Student Asteroid Teams Summative Evaluation

March, 2011

Prepared for:

Space Science Institute

Prepared by:
Sasha Palmquist, Senior Research Associate
Tammy Messick, Research Associate

Institute for Learning Innovation
3168 Braverton St. Suite 280, Edgewater, MD 21037 t: 410-956-5144 f: 410-956-5148 www.ilinet.org
Understanding, fostering, and promoting lifelong learning

About the Institute for Learning Innovation:

Established in 1986 as an independent non-governmental not-for-profit learning research and development organization, the Institute for Learning Innovation is dedicated to changing the world of education and learning by understanding, facilitating, advocating and communicating about free-choice learning across the life span. ILI provides leadership in this area by collaborating with a variety of free-choice learning institutions such as museums, other cultural institutions, public television stations, libraries, community-based organizations such as scouts and the YWCA, scientific societies and humanities councils, as well as schools and universities. These collaborations strive to advance understanding, facilitate and improve the learning potential of these organizations by incorporating free-choice learning principles in their work.

Executive Summary

The Asteroids! project is a multi-faceted informal education initiative that supports public engagement and understanding of the dynamic structure of the solar system through investigations of asteroids and comets and their relationship to Earth. The centerpiece of this project is the development of the traveling exhibition *Great Balls of Fire!*. In coordination with the design development phase of the exhibition, three teams of middle school students were recruited to form Student Asteroid Teams (SATs). 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 fabrication process.

The SAT program was designed to support six areas of development for youth participants:

1. Understanding of asteroids, comets, and meteors
2. Excitement and interest in asteroids, comets, and meteors
3. Positive attitudes about science and scientists
4. Scientific skills and habits of mind
5. Science communication skills, practices, and resources
6. Develop an identity as a science learner

The summative evaluation used a mixed methods approach to measure the impact of the SAT program on youth participants. 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. The results from the pre-post SAT program questionnaires and interview provided evidence of improvement across all impact categories. Findings are organized by target outcome.

Understanding of asteroids, comets, and meteors

- 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.

- Participants did not seem to refine their understanding of common misconceptions of meteorites (e.g. many still indicated that meteorites are hot when they hit the earth). This suggested that program activities may have focused less on the characteristics of specimens as they transition from meteors to meteorites. Instead, participant responses indicated that meteorites were understood as a source of evidence of asteroid impacts and a critical focus of scientific investigation.

Excitement and interest in asteroids, comets, and meteors

- Participant excitement about space science was apparent before, during and after the program. Consistent with previous research on the connections between interest and preparation for future learning, summative measures indicated that interest in these topics increased following the program and these gains were often connected to increased knowledge and awareness about asteroids, comets, and meteors. Participants reported enjoying the focus of their individual projects as well as being a part of the larger design development experiences.

- Managing youth expectations was a challenge for the SAT program. Focus groups in particular indicated that many participants had not expected to have the degree of personal responsibility they were given for the design and development of their team projects. While participants were not surprised about *what* they were learning, they were surprised about *how* they were encouraged to learn. Participants indicated that this mismatch of expectation and experience made them more engaged and interested in the program.

Positive attitudes about science and scientists

- 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.

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

Scientific skills and habits of mind

- 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.

Science communication skills, practices, and resources

- 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.

Develop an identity as a science learner

- Many participants identified with science prior to engaging with this program. For these students, the SAT program often deepened and strengthened their relationship with science. Other participants gained a new appreciation for science, in some cases participants acknowledged that the program gave them opportunities to learn about real science and this made them “science people”.

Table of Contents

Executive Summary 1
Introduction 6
Methods 6
SAT Questionnaire 7
SAT Interview 7
Findings 7
Understanding of asteroids, comets, and meteors 7
Excitement and interest in asteroids, comets, and meteors 11
Positive attitudes about science and scientists 12
Scientific skills and habits of mind 13
Science communication skills, practices, and resources 18
Develop an identity as a science learner 20
Conclusions 21
References 23

List of Tables

Table 1: Summary of completed SAT questionnaires by site 7
Table 2: Summary of completed SAT interviews by site 7
Table 3: Which of these is under the influence of gravity? 8
Table 4: How do we know if this did or did not happen? 8
Table 5: Examples of pre-post explanations: *How do we know that an impact did or did not happen?* 9
Table 6: How likely is it that an Asteroid will hit Earth during your lifetime? 9
Table 7: What do you think are the differences between comets and asteroids? 10
Table 8: Are comets and asteroids generally from the same part of the solar system? 10
Table 9: What happens to a comet as it approaches the sun? 10
Table 10: Which do you think are true statements? [about meteorites] 11
Table 11: Summary of the SAT program impacts on attitudes towards science and scientists: Retrospective-pre program and post program ratings 13
Table 12: Responses to the item: Science is…. 13
Table 13: How do scientists study asteroids, comets, and meteors? 14
Table 14: Examples of pre-post explanations provided by participants 14
Table 15: Summary of the SAT program impacts on scientific process and habits of mind: Retrospective-pre program and post program ratings 15
Table 16: Distribution and frequency of design process emergent coding categories 16
Table 17: Participant responses and emergent codes describing the design process 16
Table 18: Distribution and frequency of design process deductive coding categories 17
Table 19: Participant responses and deductive codes describing the design process 17
Table 20: Summary of the SAT program impacts on science communication skills, practices, and resources: Retrospective-pre program and post program ratings 18
Table 21: Participant baseline and summative ratings of engagement with science activities 19
Table 22: Summary of the SAT program impacts on identity as a science learner: Retrospective-pre program and post program ratings 20

List of Appendices

Appendix 1 Impacts, indicators, and connections to positive youth development outcomes 24
Appendix 2 SAT Baseline Questionnaire..25
Appendix 3 Post Program Questionnaire 28
Appendix 4 SAT Summative Interview Protocol 31

Introduction

The Asteroids! project is a multi-faceted informal education initiative that supports public engagement and understanding of the dynamic structure of the solar system through investigations of asteroids and comets and their relationship to Earth. The centerpiece of this project is the development of the traveling exhibition *Great Balls of Fire!*. In coordination with the design development phase of the exhibition, three teams of middle school students were recruited to form Student Asteroid Teams (SATs). Teams were established in three locations that reflected the target audience for the exhibition: 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 (Bell et.al., 2009; Dussault, 2009; Koke & Deirking, 2007; NRC, 2002). 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 some of the target outcomes that reflect successful positive youth development efforts including competence, confidence, connection and contribution (Lerner, 2005; Luke et. al., 2007).

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 fabrication or production process.

The SAT program was designed to support six areas of development for youth participants:

1. Understanding of asteroids, comets, and meteors
2. Excitement and interest in asteroids, comets, and meteors
3. Positive attitudes about science and scientists
4. Scientific skills and habits of mind
5. Science communication skills, practices, and resources
6. Develop an identity as a science learner

This report examines how the SAT program addressed target outcomes. A separate report provides details about site specific implementation and outcomes (Palmquist and Cherry, 2011b).

Methods

The summative evaluation used a mixed methods approach to measure the impact of the SAT program on youth participants. 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

Questionnaires were completed by participants 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 (See appendix 2 & 3). 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 program. SAT program leaders at each site administered questionnaires. ILI researchers analyzed the results from the baseline and summative questionnaires.

Table 1: Summary of completed SAT questionnaires by site

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

SAT Interview

Interviews were conducted by phone in September 2010 by Victor Yocco, Research Associate at the Institute for Learning Innovation. Semi-structured interviews were designed to provide additional detail about the personal impacts of the program on youth participants (see appendix 4). 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 maximum of three attempts to conduct phone interviews were made with each participant. A total of 19 interviews were completed (Table 2). The sample included responses from 9 boys and 10 girls. ILI researchers coded and analyzed interview responses.

Table 2: Summary of completed SAT interviews by site

Site	%	n=19
Colorado	37%	7
North Carolina	31.5%	6
New Mexico	31.5%	6

Findings

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 asteroids, comets, and meteors

In the questionnaire, participants completed a range of items designed to measure their understanding of asteroids, comets, and meteors. 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 asteroids, comets, 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 asteroids, comets, 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 (Table 3).

Table 3: Which of these is under the influence of gravity?

	Baseline %	n=34	Summative %	n=33
Correct	56%	19	85%	28
Partially correct	26%	9	12%	4
Don't know	18%	6	3%	1

Answer choices: Space shuttle in orbit; Asteroids, meteors, comets; Earth's moon; All of the above; Don't know.

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 (Table 4).

Table 4: How do we know if this did or did not happen?

	Baseline %	n=31	Summative %	n=37
Evidence of impact*	54%	17	73%	27
Extinction of dinosaurs	13%	4	21%	8
Expert sources	13%	4	0%	0
Other	10%	3	3%	1
Don't know	10%	3	3%	1

*significant at p<.001 Note: Multiple responses allowed.

The significant increase of students using evidence based explanations was very encouraging. However, 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 5).

Table 5: 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

Student responses were nearly equally distributed in regards to how likely it is that an Asteroid will hit Earth in their lifetime. Slightly more students (28%) chose *Probably won't*, followed closely by those who selected *Definitely* (24%) and *Probably will* (21%). This range of answers suggested that students are aware of the uncertainty around this issue (Table 6).

Table 6: How likely is it that an Asteroid will hit Earth during your lifetime?

Multiple Choice Options	%	n=33
Probably won't	28%	11
Definitely	24%	8
Probably will	21%	7
Not sure	18%	6
Definitely will not	3%	1

Note: There is no comparative data from the baseline questionnaire.

In addition to exploring the relationships between asteroids and Earth, students were also expected to refine their understanding of the distinctions between asteroids and comets. The majority of students on the baseline assessment were familiar with the critical difference between asteroids and comets with 74% selecting the correct answer. Following the program, 88% of students correctly identified that *comets were ice and rock while asteroids are metal and rock* (Table 7). This increase demonstrated improved understanding however the change was not statistically significant. It was interesting to note that the misconception about the behavior and movements of asteroids and comets experienced the largest decrease. This suggested that while there remains some confusion about the size and frequency of asteroids and comets, students developed a more accurate understanding of the salient features and movement styles.

Table 7: What do you think are the differences between comets and asteroids?

Multiple Choice Options	Baseline %	n	Summative %	n
Comets are ice and rock while asteroids are metal and rock	74%	25	88%	30
Comets are always larger than asteroids	12%	4	12%	4
There are more comets than asteroids	9%	3	15%	5
Comets travel in an orbit while asteroids do not move	18%	6	6%	2
There are no differences between asteroids and comets	0%	0	0%	0
Don't know	12%	4	9%	3

Note: Multiple responses allowed

On the summative questionnaire, participants were asked an additional question that explored their understanding of the relationship of asteroids and comets within the solar system. While 43% of students correctly identified the relative position of comets as further away from Earth and the Sun than asteroids, 32% identified asteroids as being further away, and 15% indicated that asteroids and comets were from the same part of the solar system (Table 8). This pattern of responses suggested that students were sensitive to the dynamic movements of asteroids and comets within the solar system and that the origins of asteroids and comets may have been less of a focal point of program activities.

Table 8: Are comets and asteroids generally from the same part of the solar system?

Multiple Choice Options	%	n=34
No, comets are much further…	41%	14
No, asteroids are much further…	32%	11
Yes, same part	15%	5
Don't know	12%	4

Note: Data from summative questionnaire only

The summative questionnaire used an open ended question to explore student understanding of the effects on comets as they approach the sun. In 49% of responses participants provided explanations that referenced the heat of the sun or that the comet melted as it got closer. Of the remaining responses, 28% referenced the creation of a tail, 13% identified that the sun caused the comet to break apart without any reference to heat, and 8% of responses mentioned changes to a comets' path or orbit (Table 9). These responses indicated a fairly consistent understanding of the effects of the sun on comets.

Table 9: What happens to a comet as it approaches the sun?

	%	n=47
Heats up, burns, or melts	49%	23
Makes a tail	28%	13
Breaks apart	13%	6
Changes the orbit or path	8%	4
Don't know	2%	1

Note: Data from summative questionnaire only. Multiple responses allowed.

While the questionnaire primarily measured content knowledge about asteroids and comets, one item was included that explored common misconceptions about meteorites. Participants were invited to choose true statements about meteorites from a list and *circle all that apply*. On the baseline assessment, 97% of students answered this item incorrectly and there was minimal improvement on the summative with 91%

selecting an incorrect option. Students most frequently indicated that *Meteorites are hot when they hit Earth* as the true statement on both the baseline and the summative. Table 10 provides a summary of the frequency and distribution of responses. This pattern suggested that there might have been fewer opportunities for participants to revise their understanding of meteorites throughout the program. In addition, it is often difficult for participants to select *none of the above* on a multiple choice item unless they are very confident in their knowledge.

Table 10: Which do you think are true statements? [about meteorites]

Multiple Choice Options	Baseline %	n=41	Summative %	n=40
Meteorites are hot when they hit Earth	59%	24	73%	29
Meteorites are falling stars and are very far away from Earth	7%	3	12%	5
All meteorites that enter the atmosphere hit Earth intact	7%	3	3%	1
All of the above	12%	5	5%	2
Don't know	12%	5	0%	0
None of the above*	3%	1	7%	3

*Correct answer. Multiple responses allowed.

Excitement and interest in asteroids, comets, and meteors

Participants consistently expressed excitement and interest in the science content of the program. Level of excitement and interest was measured through the baseline questionnaire, mid-program focus groups, and post program phone interviews. The role of excitement and interest in informal learning is a growing area of research and gained additional attention from its emphasis in the NRC strands of learning (Bell et al, 2009). The contextual model of learning in informal settings has also suggested there may be increased opportunities for learning among individuals with high interest in a topic paired with relatively low knowledge (Falk and Storksdieck, 2005). Prior to the program, 71% of the SATs reported that they were interested in learning about space science content and acknowledged that they currently had limited opportunities to learn about these topics (Palmquist & Koepfler, 2009). This finding from the baseline questionnaire suggested that the majority of participants were prepared for future learning that would be offered through the SAT program. This hypothesis was supported by the content knowledge gains measured on the summative questionnaire and reinforced the potential importance of leveraging participants' interests to encourage learning.

Midway through the SAT program, in the fall of 2009 focus groups were conducted with SATs. These discussions were designed to explore the current SAT experience, document participant descriptions of the program, and determine whether expectations were being fulfilled. Participants reported that they enjoyed working as a team, appreciated the unique opportunity to learn about asteroids, comets, and meteors and space science more generally often directly from scientists, and were excited to produce a project deliverable based on the new concepts they had learned. At this point in the program, levels of interest and engagement remained high along with apparent curiosity about the remainder of the program and their ability to complete their site-specific projects. One participant summarized the feelings of his team when he commented, "Being one of the three teams chosen in the entire country to be a part of this program is pretty amazing. We're lucky to have this once in a lifetime experience."

One critical finding that emerged from the focus group conversations was the shared opinion that the program was not aligned with participants' expectations. It was apparent that participants were articulating their opinions during the conversation and had not previously considered the fit between their expectations of the program and their experiences. However, the comments provided made it clear that the SAT experience was completely different and for most participants it had exceeded expectations. One participant shared her perspective and stated, “This program is totally different than what I expected. I guess I thought it would be more like another class where we would learn about asteroids and space, which would be great, but very school-like. But we’re not doing normal things like worksheets, watching videos, and taking quizzes. We’re doing all sorts of learning activities and it’s really fun.” In general, participants were surprised at the amount of responsibility that they had within the program to make decisions, enjoyed hands-on activities and field trips, and particularly liked learning about complex concepts without it feeling like school. As one participant commented, “Science is a lot more fun when you can try things out and not need to worry about being graded.” Some team members expressed concerns about their ability to complete their projects on time given what they had experienced about the challenges of working as a team and having to make decisions as a team. However, most students seemed highly motivated to succeed and were excited about the future learning experiences provided by the SAT program.

Following the program, phone interviews with participants explored perceived level of interest and engagement with space science concepts. The majority of interview responses indicated that the SAT program had changed their interest and engagement with asteroids, comets, and meteors. Participants in the SAT program recognized their increased competence in these topic areas and this seemed to influence their confidence about future learning. As one student commented, “I didn't know much about space. I wasn't really sure about meteors and asteroids before [the program] and I'm happy I learned about it. Knowledge is power and it was interesting.” (NM SAT)

While the majority of SATs were interested in space science prior to the program, some participants acknowledged that the program deepened their interest and encouraged them to explore new questions about these topics. For example:

> *“It made me more interested in space, asteroids, and comets and how they have had an effect on Earth.” CO SAT*
>
> *“It made me more intrigued about it—like more interested in space beyond the features of our solar system.” NC SAT*
>
> *“Yes, I’m definitely more interested now. I think there is a lot more cool stuff out there than most people realize.” NM SAT*

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 11). 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 may have changed more on average than their knowledge and attitudes about science itself.

Table 11: Summary of the 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 12). In general, participants own definitions acknowledged that science can be described more broadly than the options the item provided.

Table 12: 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 13). 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.

Table 13: 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 or 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 14 provides examples of how the quality of student responses shifted between baseline and summative.

Table 14: 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 they were a member 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 of the process identified to solve this problem. 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 15% of responses focused on one step of the scientific process like “careful observation under a microscope” or “testing the composition” 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 15). 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 15: Summary of the 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. 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 16).

Table 16: Distribution and frequency of design process emergent 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 17).

Table 17: Participant responses and emergent codes 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 18)

Table 18: 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 feedback	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 19).

Table 19: 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 with 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 need and then work really hard to make it.	Design, Build	Make your idea ready, test it, have other people review, then make a real model.	Brainstorm, 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. 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 20). 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 which may have accounted for the relatively smaller rating increase.

Table 20: Summary of the SAT program 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 from all teams recognized 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 and we learned to direct ourselves 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 self 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 21).

Table 21: 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.

Museum exhibition design was a core component of the SAT program. Participants were asked to describe the characteristics of a great museum exhibit on the baseline and summative assessments. The majority of responses on both the baseline and the summative mentioned that a great exhibition would be engaging, fun, and interesting. On the baseline, 41% of participant responses included the importance of having hands on "things to do", 41% thought the experience should be educational, 29% focused on the inclusion of real objects while the remaining 20% mentioned specific topics that would need to be featured like dinosaurs. On the baseline, participants seemed to be thinking like visitors to an exhibition. They stated:

> *A great museum exhibit would be one that grabs your attention and keeps it and it also lets you have fun while you learn. NC SAT*

> *Interactive, entertaining, informative, and creative NM SAT*

> *An exhibit that has hands on activities, and real objects and presentations CO SAT*

On the summative assessment, the majority of responses (62%) focused on the importance of creating an interactive experience, 38% felt that it needed to be educational and only 6% emphasized the inclusion of real objects. This pattern suggested that the experience of developing an exhibition around asteroids, comets, and meteors highlighted the challenge of communicating complex concepts to others. Museum exhibit design can be a powerful form of science communication. On the summative, participants seemed to think more like designers and expressed a more visitor centered approach to their assessment of what makes a great museum exhibition. They stated:

A great museum exhibit would be something that will catch the eye of the many people and it is appealing to not only the older citizens but children and teenagers as well. *NC SAT*

A great museum exhibit would appeal to all ages and be interactive/hands-on. It would be visually appealing, interesting and would draw in audiences. Organization is also a key point in creating a great exhibit because, without it, nobody would understand it or want to see it, and it would be difficult to comprehend. *NM SAT*

I would describe a great museum exhibit like, hands on activities, and easy to understand for all ages. *CO SAT*

Develop an identity as a science learner

While previous aspects of the SAT program evaluation indicated that participants were interested and engaged with science, specific items were designed to measure indicators of science identity development. Retrospective pre-post rating scales on the summative questionnaire were one approach used to measure perceived change in identity as a science learner. Analysis revealed statistically significant differences between the retrospective-pre and post ratings for all of the items focused on science learner identity development (Table 20).

Table 22: Summary of the SAT program impacts on identity as a science learner: Retrospective-pre program and post program ratings

Item	Retro-Pre Mean	Post Mean	Z	p
I can connect science to my daily life	4.41	5.85	-3.65	**.000**
I think of myself as a science person	4.38	5.36	-3.46	**.001**

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

In the phone interview, participants were asked if they thought of themselves as a “science person.” While this replicated the rating item included in the summative questionnaire, the interview format provided the opportunity to measure what being “a science person” meant to participants. The majority of responses indicated that participants strongly identified with science and agreed that they thought of themselves as “a science person”. For example, one participant from New Mexico commented, “Yeah, I’m a science person, I love science. I love learning new things, I love performing experiments. You can use it to see how stuff happens. It’s the whole idea of learning new things.” While not all participants expressed this level of identification with science, it was apparent that the SAT program enabled other participants to begin to think of themselves in this way. For example:

“The opportunity that the science center gave me was that I was able to understand more. That made me a science person. Now I know about meteors.” NC SAT

“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

“I'd say I like science more now. It's never been my favorite subject but I like it more now.” *CO SAT*

The interview also revealed that not all of the participants considered themselves “a science person” but even those who did not strongly identify in this way were still positive about science. One participant from Colorado said, “I like science but it's not my favorite.”

Conclusions

The SAT program was designed to support six areas of development for youth participants. Combined analysis of the program participants across the three SAT sites provided evidence of improvement across all impact categories.

Understanding of asteroids, comets, and meteors

- 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.

- Participants did not seem to refine their understanding of common misconceptions of meteorites (e.g. many still indicated that meteorites are hot when they hit the earth). This suggested that program activities may have focused less on the characteristics of specimens as they transition from meteors to meteorites. Instead, participant responses indicated that meteorites were understood as a source of evidence of asteroid impacts and a critical focus of scientific investigation.

Excitement and interest in asteroids, comets, and meteors

- Participant excitement about space science was apparent before, during and after the program. Consistent with previous research on the connections between interest and preparation for future learning, summative measures indicated that interest in these topics increased following the program and these gains were often connected to increased knowledge and awareness about asteroids, comets, and meteors. Participants reported enjoying the focus of their individual projects as well as being a part of the larger design development experiences.

- Managing youth expectations was a challenge for the SAT program. Focus groups in particular indicated that many participants had not expected to have the degree of personal responsibility they were given for the design and development of their team projects. While participants were not surprised about *what* they were learning, they were surprised about *how* they were encouraged to learn. Participants indicated that this mismatch of expectation and experience made them more engaged and interested in the program.

Positive attitudes about science and scientists

- 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.

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

Scientific skills and habits of mind

- 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.

Science communication skills, practices, and resources

- 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.

Develop an identity as a science learner

- Many participants identified with science prior to engaging with this program. For these students, the SAT program often deepened and strengthened their relationship with science. Other participants gained a new appreciation for science, in some cases participants acknowledged that the program gave them opportunities to learn about real science and this made them "science people".

References

Bell, P., Lewenstein,B. , Shouse,A. and Feder , M. *Editors (2009). Learning Science in Informal Environments: People, Places, and Pursuits.* Committee on Learning Science in Informal Environments, Board on Science Education. National Research Council of the National Academies. The National Academies Press. Washington, D.C.

Falk, J. H. & Storksdieck, M. (2005). Using the Contextual Model of Learning to understand visitor learning from a science center exhibition*. Science Education*, *89*(5), 744 - 778.

Foutz, S. (2010) *A Youth-Directed Café Scientifique Summative Evaluation.* Technical evaluation report. Edgewater, MD: Institute for Learning Innovation.

Fenichel, M., Schweingruber, H. *(2009) Surrounded By Science*. Committee on Learning Science in Informal Environments, Board on Science Education. National Research Council of the National Academies. The National Academies Press. Washington, D.C.

Dussault,M.(2009). Tapping the Fountain of Youth. Session at annual meeting of the Association of Science and Technology Centers,Fort Worth, TX.

Koke, J. & Dierking, L. (2007). Museums and Libraries Engaging America's Youth: Final Report of a Study of IMLS Youth Programs, 1998-2003. Washington, DC: IMLS.

Lerner, R. (2005). Positive Youth Development: A View of the Issues. *Journal of Early Adolescence* 25(1): 10–16.

Luke, J. J., Stein, J., Kessler, C., and Dierking, L. D. (2007). Making a Difference in the Lives of Youth: An Analysis of Four Museum Programs. *Curator* 50 (4) 417-434.

McLaughlin, M. (2000). *Community Counts: How Youth Organizations Matter for Youth Development.* Washington, DC: Public Education Fund Network.

Palmquist, S. & Cherry, T. (2011b). Student Asteroid Teams Summative Evaluation: Site-specific influences on impacts. Technical evaluation report. Edgewater, MD: Institute for Learning Innovation.

Palmquist, S. & Koepfler, J. (2009) *Front-end evaluation for the Space Science Institute Asteroids Exhibition.*Technical evaluation report. Edgewater, MD: Institute for Learning Innovation.

Appendix 1 Impacts, indicators, and connections to positive youth development outcomes

Target Impacts	Indicators	Connection to PYD Outcomes
Understanding of asteroids, comets, and meteors	Increased knowledge of asteroids, comets, and meteors and their role in the solar system; Improved ability to use scientific terms and apply knowledge to project goals	Competence, Confidence, Contribution
Excitement and interest in asteroids, comets, and meteors	Increased motivation to engage with content about asteroids, comets, and meteors	Connection
Positive attitudes about science and scientists	Improved understanding of positive contribution of science and scientists	Connection
Scientific skills and habits of mind	Increased recognition and use of observation, inquiry, experimentation, and evidence interpretation	Competence, Contribution
Science communication skills, practices, and resources	Improved use of popular science content and willingness to share science with others	Competence, Confidence
Develop an identity as a science learner	Described themselves as science learners and demonstrated personal engagement with science	Connection, Confidence

Appendix 2 SAT Baseline Questionnaire

Welcome to the Student Asteroid Team survey. We're interested in how you think about teamwork, space science, and out of school activities. Please complete the questions below with as much detail as possible. Thanks for sharing your thoughts with us!

Name:______________________ Date:______

1. What are you most looking forward to as a member of a Student Asteroid Team? (circle all that apply)
    a. Working on this project as a team
    b. Learning about asteroids and space science
    c. Designing activities and programs that could be used in an exhibit
    d. Connecting with SAT teams in other states

    Please explain why you are looking forward to this:

2. How do you think being a member of a Student Asteroid Team will be <u>different</u> from other team experiences?

3. How can you tell when a team is working together well?

4. Members of design teams who create new products like toys, games, or experiences like museum exhibits often follow a set of steps that help them get the job done. Imagine that you are part of a design team making a museum exhibit. Please describe what steps you think you might take to get from your idea to the finished product.

5. How would you explain gravity to a friend who has never learned about it before?

6. Which of these are under the influence of gravity?
    a. Space shuttle in orbit
    b. Asteroids, meteors, comets
    c. Earth's Moon
    d. All of the above
    e. Don't know

7. Choose the answer that places these objects from closest to farthest from Earth.

Earth

	Closest 1	2	Farthest 3
a	Space Shuttle in orbit	Stars	Asteroid Belt
b	Asteroid Belt	Space Shuttle in orbit	Stars
c	Stars	Asteroid Belt	Space Shuttle in orbit
d	Space Shuttle in orbit	Asteroid Belt	Stars
e	Don't Know		

8. Which do you think are differences between comets and asteroids? (Circle all that apply)
   a. Comets are always larger than asteroids
   b. Comets are ice and rock while asteroids are metal and rock
   c. There are more comets than asteroids
   d. Comets travel in an orbit while asteroids do not move
   e. There are no differences between asteroids and comets
   f. Don't know

9. Has an asteroid ever hit Earth in the past?
   a. Yes
   b. No

   How do we know if this did or did not happen?

10. Which do you think are true statements? (circle all that apply)
    a. Meteors are falling stars and are very far away from Earth
    b. All meteors that enter the atmosphere hit Earth intact
    c. Meteorites are hot when they hit Earth
    d. All of the above
    e. None of the above
    f. Don't know

11. How do scientists' study asteroids, comets, and meteors?

12. Compared to your peers, how would you rate your interest in Astronomy/ Space Science?

Less interested   About the same   More interested

13. Please circle the phrase that is most like your definition of science or fill in what the word science means to you.
   a. Science is the study of the natural world that describes both what happens and why it happens
   b. Science is a body of knowledge about topics like biology, chemistry, astronomy, physics, or geology
   c. Science is defined by the work of researchers and scientists
   d. Science is:
   ____

14. Please circle how often you have chosen to do the following in the last month:

	Not at all					once a day or more
Watch science-related shows on TV	1	2	3	4	5	6
Read science-related books or magazines	1	2	3	4	5	6
Visit science-related museums or exhibits	1	2	3	4	5	6
Pay attention to science-related news	1	2	3	4	5	6
Visit science related websites	1	2	3	4	5	6
Talk with family or friends about science-related topics	1	2	3	4	5	6

15. Compared to your peers, how would you rate your interest in museums?

Less interested   About the same   More interested

16. What do you like best about museum exhibits?
   a. Hands on activities
   b. Seeing real objects
   c. Discovering new things
   d. Multi-media presentations
   e. Sharing the experience with friends and family
   f. Thinking about activities and displays

17. How would you describe a great museum exhibit?

Great Balls of Fire

Spring 2010

Student Asteroid Team Survey

Welcome to the Student Asteroid Team survey! As the project moves into the next phase, we're interested in getting information on how you think about teamwork, space science, and out-of-school activities. Please complete the questions below with as much detail as possible. Thanks for sharing your thoughts with us!

Name:_____________________________ Date:___________

1. Members of design teams who create new products (such as toys, games, or experiences like museum exhibits) often follow a set of steps that help them get the job done. Imagine that you are part of a design team making a museum exhibit. Please describe what steps you think you might take to get from your idea to the finished product.

2. How would you describe a great museum exhibit?

3. How would you explain gravity to a friend who has never learned about it before?

4. Which of these are under the influence of gravity?
   a. Space shuttle in orbit
   b. Asteroids, meteors, comets
   c. Earth's Moon
   d. All of the above
   e. Don't know

5. Which do you think are differences between comets and asteroids? (Circle all that apply)
   a. Comets are always larger than asteroids
   b. Comets are ice and rock while asteroids are metal and rock
   c. There are more comets than asteroids
   d. Comets travel in an orbit while asteroids do not move
   e. There are no differences between asteroids and comets
   f. Don't know

6. Has an asteroid ever hit Earth in the past? ❑ Yes ❑ No
   How do we know if this did or did not happen?

7. How likely is it that an Asteroid will hit Earth during your lifetime?

❑Definitely ❑Probably Will ❑Not Sure ❑Probably Won't ❑Definitely Will Not

8. What happens to a comet as it approaches the sun?

9. Which do you think are true statements? (circle all that apply)
   a. Meteors are falling stars and are very far away from Earth
   b. All meteors that enter the atmosphere hit Earth intact
   c. Meteorites are hot when they hit Earth
   d. All of the above
   e. None of the above
   f. Don't know

10. Are Comets and Asteroids generally from the same part of the solar system?
   a. No, asteroids are much further from the Earth and the Sun
   b. No, comets are much further from the Earth and the Sun
   c. Yes, comets or Asteroids are generally from the same part of the solar system
   d. Don't know

11. How do scientists' study asteroids, comets, and meteors?

12. Please circle the phrase that is most like your definition of science or fill in what the word science means to you.
   a. Science is the study of the natural world that describes both what happens and why it happens
   b. Science is a body of knowledge about topics like biology, chemistry, astronomy, physics, or geology
   c. Science is defined by the work of researchers and scientists
   d. Science is: ____

13. Please circle how often you have chosen to do the following in the last month:

	1= Not at all,			7 = Once a day or more			
Watch science-related shows on TV	1	2	3	4	5	6	7
Read science-related books or magazines	1	2	3	4	5	6	7
Visit science-related museums or exhibits	1	2	3	4	5	6	7
Pay attention to science-related news	1	2	3	4	5	6	7
Visit science related websites	1	2	3	4	5	6	7
Talk with family or friends about science-related topics	1	2	3	4	5	6	7

14. For each statement, circle a rating for both BEFORE and NOW.

BEFORE being involved with this Project 1= Disagree, 7 = Agree								**NOW that I am involved with this Project** 1= Disagree, 7 = Agree						
1	2	3	4	5	6	7	Science is interesting	1	2	3	4	5	6	7
1	2	3	4	5	6	7	I like science	1	2	3	4	5	6	7
1	2	3	4	5	6	7	I think of myself as a science person	1	2	3	4	5	6	7
1	2	3	4	5	6	7	I am interested in the process of scientific research	1	2	3	4	5	6	7
1	2	3	4	5	6	7	I have a good understanding of the process of scientific research	1	2	3	4	5	6	7
1	2	3	4	5	6	7	I am interested in hearing more about science issues that are in the news	1	2	3	4	5	6	7
1	2	3	4	5	6	7	I have a good understanding of science issues that I hear about in the news	1	2	3	4	5	6	7
1	2	3	4	5	6	7	People should understand science because it effects their lives everyday	1	2	3	4	5	6	7
1	2	3	4	5	6	7	Scientists make important contributions to daily life	1	2	3	4	5	6	7
1	2	3	4	5	6	7	I can connect science to my daily life	1	2	3	4	5	6	7
1	2	3	4	5	6	7	I know what scientists do	1	2	3	4	5	6	7
1	2	3	4	5	6	7	I am interested in talking to scientists about their work	1	2	3	4	5	6	7
1	2	3	4	5	6	7	I know about a variety of careers in science	1	2	3	4	5	6	7
1	2	3	4	5	6	7	When talking to others about science, I use facts to support my point of view.	1	2	3	4	5	6	7
1	2	3	4	5	6	7	I feel confident sharing with others what I know about current science issues	1	2	3	4	5	6	7
1	2	3	4	5	6	7	Before I make up my mind, I consider multiple sides of the issue	1	2	3	4	5	6	7

Great Balls of Fire

Spring 2010

Student Asteroid Team Phone Interview

Hi! This is _____ from ILI; we're the evaluators for the Asteroids project and the Great Balls of Fire exhibit. As _____ (site coordinator) discussed with you, we're calling you to follow up on your recent experiences being part of the team that developed the Great Balls of Fire Exhibition. The interview should take about 10-15 minutes.

1. Scientists are often faced with questions where the answer is unclear or unknown. Imagine that you are an astronomer and you are part of a team who tracked a meteor that entered earth's atmosphere. You know that most of the meteor will never reach the ground but based on your calculations you search the most likely area for possible meteorites. You collect a few rocky samples that might be what you are looking for. What **steps** could you take to figure out if what you have is a rock or a meteorite?

2. Do you think of yourself as a "science person"? In what ways or ways not?

3. Tell me about the best part of participating in the Student Asteroid Team for you.

4. Tell me what was difficult, confusing or not enjoyable about participating in the SAT.

5. Did participating in the SAT change you in any way? If so, how?

    a. In terms of your attitude about science?
    b. In terms of your attitude about space?
    c. In terms of learning how to work on a team?