design (The Black Hole Experiment Gallery, NSF# 0638963). The youth participants that experienced the most significant gains in science content knowledge and understanding of the design process were those who were involved for a sustained period of time and participated in iterative testing of exhibition components (Dussault, 2009).

The SAT program extended the work of the Black Holes project and explored whether similar learning outcomes could be achieved with middle school aged youth. Beginning in 7th grade and continuing through the end of their 8th grade school year, SATs participated in a variety of experiences related to space science content, scientific practice, the design development process, and the evaluation of exhibit components. In addition, each team created a project deliverable focused on space science content that allowed them to work through an authentic design, development, and production process. This article will describe how the SAT program was designed to address the following target outcomes:

-Understanding of comets, asteroids, and meteors
-Positive attitudes about science and scientists
-Scientific skills and habits of mind
-Science communication skills, practices, and resources

It will also discuss the implications for exhibition design teams of working with youth to co-create informal science learning experiences.

Methods

A mixed methods approach was used to measure the impact of the SAT program on youth participants. All youth participants and their parents provided signed informed consent to participate in the program and associated evaluation activities. All IRB approvals were provided by IRC (www.irb-irc.com). Quantitative analysis of pre-post questionnaires investigated change in knowledge, attitudes, and level of engagement with science topics. Qualitative analysis of post program interview responses provided elaboration of these patterns of change.

SAT Questionnaire

Youth participants completed questionnaires prior to beginning the SAT program and an adapted version was completed at the conclusion of the program in spring 2010. A combination of multiple choice, Likert-like scales, and open ended items were used to measure target outcomes. While a total of 47 youth participated in some aspects of the SAT program, a subset of 34 youth completed both baseline and summative questionnaires (Table 1). The sample included responses from 16 boys and 18 girls. Participant attrition was primarily the result of youth changing schools, illness, and schedule conflicts that emerged over the course of the 18-month program. SAT program leaders at each site administered questionnaires. Researchers analyzed the results from the baseline and summative questionnaires.

Table 1: Summary of completed SAT questionnaires by site

Site	%	n=34
Colorado	41%	14
North Carolina	27%	9
New Mexico	32%	11

SAT Interview

Interviews were conducted by phone in September 2010. Semi-structured interviews were designed to provide additional detail about the personal impacts of the program on youth participants. Each of the students for which we had available information was contacted at least once and asked if they would like to participate in an interview. A total of 19 interviews were completed representing a nearly equal number of responses from each SAT team (CO=7; NC=6; NM=6). There were 9 boys and 10 girls interviewed. Researchers coded and analyzed interview responses.

Results

The results from the pre-post SAT program questionnaires and interview provided evidence for the impact of the program on the youth participants. Findings are organized by target outcome.

Understanding of comets, asteroids, and meteors

In the questionnaire, participants completed a range of items designed to measure their understanding of comets, asteroids, and meteors as well as some related astronomy topics like gravity. Consistent with the baseline assessment, an overall astronomy knowledge score was calculated based on responses to a subset of multiple-choice questions. The maximum total knowledge score was 7 points. On the baseline assessment, SATs average knowledge score was 4.03 (SD=1.79) while on the summative the average score was 4.88 (SD=1.22). This change demonstrated a significant increase in student understanding of scientific concepts related to comets, asteroids, and meteors ($t_{32}=3.16$, $p=.003$). It was also interesting to note that while boys (M=4.81, SD=1.80) had significantly higher scores than girls (M=3.44, SD=1.58) on the baseline assessment ($t_{32}=2.34$, $p=.026$), these differences did not emerge on the summative assessment. This suggested that following the program on average girls and boys were equally knowledgeable about comets, asteroids, and meteors.

Item level analysis revealed improved understanding of the influence of gravity on objects including the space shuttle in orbit; asteroids, meteors, comets; and Earth's moon. In the summative questionnaire 85% of students (n=28) recognized that gravity influenced all of these objects compared to the baseline where nearly half indicated that gravity only influenced some of the objects or were unsure about the influence of gravity on objects.

Student knowledge about asteroid impacts also increased. Following participation in the SAT program, 100% of youth agreed that an asteroid had hit Earth in the past. This was an increase from the baseline where 88% of youth agreed with this statement. When asked to describe how we would know if an asteroid has ever hit Earth in the past, 73% of responses in the summative discussed sources of evidence of the impact including craters and fragments of the object (M=.82, SD=.50). This was a significant increase from the 54% that provided this category of explanation on the baseline (M=.61, SD=.39, t_{27}=1.99, p=.05). An additional 21% cited the extinction of dinosaurs as an indication of past asteroid impacts as compared to 13% on the baseline though this was not a significant change. The significant increase of students using evidence-based explanations was very encouraging. The dramatic improvement in the level of detail included in student explanations among many of those who did not change response categories also indicated an increased scientific competence among SATs.

Table 2: Examples of pre-post explanations: *How do we know that an impact did or did not happen?*

Site	**Code**	**Baseline**	**Summative**
NC	Evidence	There will be a crater and there would be materials left over from the asteroid	Scientists have found iridium in the ground. Iridium is very common in space, but very rare on earth. If they find areas of highly concentrated iridium, the scientists know something from space hit the Earth, even if there isn't an impact crater
NM	Evidence	Craters and traces left behind	We found impact craters left behind, along with shards of asteroids that didn't burn up in the atmosphere
CO	Extinction of dinosaurs	Because dinosaurs went extinct due to an asteroid that hit Earth	Because some of the dinosaur fossils [have] material that comes from space

Positive attitudes about Science and scientists

On the summative questionnaire, a set of items measured participants' rating of their attitudes towards science and scientists from before the program and following the program. Retrospective pre-post rating scales like these have been used successfully to measure perceived change in knowledge, interest, and attitude with middle school youth audiences (Foutz, 2010). Analysis revealed statistically significant differences between the retrospective-pre and post ratings for all of the items focused on positive attitudes towards science and scientists (Table 3). For this set of items, ratings increased the most for the statement "Scientists make important contributions to daily life" and the least for "I like science." This suggested that student knowledge and attitudes about scientists and their work seemed to change more on average than their knowledge and attitudes about science itself.

Table 3: SAT program impacts on attitudes towards science and scientists: Retrospective-pre program and post program ratings

Item	Retro-Pre Mean	Post Mean	Z	**p**
Scientists make important contributions to daily life	5.04	6.32	-3.56	**.000**
I know about a variety of careers in science	4.57	5.79	-3.59	**.000**
Science is interesting	5.03	6.21	-3.48	**.001**
I am interested in talking to scientists about their work	4.25	5.15	-3.65	**.000**
I know what scientists do	4.81	5.58	-3.10	**.002**
I like science	5.31	6.06	-2.83	**.005**

Note. The Wilcoxon Signed-ranks test was used to test for statistical significance.

During the post program interview, participants were asked whether they felt the program had changed their attitudes or opinions about science. Nearly half of the responses indicated that the program had positively influenced their attitudes towards science. For these participants, the experiences in the program seemed to expand their definition of science beyond book learning or Earth science. As one participant in this group commented, “Yes, because I didn't have a lot of experience with science. I used to think that science was probably boring but when I got into it I found out it was really interesting.” (NM SAT). Another participant suggested that the program had also changed her level of excitement about doing science. She commented, “Definitely! I sort of wasn't into it. It was like—science, oh boy an experiment—and now I’m like SCIENCE! Great let’s do an experiment!” For the participants that did not feel as though the program changed their attitudes towards science, most of their responses acknowledged that they already “liked” or “loved” science and that the program just reinforced those positive opinions. For example, one student commented, “No, there was not much to change. I've always been excited about science.” *NC SAT*

Scientific skills and habits of mind

The SAT program used engaging activities and experiences focused on topics like asteroids, comets, and meteors to provide a context for the development of scientific skills and habits of mind. Participants were asked on the pre and post program questionnaire to indicate what they felt was a good definition of science. The largest percentage of participants chose “Study of the natural world that describes both what happens and why it happens” on both the baseline (59%) and the summative (55%). The summative pattern of responses revealed some interesting trends. Following the program, participants were more likely to provide their own definitions of science and to associate science with the work of practitioners. In addition, participants were less likely to associate science with specific fields of study or with the processes of describing what and why (Table 4). In general, participants' definitions acknowledged that science can be described more broadly than the options the item provided.

Table 4: Responses to the item: Science is….

Multiple Choice Options	Baseline	n=34	Summative	n=31
Study of the natural world that describes both what happens and why it happens	59%	20	55%	17
Body of knowledge about topics like biology, chemistry, astronomy, physics, or geology.	23%	8	13%	4
Defined by the work of researchers or scientists.	3%	1	10%	3
Own definition	15%	5	22%	7

Another approach to measuring this impact was through a questionnaire item that explored participants understanding of scientific practice. The summative questionnaire revealed that 82% of responses mentioned the tools and equipment that scientists use to study asteroids, comets, and meteors (M=0.82, SD=0.39). This was a significant increase from the 64% of responses that mentioned tools on the baseline (M=0.62, SD=0.49, t_{33}=2.51, p=.017). The percentage of responses that focused on the role of evidence interpretation (35%) and scientific process (32%) also increased compared to the baseline though these changes were not significant (Table 5). In addition, the finding that no responses to the summative were outside of the tools, evidence, or process coding categories suggested that students had a more consistent understanding of the ways that scientists study asteroids, comets, and meteors following the program.

Table 5: How do scientists study asteroids, comets, and meteors?

	Baseline	n=33	Summative	n=34
Tools*	64%	21	82%	28
Evidence	21%	7	35%	12
Process	27%	9	32%	11
Other	6%	2	0%	0
Don't know	12%	4	0%	0

*Significant at p<.05. Note: Multiple responses allowed.

The significant increase of students using tool-based explanations suggested an improved recognition of the importance of tools and equipment to the scientific study of asteroids, comets and meteors. However, taking a closer look at student responses revealed additional qualitative changes between baseline and the summative explanations. On the baseline, many responses focused on just one of these categories, indicating that scientists used telescopes <u>or</u> collected samples to conduct their work. In contrast, on the summative many student responses included references to at least two of the three coding categories. This improvement in the level of detail included in student explanations suggested an increased competence to describe the ways that scientists generate new knowledge. Table 6 provides examples of how the quality of student responses shifted between baseline and summative.

Table 6: Examples of pre-post explanations provided by participants

Site	Baseline	Codes	Summative	Codes
NM	Telescopes	Tools	Telescopes and infrared technology and microscopes to look at samples found on Earth	Tools, Evidence
CO	They get samples from crashed objects	Evidence	They gather specimens. The first comet specimen was collected by the satellite deep impact. And some asteroids can reach Earth's surface intact.	Tools, Evidence
NC	They use telescopes and study pieces of asteroids found in different places.	Tools, Evidence	They use telescopes to take a photo of the sky. Then they take another photo and layer them on top of each other. If something moves, it is probably an asteroid, comet, or meteor. They can then determine its speed, size, and shape.	Tools, Evidence, Process

Recognition of the components of scientific practice is an important indication of the level of participant understanding. In the phone interview, participants were asked to demonstrate their ability to generate the steps of a scientific process. This approach explored whether participants had developed this additional level of competence. Participants were asked to imagine that they were members of a science team collecting samples from an impact site. They were asked to describe what steps they might take to figure out whether a collected sample was a rock or a meteorite. Responses to this question were coded for level of sophistication. The majority of participants (85%) provided explanations that included a multi-step process. The most sophisticated of these explanations recognized the importance of careful observation, collecting and comparing samples to existing specimens, conducting tests of magnetism and hardness, and interpreting the data. The remaining participant responses focused on one step of the scientific process. For example, participants' described the importance of "careful observation under a microscope" or "testing the composition" of a sample without further elaboration.

On the summative questionnaire, retrospective pre-post rating scales were also used to measure perceived change in scientific skills and habits of mind. Analysis revealed statistically significant differences between the retrospective-pre and post ratings for all of the items focused on scientific skills and habits of mind (Table 7). For this set of items, ratings increased the most for the statement "I have a good understanding of the process of scientific research" and the least for "I am interested in the process of scientific research." This suggested that student knowledge about the research process may have changed more than their intrinsic interest in the process itself.

Table 7: SAT program impacts on scientific process and habits of mind: Retrospective-pre program and post program ratings

Item	Retro-Pre Mean	Post Mean	Z	**p**
I have a good understanding of the process of scientific research	3.89	5.65	-4.16	**.000**
People should understand science because it effects their lives everyday	4.75	6.32	-3.14	**.000**
Before I make up my mind, I consider multiple sides of the issue	4.71	5.85	-3.68	**.000**
I am interested in the process of scientific research	4.44	5.50	-3.86	**.000**

Note. The Wilcoxon Signed-ranks test was used to test for statistical significance.

In addition to developing familiarity with the value and process of science, the SAT program was committed to engaging participants in an authentic design process. The process of design requires skills and habits of mind that can be applied across learning contexts. An open-ended item was designed to measure participants' ability to think through the steps they might take to create a museum exhibit. Responses to this question were analyzed with both emergent and deductive codes (Chi, 1997). Emergent codes captured the descriptive components of participant responses. Deductive codes captured the relationship between participant and expert mental models of the design process.

On the summative questionnaire, participants most frequently included product oriented, iterative, and linear process aspects of the exhibit design process. Analysis revealed a significant increase in product oriented codes with only 33% of participants including it on the baseline (M=0.34, SD=0.48) compared to 77% of participants including this category in their summative response (M=0.78, SD=0.42, t_{31}=4.00, p<.001). A significant increase was also found for iterative codes with only 21% of participants including it on the baseline (M=0.22, SD=0.42) compared to 53% of participants including this category in their summative responses (M=0.53, SD=0.51, t_{31}=3.30, p=.002). In addition, a significant decrease was found for descriptive codes with 46% on the baseline (M=0.47, SD=0.51) compared to only 18% of participants including this category in their summative responses (M=0.17, SD=0.37, t=2.92, p=.005) (Table 8).

Table 8: Distribution and frequency of design process coding categories

Emergent Coding Categories	**Example Responses**	**Baseline %**	**n=33**	**Summative %**	**n=34**
Product oriented*	Build it, Make sketches, Design	33%	11	77%	26
Iterative*	Get feedback and revise	21%	7	53%	18
Linear process	1.Idea 2.Build it 3.Test it	39%	13	35%	12
Descriptive*	Creativity and hard work	46%	17	18%	6
Other	Add specimens of dinosaur fossils	6%	2	6%	2

*significant at p<.01. Note: Multiple responses allowed.

On average, the responses provided on the summative questionnaire were more detailed than those provided on the baseline. The increased level of sophistication in responses suggested which aspects of the design process were more salient to participants following their experiences in the program (Table 9).

Table 9: Participant responses describing the design process

Site	**Baseline**	**Codes**	**Summative**	**Codes**
NC	You need creativity, optimism, hard work, and good teamwork	Descriptive	First brainstorm the idea. Think of what the people want. Then design it and see if others like it.	Linear process, Product oriented, Iterative

NM	Think of idea, Share and improve ideas, Map or make picture of ideas, gather materials, and Build	Linear process, Product oriented, Iterative	1. Educate yourself on the topic. 2. Brainstorm/discuss ideas. 3. Make a basic plan. 4. Gather materials. 5. Put together pieces and form plan to create a basic project. 6. Critique/Get feedback. 7. Use suggestions to improve the project. 8. Make revisions.	Linear process, Product oriented, Iterative
CO	Decide on its use and make it fun	Product oriented, Descriptive	Find what people want. Design a product. Ask people what they think. Make adjustments accordingly.	Linear process, Product oriented, Iterative

Analysis of participants' responses on the summative questionnaire also revealed that their mental models of the design process following the program were more closely aligned with an expert model. The deductive coding system revealed that participants recognized and articulated more of the intermediate steps necessary to successfully implement the design process. On the summative questionnaire, participants most frequently included design, build, and integrate feedback aspects of the exhibit design process. Analysis revealed a significant increase in design oriented codes with only 30% of participants including it on the baseline (M=0.31, SD=0.47) compared to 79% of participants including this category in their summative responses (M=0.78, SD=0.42, t_{31}=4.27, p<.001). A significant increase was also found for build codes with only 27% of participants including it on the baseline (M=0.28, SD=0.46) compared to 64% of participants including this category in their summative responses (M=0.63, SD=0.49, t_{31}=2.47, p=.019). In addition, a significant increase was found for evaluate codes with only 3% on the baseline (M=.03, SD=0.18) compared to 29% of participants including this category in their summative responses (M=0.31, SD=0.47, t_{31}=3.48, p=.002) (Table 10).

Table 10: Distribution and frequency of design process deductive coding categories

Deductive Coding Categories	**Example Responses**	**Baseline %**	**(n=33)**	**Summative %**	**(n=33)**
Design*	Make a sketch, Draw plans	30%	10	79%	26
Build*	Make it, Build it	27%	9	64%	21
Brainstorm	Create some ideas	24%	8	36%	12

Test	See if it works, Test it	21%	7	36%	12
Evaluate*	Critique, Get feed-back	3%	1	30%	10
Define the problem	Decide what it's about	18%	6	27%	9
Integrate feedback	Correct errors, Revise	9%	3	18%	6
Research	Find out more about topic	15%	5	6%	2

*Significant at p<.02 Note: Multiple responses allowed.

The increased level of sophistication in participant responses provided insight into the ways that their mental models of the design process had changed. While many participants did not articulate all of the aspects of the expert model, the majority demonstrated improvement in their ability to articulate a design process (Table 11).

Table 11: Participant responses and deductive codes describing the design process

Site	Baseline	Codes	Summative	Codes
NC	Research it. Set it up. Test it out.	Research, Build, Test	First, I would come up with the idea, and perfect it and then make a drawing board. Then, I would prototype it and ask people what they think about it. After that, I would add finishing touches and show it to the world.	Define the problem, Design, Evaluate, Integrate feedback, Build
NM	Decide what kind of exhibit you want to build, what story you want to tell, and then make what you want to put in it.	Design, Define the problem, Build	First, figure out what you are designing. Then brainstorm what things you want in your exhibit. Then decide what to keep in your exhibit, for example if the space is too small for what you want. Then work on making each item you want in the exhibit.	Design, Brainstorm, Design, Evaluate, Build
CO	Well I would make sure I have all the materials I	Design, Build	Make your idea ready, test it, have other people review, then make a real model.	Brainstorm,

need and then work really hard to make it.	Test, Evaluate, Build

Science communication skills, practices, and resources

On the summative questionnaire, retrospective pre-post rating scales were also used to measure perceived change in science communication skills, practices, and resources. Encouraging the development of these skills is an important aspect of achieving scientific literacy (Bell et. al, 2009). Analysis revealed statistically significant differences between the retrospective-pre and post ratings for all of the items focused on science communication skills, practices, and resources (Table 12). For this set of items, ratings increased the most for the statement "I am interested in hearing more about science issues that are in the news" and the least for "When talking to others about science, I use facts to support my point of view." This suggested that participants were more interested consumers of science related news. In contrast, while they recognized that their competence in expressing evidence-based opinions had improved, this was a more substantial personal change that may have accounted for the relatively smaller rating increase.

Table 12: Impacts on science communication skills, practices, and resources: Retrospective-pre program and post program ratings

Item	Retro-Pre Mean	Post Mean	Z	**p**
I am interested in hearing more about science issues in the news	4.21	5.91	-4.09	**.000**
I have a good understanding of science issues that I hear about in the news	3.89	5.55	-4.08	**.000**
I feel confident sharing with others what I know about current science	4.29	5.44	-3.67	**.000**
When talking to others about science, I use facts to support my point of view	4.43	5.41	-3.08	**.002**

Note. The Wilcoxon Signed-ranks test was used to test for statistical significance.

The post program interview provided another opportunity to measure the impact of the SAT program on science communication skills and practices. For some participants, the program had a dramatic impact on their communication skills. For example, a participant from the North Carolina team said, "Yeah, I got to meet new people and overcame most of my shyness. I usually don't talk to people and explain my ideas. On the asteroids team I was able to talk to my team." Throughout the interviews, participants commented that the SAT program had given them opportunities to develop more effective communication strategies. Another participant from the North Carolina team said, "Yeah, it actually helped me get along in groups better and communicate my ideas. Now in school I can get things done quicker working in groups." Responses like these suggested that SATs developed confidence in their ability to express themselves across contexts. Participants also felt that they contributed to their final projects and that learning to communicate with others was critical to achieving their goals. As one student from the Colorado team commented, "There were a lot of people in the group who had different learning styles. Some people liked things long and in depth, others liked to watch videos, and others liked to read. We found a way to work it out. Everyone did something they liked, and we got it done, but it was challenging." Participants seemed to recognize that the SAT program had improved their ability to communicate about science concepts.

> *Yeah, I used to be VERY nervous around strange people. I got to practice talking to groups about science and get more comfortable doing that. NC SAT*

> *The program made me a lot more comfortable with the public and with people I didn't know. Also, we had a lot of important speakers and we learned how to talk with them about science in a mature and responsible manner. NM SAT*

> *Yeah, now that I'm more informed about these topics, I like to share my knowledge. CO SAT*

In addition to perceived changes, comparison of participant responses on the baseline and summative questionnaire explored the frequency with which participants engaged in science activities. Participants were asked to rate their level of engagement on a scale from "not at all" to "once a day or more". These items provided some insight on how participants typically used different kinds of science communication resources. On the summative questionnaire, participants indicated that they most frequently talk with family or friends about science and least frequently read science related books or magazines. This was a change from participant responses on the baseline that indicated they most frequently paid attention to science news and least frequently visited science websites. These adjustments in the order of activity engagement suggested that participant confidence and competence to talk about science increased following the program. The decrease in reading science related books suggested that participants were engaging with science in more social contexts as compared to more individualized activities. Analysis of baseline and summative ratings revealed a significant difference in frequency of participant engagement in science talk with family and friends and visits to science museums or exhibits (Table 13).

Table 13: Participant baseline and summative ratings of engagement with science activities

Item	Baseline Mean	Summative Mean	Z	P
Talk with family or friends about science related topics*	4.03	4.79	-2.36	**.018**
Pay attention to science-related news	4.18	4.52	-1.33	**.183**
Visit science related museums or exhibits*	3.09	3.65	-2.05	**.041**
Watch science related shows on TV	3.26	3.32	-.049	**.961**
Visit science-related websites	3.03	3.26	-.694	**.488**
Read science related books or magazines	3.44	3.00	-1.14	**.253**

**Significant at p<.05. Note.* The Wilcoxon Signed-ranks test was used to test for statistical significance.

> "I think it made me more open and interested in science. I think I pay more attention now to things that are going on like scientific news. I may be interested in a career in science." NM SAT

Discussion

Combined analysis of the program participants across the three SAT sites demonstrated gains in the youth outcomes the program was designed to target.
The program was successful at providing learning opportunities about asteroids and comets, their relationship to Earth and the broader solar system. Participants showed increased understanding of the role of gravity, the differences between asteroids and comets, the ways that astronomers and space scientists developed new knowledge, and the behavior of asteroids and comets. These gains were apparent in participants increased accuracy on post-test measures and use of scientific and technical vocabulary.

In addition, many participants entered the program with positive attitudes about science. For these participants, the SAT program connected them more deeply with science and in some cases encouraged them to think about future learning opportunities and careers in science. Other participants reported that the SAT program encouraged them to see science in a more positive way. Many of these participants entered the program believing that science was boring and by the end of the program reported enjoying and valuing the role of science in everyday life. The timing of this shift in interest and attitude toward science may be particularly valuable for these participants as research suggests that positive middle school experiences with STEM can be a strong predictor of future career paths (Catsambis, 1995; Tai, et.al., 2006).

Another important program component was the exposure to the work of scientists. Participants enjoyed meeting scientists, hearing directly about their research, and learning how to use current science in their projects. These interactions helped students re-define their ideas about what it means to be a scientist and contributed to significant increases in participants' positive attitudes about science and scientists.

The ability to recognize and use scientific skills and habits of mind increased significantly following the program. Participants were more consistent in their ability to describe components of scientific practice, apply those skills to solve problems, and think critically about scientific concepts. Participants also improved their understanding of the design process. Analysis revealed that following the program participants were better able to articulate the intermediate steps that move a project from an idea to a finished product, including the importance of evaluation in that process.

Participants demonstrated significant improvement in their communication skills as a result of engagement in program activities. Many participants commented that their confidence and competence to share their thoughts and opinions with friends and family increased throughout the program. Participants also learned the value and importance of teamwork and developed strategies for communicating as a member of a group. These skills could have powerful implications for future success across learning contexts. Participants gained confidence in their ability to talk about science concepts with others. Opportunities to work with team members and with members of the general public to explain science concepts allowed participants to see themselves as contributing to the learning experiences of others. Analysis also suggested that participants increased their levels of interest and engagement with some popular science resources like news, museum exhibits, TV programs, and websites. Following the program, participants described museum exhibitions as opportunities to communicate complex science concepts and adopted a more audience-focused approach for the goals of a great museum exhibition.

These successful outcomes were facilitated by the implementation of lessons learned from previous work with youth in informal science learning programs that emphasize key elements of positive youth development (Lerner, 2005). In particular, this program delivered opportunities for participants to develop community within and across SAT teams, refine their ability to communicate about the project and related science and design content, to develop collaboration skills with their peers, and have significant ownership of the final team project. The importance of authentic engagement and ownership of the final product of the program has emerged as a critical design element across successful youth programs. Whether youth are engaged in exhibition design, curriculum development, or the planning and coordination of youth science cafes the opportunity to "have a say" and take responsibility for project components seems to consistently translate into significant positive identity and attitude outcomes (Dussault, 2009; Foutz, 2010; Foutz et. al., 2011; Norland et. al, 2009)

The success of the SAT program provides additional evidence of the importance of providing youth with the space to be creative and empowered within informal learning contexts. In order to more effectively engage youth in STEM it is critical to continue to investigate and better understand the relationship between learning that occurs across contexts. Programs that operate within a Positive youth development context provide an important opportunity to think about learning in a more holistic way and recognize how the development of 21st century skills can be embedded in these experiences.

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