Bridging Earth and Mars (BEAM)

Program Front-end Evaluation

Conducted for
Saint Louis Science Center
St. Louis, Missouri
Carey E. Tisdal
Tisdal Consulting
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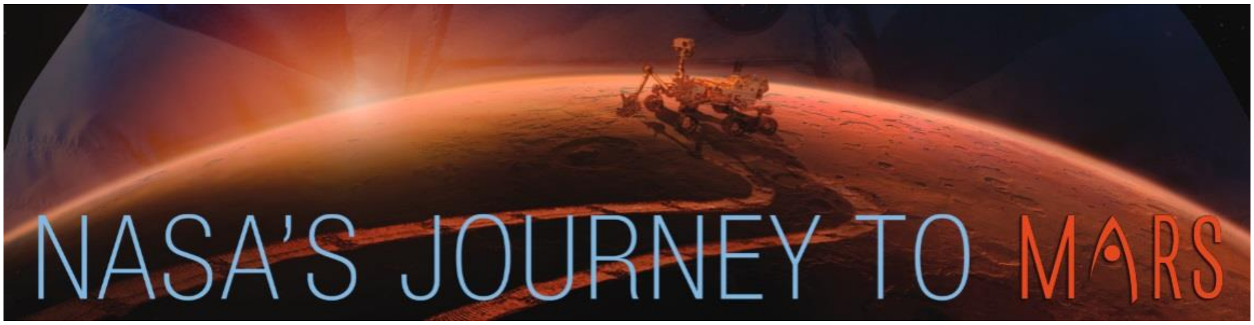

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Executive Summary

The Saint Louis Science Center (SLSC) project Bridging Earth and Mars (BEAM) will engage the general public and children from schools and community groups with the National Aeronautical and Space Administration's (NASA's) exploration of Mars through exhibits simulating control of robotic rovers on the surface of Mars as well as related educational programming. This front-end evaluation for BEAM youth programs provides information to the BEAM project team about the levels of knowledge, attitudes, and skills among low-income and minority young people who are part of the field trip workshop audiences. In these workshops, children will be asked to work in teams to find an innovative solution to problems simulating real NASA challenges. Young people will use the engineering design process, which encourages the testing and refining of problem solutions until they are successful.

Findings and conclusions from this front-end evaluation can be used to guide design decisions and adaption of existing NASA materials. The study involved four focus groups with a total of 21 respondents. Three focus groups focused on the understandings and interests of specific age groups. Age groups included 6- to 8-year-olds, 9- to 11-year-olds, and 12- to 14-year-olds. Data were collected between September 27 and October 27, 2014. Carey Tisdal of Tisdal Consulting was contracted to conduct the study as part of a multiphase evaluation plan for BEAM, an SLSC project funded by NASA.

Findings

How do students think about space exploration?
Older respondents appeared to view space exploration from the perspective of the Solar System, while younger children seemed to view it from Earth orbit. Objects within the drawings were coded to identify ideas at the top-of-mind for children when they thought about space exploration. Few people were portrayed, and only two astronauts were featured across all 17 drawings. Some of the drawings (7 of the 17) featured tools that people use to explore space. The most frequently drawn tools were spacecraft. Only one respondent drew a Mars rover. Among older respondents, there were a few detailed drawings of the Solar System that revealed higher levels of knowledge about this topic. Respondents drew Earth far more often than other planets, and 10 included the Sun in their drawing. Saturn, with its memorable rings, was featured in 4 drawings, and Pluto, Jupiter, and Mars in 1 drawing each.

To what extent are children interested in the focus and activities of the program?
Young people across all three age groups exhibited higher levels of interest in activity-based topics such as *learning to program a robot* and *designing a vehicle to explore Mars* than in knowledge-based topics such as finding out about NASA, Mars, exploring space, and jobs. Respondents of all ages and at both sites expressed high levels of interest in robots in general, which may be the most popular topic to use in eliciting excitement and building positive

expectations about the workshops. It also seemed that lower levels of interest in several areas appeared to be connected to the lack of familiarity and knowledge about topics.

To what extent and in what ways are children familiar with Mars?
Most respondents appeared to know that Mars was one of the planets in the solar system and most identified it as one of the planets closer to Earth. Yet they often confused Mars with other planets when trying point it out in a model Solar System. On the other hand, when shown a photo, most identified the planet by the predominate color and used the phrase "the red planet." Respondents agreed that Mars was rocky and that there was no air to breathe, but there was little agreement about the temperature. Among both younger and older respondents, knowledge of Mars was very rudimentary at best.

To what extent are children familiar with NASA's unmanned missions to explore Mars and with Mars rovers?
About half of respondents in all age groups had the misperception that humans had already landed on Mars, and only half the older respondents and none of the younger respondents were familiar with the Mars rovers. Among those familiar with the Mars rovers, respondents of had a basic understanding of what a rover might do on Mars (e.g. collect rocks, take pictures), but only a sketchy connection to the underlying scientific question about Mars the rovers could be used to answer.

To what extent and in what ways do members of these target audiences consider the exploration of Mars as valuable?
Overall, respondents appeared to rank the importance of Mars exploration at lower levels of importance than social concerns such as stopping war, reducing homelessness, curing disease, and stopping violence, but at a higher level than personal interests such as getting tattoos or having fun. Personal interest among scientists and explorers was cited as the primary rationale for Mars exploration, and a few gave examples of scientific questions that could be explored. A few said that finding a place to live and grow food should Earth become unlivable was a rationale for exploration.

Given a design challenge, to what extent and in what ways do members of the target audience use the engineering design process to guide their efforts?
In general, younger children (6-to-8-year-olds) appeared to be less able to develop a set of sequential, progressive steps to reach a goal–that is, to articulate a multi-step process that portrays their own thinking and behavior. These younger children focused on the characteristics of the rover or robot itself rather than the process they would use to design the robot. One theme among these younger children was that robots need to protect themselves from physical attack as in cartoon or film adventures.

Several older children (8 out of 10) did present sequential, progressive processes. *Design* (n = 9) (which included sketching and developing blueprints) and *Building* (n = 8) were the two most frequently cited steps and appeared the most clearly understood by the respondents. Yet few of these 12- to 14-year-olds clearly defined the engineering problem or identified constraints.

These steps are the points in the process where existing scientific information can be used to guide the design; given the goals of the project, they need to be explicitly included in the design process. In addition, only a few respondents (n = 3) presented the step *Conceptualizing or Thinking*.

It appeared that respondents focused on the mechanical design of the rovers and gave less attention to communication, transporting the vehicle, and transportation. Finally, about a third (n = 4) of the children providing written responses (N = 10) included the idea of testing and revising their designs, and only two of these respondents clearly indicated they would carry out empirical testing. Only one presented the idea of iterative testing.

To what extent and in what ways do members of the target audience consider the surface characteristics of Mars and the communications time lag between Mars and Earth in their design process?

None of the respondents included the characteristics of Mars or the communications time lag between Mars and Earth in their design process. This may have been due to how the design task was presented, but it is likely to have been influenced also by little awareness of the processes of identifying problems and constraints as well as lack of awareness about either of these topics.

To what extent do members of the target audience see themselves as someone who could be a NASA engineer?

Respondents were asked to select photos of people they thought worked at NASA on a Mars rover project. Despite the concentration of female and African-American respondents, the top four most-selected photos showed men three who appeared white or one who appeared Asian in ethnicity. Among the four least-selected photos, three appeared female and three appeared to be people of color. Based on follow-up conversations, this tendency to think people working at NASA are white or Asian men appeared unconscious.

What are children's perceptions and misperceptions about space exploration?

Respondents were less likely to identify photos of women and people of color as working for NASA on the Mars rover projects and more likely to identify white and Asian men. A majority of respondents were African-American females. Recognizing people like themselves working in science, technology, engineering, and mathematics (STEM) fields is very important for young people as they consider education and career paths. In other areas, rather, than being peppered with misperceptions, most respondents' knowledge can be described as somewhat rudimentary, vague, and not well-connected.

There were two other uncertainties across all age groups: (1) Many were unfamiliar with the acronym NASA, and some were unaware of the agency or its mission at all; and (2) some respondents, including both older and younger children, were unclear about whether human beings had traveled to Mars. Younger respondents in general had less knowledge about the

Solar System and about space exploration. A few younger respondents appeared to believe there could be aliens on Mars.

Conclusions

Conclusions and recommendations are how the findings become the basis for action—in this case, the design of engaging through productive workshop experiences for young people from lower-income households and among diverse ethnic communities.

First, respondents across all age groups rated *programming a robot* and *designing a vehicle to explore Mars* at the higher levels of interest. Program designers can use these topics as a "hook" to pique young learners' expectations for an engaging and interesting program. Since these activities are at the heart the workshop experience, this is good news for the BEAM team.

Respondents in all age groups appeared to have sketchy and disconnected knowledge about several topics, including the place of Mars in the Solar System, the climate and geology of Mars, and NASA and its manned and unmanned missions to Mars. A teaching-learning practice recommended to help people make deep connections to concepts is reflective practice (Schön, 1987; Murphy, 2011; Herod, 2002). I recommend that program designers look for opportunities to include this strategy before, during, and after the workshop experience.

Findings also show some important differences among children of different ages. Younger respondents, as well as a few of the older respondents, had difficulty thinking about their own cognition and behavior to produce sequential, coherent steps in the engineering design process. A strategy used to make learning more productive for learners who have not quite mastered this thinking behavior is call scaffolding. McLeod (2008) characterizes scaffolding as follows:

> *Scaffolding involves helpful, structured interaction between an adult and a child with the aim of helping the child achieve a specific goal. . . . '[Scaffolding] refers to the steps taken to reduce the degrees of freedom in carrying out some task so that the child can concentrate on the difficult skill she is in the process of acquiring.' (Bruner, 1978, p. 19)*

Materials as well as adults can provide scaffolding. Younger and older children may benefit from this strategy.

In articulating how they would design a rover to explore Mars, older children seemed to omit steps involving cognitive activities such as identifying the engineering design problem, identifying constraints, and thinking about and planning before they started to build their rover. These are the parts of the process where scientific information connects to the engineering design process. Clearly these steps in the engineering design process are critical to accomplishing the BEAM workshop and project goals. Based on these findings, the Engineering

Design Model used by NASA (Marshall Space Flight Center & Johnson, 2013, June 5) appears well-suited to call attention to these important steps and provide a framework for scaffolding.

Another set of findings relevant to program design concerns the different levels of knowledge among age groups and overall. Younger children had less knowledge about Mars, the Solar System, and NASA and its missions than did older children. Yet older children's knowledge, while greater, was not deep or detailed. Pre-visit activities could include directing classes to online resources that let them "find out what we already know about the Mars landscape your rover will explore." On site and prior to design activities, making use of exhibits focusing on the Solar System and orbits to introduce the idea of a time lag may be helpful in providing this important context and knowledge base for design.

Respondents across all ages found exploring space and Mars to be less important priorities than solving some social issues. In addition, they lack clear reasons for why it is important to explore Mars—that is, what can be learned and how it could benefit human beings. This finding is of real concern because it points to how relevant and personal young people will perceive their learning about Mars, designing rovers, and their view of space exploration in general. I strongly recommend the BEAM design team, with the help of advisors, identify three important practical benefits to humans for Mars exploration that would be understandable and relevant to young people. Then, ways to introduce and stress these benefits throughout the programming needs to be considered.

Finally, respondents appeared to think that people like themselves, particularly in terms of gender (for girls) and ethnicity, were less likely at NASA on the Mars rover projects. This is clearly a misperception. The Jet Propulsion Laboratory (JPL) website (2014) provided most of the photos for this exercise and showed people of a wide range of ethnicities and many women. Face-to-face visits to the workshops by scientists and engineers need to reflect this type of diversity. In addition, JPL and other NASA connections to the diverse, enthusiastic group of people working on NASA's Journey to Mars need to be mined for online visits, videos of work, and communication with students where ethnic and gender diversity is apparent.

By reflecting on these finding and conclusions, I hope these findings can be put to work, along with the ideas and creativity of the team, in designing experiences that connect with lower income and minority youth as well other young people throughout the St. Louis community.

Introduction

The Saint Louis Science Center (SLSC) project Bridging Earth and Mars (BEAM) will engage the general public and children from schools and community groups with the National Aeronautics and Space Administration's (NASA's) exploration of Mars through exhibits simulating control of robotic rovers on the surface of Mars as well as related educational programming. One set of the BEAM field trip workshops focuses on youth in grades K–8, including girls and those from minority ethnic groups who are traditionally underrepresented in science, technology, engineering, and mathematics (STEM) careers. These programs aim to (1) ignite interest in STEM topics and careers for diverse K–8 students, and (2) encourage students in grades 6–8 to sustain participation in educational experiences along the STEM pipeline.

This front-end evaluation for BEAM youth field trip workshops provides information to the BEAM project team about the levels of knowledge, attitudes, and skills among low-income and minority young people who are part of the field trip workshop audiences. The study involved four focus groups, with a total of 21 respondents. Data were collected between September 27 and October 27, 2014. Carey Tisdal of Tisdal Consulting was contracted to conduct the study as part of a multiphase evaluation plan for BEAM, an SLSC project funded by NASA.

In these BEAM field trip workshops, children will work in teams to find innovative solutions to real NASA challenges related to Mars robotic exploration. Young people will use the engineering design process, which encourages the testing and refining of problem solutions until they are successful. The project proposal describes these field trip workshops.

> *These Innovation Workshops . . . will be held in the Exploring Mars: Mars Lab area [in the Planetarium building]. Interactives in this area will convert easily into tables suitable for group programming; tabletops will be placed over touchscreen displays, or hands-on activities will fold into built-in storage spaces. Having the Mars rovers in close proximity to the workshop activities will add an element of excitement and a connection to the Martian landscape. The location will also reinforce how scientists continue to use fundamental science concepts and a standard engineering design process to accomplish interplanetary missions.*
>
> *Workshops will provide a guided, engaging experience for a smaller subset of visitors, particularly children in grades K-8 from backgrounds underrepresented in the sciences. Tailoring recruitment activities to St. Louis Public Schools and community organizations engaging underrepresented individuals, plus providing transportation when needed, will enable this focus. Additional openings in workshops will be open to the general public. (Saint Louis Science Center, p. 7).*

The BEAM field trip workshops will begin in April 2016 and conclude in 2017. Ten field trips will be offered each year, five of which will offer funded transportation for schools or community groups with underserved students. In five additional BEAM field trip workshop sessions, children participating in the program will come to the SLSC for regular field trips or as participants in Summertime Science, part of the Youth Exploring Science (YES) program, which recruits participants from community organizations that serve minority and low-income children and their families. After the NASA project ends, these workshop programs will be integrated into the ongoing catalog of fee-based school and community programs and used as part of the YES Summertime Science program.

Mars rovers, the focus of the BEAM project, are robots. Exhibits and programming featuring robotics have been implemented in schools and science museums throughout the world (Polishuk, Klein, Inbar & Mir, 2012). Robots have been used to demonstrate concepts and provide actual experience in programming, and some of these educational experiences have been situated, as in this project, in the context of NASA's rover program (National Research Council, 2009; Nourbakhsh, Hamner, Ayoob, Porter, Dunlavey, Bernstein, Crowley, Lotter, Shelly, Hsiu, & Clancey, 2006). In addition, educational experience is one important element affecting career choice, but there may be differences in the social and cultural factors by gender and ethnic identification (Tan & Barton, 2008; Tang & Pei, 2008). Yet questions remain about the specific educational strategies and topics in the design of this program, particularly in identifying which are appropriate for different age groups of children among minority and lower-income students. Few evaluation results are available for NASA-developed curriculum materials that will be used as models for these BEAM workshops. Reading levels appear to be far about the grade levels indicated; Grades 3 to 5 materials test at the Grade 7 level of reading. These levels may be an issue for minority youth from low-income areas.

In addition, the BEAM field trip workshops will engage children and youth in the use of engineering design. There are several models of the engineering design process generally available for use in a variety of educational settings. Which one is the most appropriate to use with minority and low-income youth? Members of the BEAM development team intend to stress the need for iterative testing and refinement in the process, hypothesizing that "being wrong" is not valued in some school situations and that young people may need to be encouraged to experiment and stick with a design until it really works. While all models include this step, it is not as obvious in some models as in others.

Some models, such as EPICS Design Process (2009) featured in Figure 1, are detailed conceptualizations intended for use in undergraduate engineering education and for use by professional engineers. This conceptualization of the engineering design process includes explicit focus on the needs or problem to be solved, and specifications for the design that respond to this need or will solve the problem. Prototyping and testing are included as part of the detailed design phase.

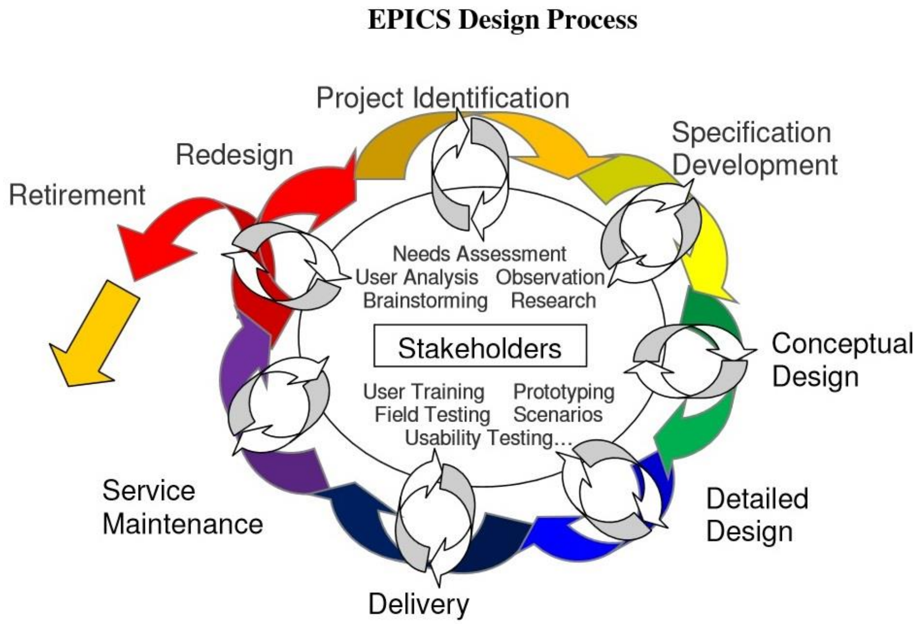


Figure 1. EPIC Design Process (EPICS, 2009, p. 2)

Another model, the Museum of Science's (MOS's) engineering design process (2014), is a much simpler conceptualization used with K–12 students' formal and information engineering education. Figure 2 shows a graphic representation of this model. This model is widely used among science centers and community organizations.

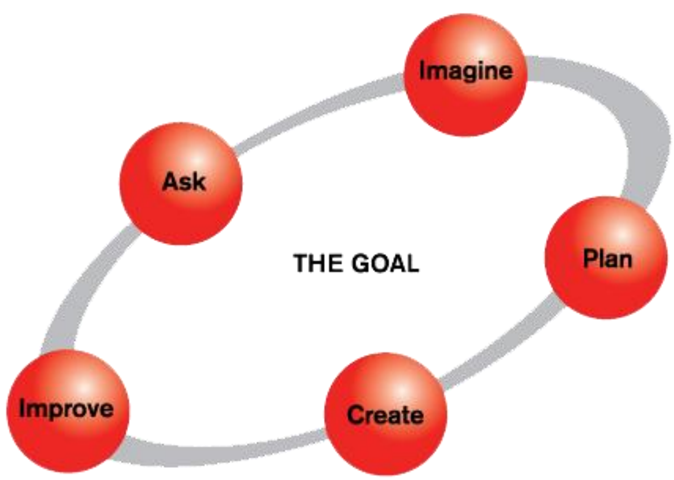


Figure 2. Museum of Science (2014) Engineering Design Process

In a description of this model, problem identification is included under the Ask step but may not be initially apparent. Similarly, testing is included as part of the Create phase but may not be initially obvious. Steps in the MOS model include:

> ***ASK:*** *What is the problem? How have others approached it? What are your constraints?*
> ***IMAGINE:*** *What are some solutions? Brainstorm ideas. Choose the best one.*
> ***PLAN:*** *Draw a diagram. Make lists of materials you will need.*
> ***CREATE:*** *Follow your plan and create something. Test it out!*
> ***IMPROVE:*** *What works? What doesn't? What could work better? Modify your designs to make it better. Test it out! (Museum of Science, 2014)*

Finally, NASA (Marshall Space Flight Center & Johnson, C. 2013, June 5) employs an engineering-specific process in the challenges and curriculum materials it offers. Conceptual steps such as identifying the problem and identifying criteria and constraints are clearly spelled out. This model, shown in Figure 3, has eight steps—three more than those in the MOS model:

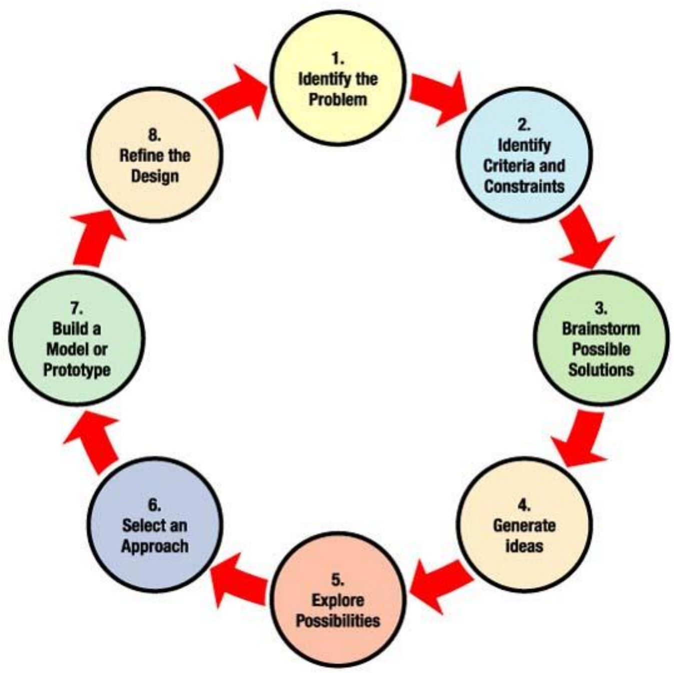


Figure 3. NASA Engineering Design Model (Marshall Space Flight Center & Johnson, 2013)

In summary, questions remain about which model or models of the engineering design process are most appropriate for an audience of minority and low-income students.

After discussion with the BEAM design team, the following questions were identified to guide this study:

1. To what extent are children interested in the focus and activities of the program?
   - Finding out more about Exploring Space
   - Finding out more about Mars
   - Finding out more about NASA
   - Finding out more about the jobs people do who explore space
   - Designing a vehicle to explore Mars
   - Learning to program a robot
2. To what extent and in what ways are children familiar with Mars?
   - Its place in the solar system
   - Distance from earth
   - Surface characteristics (geology, atmosphere, and climate)
3. To what extent are children familiar with NASA's unmanned missions to explore Mars?
4. How familiar are members of these target audiences with the Mars rovers and the NASA missions involving rovers?
5. To what extent and in what ways do members of these target audiences consider the exploration of Mars as valuable?
6. Given a design challenge, to what extent and in what ways do members of the target audience use the engineering design process to guide their efforts?
7. To what extent and in what ways do members of the target audience consider the surface characteristics of Mars and the communications time lag between Mars and Earth in their design process?
8. To what extent do members of the target audience see themselves as someone who could be a NASA engineer?
9. What are children's perceptions and misperceptions about space exploration?

Methods

Design of the Study

I was contracted to design and conduct this front-end evaluation as part of my role as the external evaluator for the BEAM project. Guidelines from Krueger (2009) guided recruitment practices, focus group size, and the development of questioning strategy for these focus groups. The intention was to interview children with peers of similar ages to allow for their comfort and to adapt, on the spot, to vocabulary and writing skills. Three focus groups were planned to explore the knowledge, skills, and understandings of members of the target audience at different ages. Three groups were planned, and four were held. Three age group ranges were targeted: (1) ages 6 to 8, (2) ages 9 to 11, and (3) ages 12 to 14. The fourth focus group had respondents across two of these levels, with ages ranging from 8 to 12 years old. While this fourth focus group was unplanned, listening to the responses across the age ranges in one group was helpful in understanding age differences.

SLSC staff members from the Community Science Department recommended three partner organizations as good options to help with recruiting young people. They also recommended holding focus groups at partner sites so that the children were in comfortable, familiar surroundings. The Community Science Department sent three emails introducing the external evaluator and asking for participation. Two partners said they were willing to hold focus groups. One site declined due to previous experiences with the complexity of studies with Institutional Review Board (IRB) consent processes. Two sites agreed: a YMCA that serves children and families in the near Northside of St. Louis City and a private day school in Hazelwood, Missouri. Both organizations serve primarily African-American audiences. Given tuition fees and interactions with children and their parents, it appeared that more of the school students were from somewhat higher-income levels than those at the YMCA. Yet lower-income students participated at both sites.

Recruitment and Informed Consent

I provided fliers and email drafts that site staff members distributed to invite parents or guardians to reserve a spot for their children to participate. A $25 gift certificate was offered for each child who participated in a focus group (with a limit of one child per family) to reimburse the family for time and travel.

Recruitment was challenging. This appeared to be the result of a requirement for a face-to-face explanation and signing of the informed consent form included in the protocol at the suggestion of the IRB staff. Protocol changes were submitted to the IRB after initial difficulties and feedback from the sites. Site representatives noted that face-to-face consent was not a community standard practice; rather, parents were accustomed to signing local universities' consent forms that children had taken home and then returned. I provided face-to-face explanations at the school site, and parents or guardians at the YMCA signed consent forms and returned them to the site coordinator. Assent was obtained from all children according to procedures approved by the IRB.

Data Collection Methods

Plans called for approximately equal numbers of boys and girls to be included in each group. Yet, recruiting yielded unequal numbers, with more girls than boys showing interest in participating. (Demographics are included in the Characteristics of Respondents section.)

Focus groups lasted between 45 minutes and one hour. I followed a script with lead questions and probed to get examples from children to clarify and understand their responses. Children in three groups also viewed a projected PowerPoint that had stimulus photos and questions. The exception was the October 13 group of 6- to 8-year-olds, where there were projection problems. As a result, these younger respondents were not able to participate in the activity to identify people who worked at NASA. Students in all groups viewed a solar system model (pictured in the PowerPoint). Children responded aloud, on response sheets, and by drawing pictures with colored markers. Younger children (6- to 8-years-olds) were asked to respond aloud rather than in writing to questions about the engineering design process, due to limited writing skills among this age group. Appendix A includes the focus group script and Appendix B shows PowerPoint slides. Appendix C shows the sheets respondents used to write responses.

Data Analysis

I analyzed data using naturalistic methods (Lincoln & Guba, 1985; Guba & Lincoln, 1989) to triangulate findings and reach conclusions. Audio recordings of focus groups were transcribed. Each question or topic was coded using QRS NVIVO, qualitative data analysis software, to identify the range of responses within each group, including perceptions and misperceptions about the topics explored. Codes were developed naturalistically—that is, directly from the data. In the case of engineering design process (EDP), children's steps were compared to formal EDP models, and consistent language was used where possible. This was done to aid team decisions in selecting models best suited to this population. I also identified themes that run across questions, e.g., knowledge from popular culture (books, movies, television, or computer games). Interest ratings were summarized using descriptive statistics and directly connected to participants' responses about the reason for ratings. After the analysis of individual questions, I looked for differences between age groups.

Procedures for Confidentiality and Security

A medical/legal transcriptionist, accustomed to maintaining secure records and confidentiality, transcribed audio recordings. Transcripts, handwritten notes, and debriefing documents became part of the data set for each focus group. Electronic files (transcripts and debriefing documents) are maintained in a secure database at Tisdal Consulting.

Limitations

This study has several limitations, two of which are due to the initial decision to hold focus groups on site at SLSC community partner organizations. There was a six-week delay in receiving one site's letter of support that was needed to submit the study for IRB review. In addition, while recruiting through site coordinators provided access to respondents, lack of communication about the importance of equal numbers of females and males provided samples with higher numbers of girls than boys. Yet respondents were familiar with and comfortable in these settings, and they appeared relaxed and open in communicating their perceptions and ideas.

Another limitation involved initial procedures that required face-to-face explanation and signing of informed consent forms by parents or guardians. While the IRB staff appeared to consider this process a prerequisite for approval, the result seemed to be a very low response to invitations to participate. Site coordinators explained this practice is not a community standard and makes it difficult for children with working parents or guardians to participate. Changes were submitted to the IRB and approved.

At the school site, focus group dates were changed three times due to school events that were not considered during scheduling. This school offers a wide range of afterschool activities and nimbly schedules and reschedules numerous events for both parents and children. The benefits of this flexibility for children were apparent to me; however, it did not have a positive impact on focus groups. For the group of 9- to 11-year-olds, it appeared that parents and guardians had not been informed of the new date and time, and arrived to pick up their children only 10 minutes into the focus group script. While some parents and guardians stayed and observed, others left about three-quarters through the script, only two respondents remained—which resulted in missing data for several questions in the script. Finally, focus groups at this site were conducted in a classroom off a hallway with a great deal of traffic. Other students looking for classes, and parents or guardians looking for their children, frequently interrupted the groups. All these factors led to missing and inconsistent data for some areas.

In summary, in interpreting the findings readers should remember that responses may be more characteristic of girls than boys. In addition, several questions were asked and responded to by only about half the respondents, and the age levels of these respondents need to be considered in applying findings about these areas. Despite these limitations, the focus groups provided rich and interesting data that can be useful, if applied carefully, in adapting and designing programs.

Characteristics of Respondents

A total of 21 respondents participated in four focus groups. Appendix D includes a table showing the gender, age, grade level, and ethnicity of each respondent by case number. Two groups were held at a YMCA in North St. Louis City and two at a school in Hazelwood, Missouri, in North St. Louis Country. Both these organizations participate as Community Partners for the Youth Exploring Science program at the SLSC and serve primarily, but not exclusively, African-American populations. The YMCA respondents attended a wide range of St. Louis City and St. Louis County public schools. The Hazelwood school was private with a tuition fee, although scholarships were available for some children. Age of respondents ranged from 6 to 14 years old, and grade levels ranged from first grade to ninth. I interviewed a total of 7 males and 14 females, with 19 respondents identifying as African-American and 2 respondents identifying as White.

Table 1 shows the size, composition and location of each of the four groups. Column two of the table shows the group name that will be used in the rest of the report to characterize findings.

Table 1. Group Composition

Group Date	Group Name	Group Size	Age Range	Gender	Site
September 27, 2014	Mixed	3	8 to 12	3 males	YMCA
October 13, 2014	Younger	6	6 to 8	2 males, 4 females	School
October 27, 2014	Intermediate	5	9 to 11	2 males, 3 females	School
October 25, 2014	Older	7	12 to 14	6 females	YMCA

Students attending the school had the option to participate in a NASA-sponsored afterschool program, and all students in grades two and above participate in a weekly robotics program where they are learning to program. While these opportunities in general appeared to influence students' levels of knowledge about some topics, the respondent who was the most knowledgeable and enthusiastic about NASA and rovers attended a YMCA focus group.

Discussion of Findings

Overview of Findings

In the focus groups, young respondents shared their ideas aloud, through drawings, and by responding on paper. Responses showed differences between the younger (6- to 8-year-olds) and older participants (12- to 14-year-olds), with the intermediate group (9- to 11-year-olds) displaying characteristics of younger or older children depending on their individual levels of maturity.

In general, younger children's responses showed limited and more personal views of space exploration. For example, some children included self-portraits in their drawings of space exploration. In addition, their knowledge was more limited and, at times, mixed with a bit of fantasy as responses spun from knowledge into adventure stories from their own imagination. Older respondents displayed greater levels of knowledge. The most striking differences between relatively younger and older children appeared in the ability of older respondents to consider the process of engineering design (an abstraction that required thinking about their own thinking and behavior) and to produce a logical and coherent set of steps. Younger respondents had difficulty in describing their own thinking and behavior, and focused instead on concrete characteristics of robots.

Yet children within each group also displayed differences. In each group, one or two respondents showed much higher levels of knowledge, interest, and capacity for abstract thought. In the mixed age group, a 12-year-old boy showed a high level of interest in and knowledge about Mars rovers; in the younger group, a six-year-old girl with striking intellectual ability and vocabulary loved robots and remote control devices. In the intermediate age group, one boy, with a substantial scientific vocabulary, produced an annotated diagram of the solar system, responding to the drawing exercise in a much more sophisticated way than did his peers. In other words, there were some differences among children of a similar age that were due simply to differences in overall intellect and/or experience.

In these findings, I characterize levels of knowledge and attitudes in terms of whether these perceptions appeared to have been held by **all** the respondents in or across the focus groups, **many** of the respondents, **some** of the respondents, only a **few** of the respondents, or **none** of the respondents. These terms help to portray both the verbal and nonverbal content of the discussions as well as to convey the range of ideas. I have organized findings around the questions of the study. High-level summaries of the findings related to each question appear first followed by more detailed evidence that provides examples of how the findings were reached.

How do students think about space exploration?

Space Exploration—Summary of Findings

Older respondents appeared to view space exploration from the perspective of the Solar System, while younger children seemed to view it from Earth orbit. Objects within the drawings were coded to identify ideas at the top-of-mind for children when they thought about space exploration. The most frequent humanlike figures, all among younger respondents, were self-portraits. Two other humanlike figures, both drawn by 14-year-old girls, were described as aliens. Surprisingly, only 2 astronauts were featured across all 17 drawings. Some of the drawings (7 of 17) featured tools that people use to explore space. There were 9 tools shown across these 17 drawings. The most frequently drawn tools were spacecraft. Only 1 respondent drew a Mars rover. Among older respondents, there were a few detailed drawings of the Solar System, revealing higher levels of knowledge about this topic. Yet none of these drawings produced by older students included ideas about how people or tools explore space. This seemed to indicate astronomy knowledge and space exploration knowledge are stored in separate categories. Respondents drew Earth far more often than other planets, and 10 included the Sun in their drawing. Saturn, with its memorable rings, was featured in 4 drawings, and Pluto, Jupiter, and Mars in 1 drawing each.

Near the beginning of the focus groups, respondents were asked to draw a picture of "Exploring Space." A total of 17 respondents drew pictures; a few were late to the focus group and did not participate in this activity. Students drew these pictures before they were asked questions that might bring to mind workshop content and topics. Thus, drawings represent the respondents' top-of-mind ideas about space exploration. In addition, the topic of the picture, *space exploration*, was very general, allowing us to assess initial levels of awareness of Mars exploration, unmanned missions, and the use of robots in space exploration. Appendix E includes copies of all these drawings. Analysis of the drawings revealed several important patterns that appear helpful in understanding the respondents' big ideas about space exploration.

Drawings show that respondents selected several different perspectives from which to portray space exploration. These perspectives appear to indicate how children mentally envision this activity. Figure 4 shows the different perspectives respondents chose for their drawing.

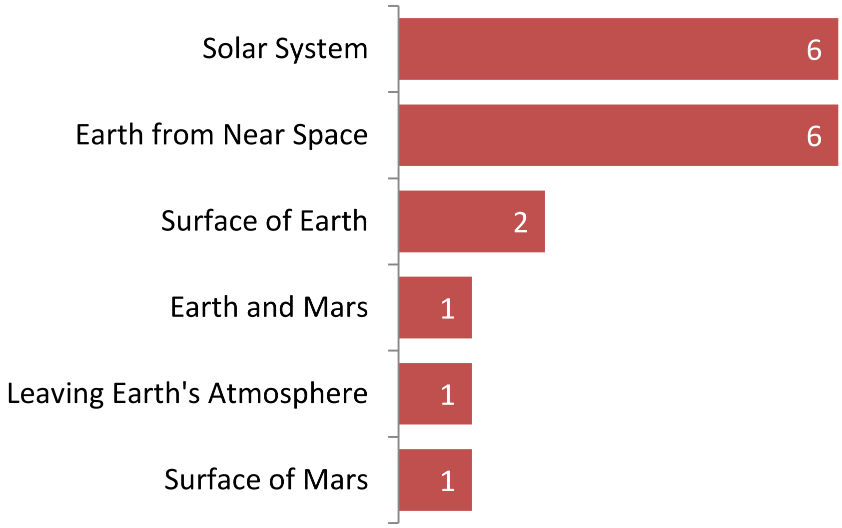
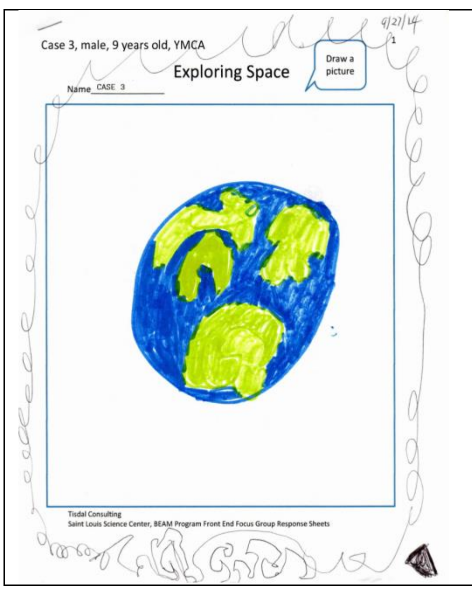


Figure 4. Perspectives of drawings (N = 17)

The two most frequent perspectives used were the Earth from near space (younger children) and the Solar System (older children). Six of the younger respondents drew views of Earth from Near Space. Figures 5 and 6 show this perspective. Most of these drawings showed land and water, with the planet Earth filling the view.



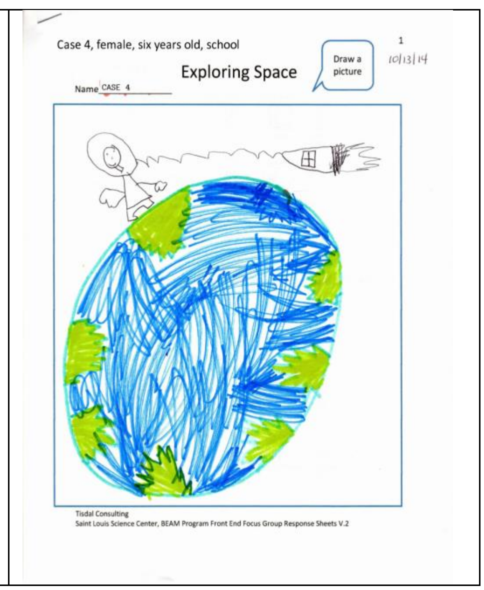


Figure 5. Exploring Space Drawing, CASE 3, male, 9 years old

Figure 6. Exploring space drawing, CASE 4, female, 6 years old

In contrast, the most frequent perspective used by older respondents (n = 6) was the Solar System. Figures 7 and 8 show drawings from this perspective. As shown in both these drawings, older respondents often included tools (such as the spacecraft and spacesuits), the Sun, and multiple planets.

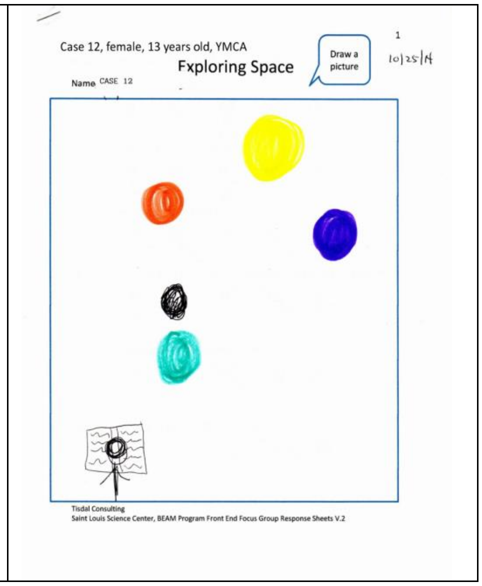


Figure 7. Exploring space drawing, CASE 11, female, 13 years old

Figure 8. Exploring space drawing, CASE 12, female, 13 years old

While the Solar System was the most frequent perspective among older respondents, it was not the only one. As shown in Figure 9, one older respondent envisioned exploring space as a scientist viewing the sky with a telescope from the Earth's surface. Figure 10 shows a rover exploring the surface of Mars.

Figure 9. Exploring space drawing, CASE 13, female, 14 years old

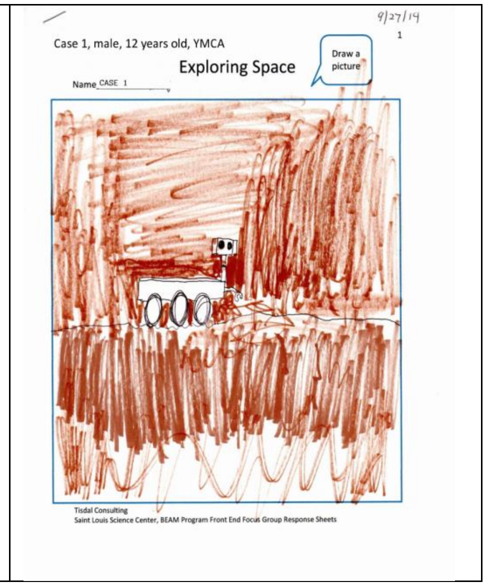


Figure 10. Exploring space drawing, CASE 1, male, 12 years old

There were 9 tools shown across these 17 drawings. Figure 11 shows the tools featured in the drawings. Respondents included spacecraft most often.

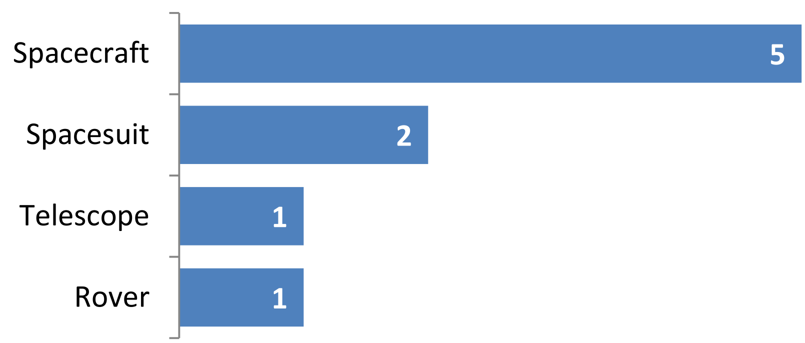


Figure 11. Tools featured in drawings (N = 17)

As shown in Figure 12, some respondents featured people in their drawings. To make certain I understood what was drawn, I asked for clarification when a figure was not clear. I had hypothesized that most people in the drawings would be astronauts, but only two respondents drew astronauts.

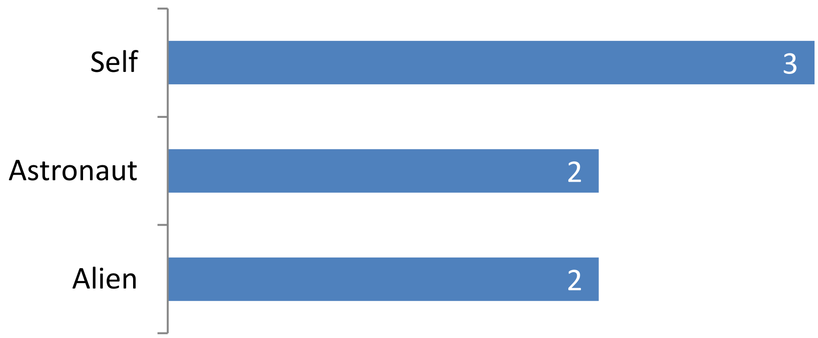


Figure 12. Humanlike items featured in drawings (N = 17)

The most frequent humanlike figures, all among younger respondents, were self-portraits. Note the explorer in Figure 13 is not wearing a space-suit; the yellow feature coming out of the top of her head was emphatically described as her blonde ponytail. This very personal perspective is typical of drawings done by younger children that I have seen in other studies. Two other humanlike figures, both drawn by 14 year old girls, were described as aliens. Figure 14 shows one of these aliens.

Figure 13. Exploring space drawing, CASE 8, female, 6 years old

Figure 14. Exploring space drawing, CASE 14, female, 14 years old

Across all 17 drawings, only 9 tools for space exploration were included. Figure 15 shows the number of each tool selected.

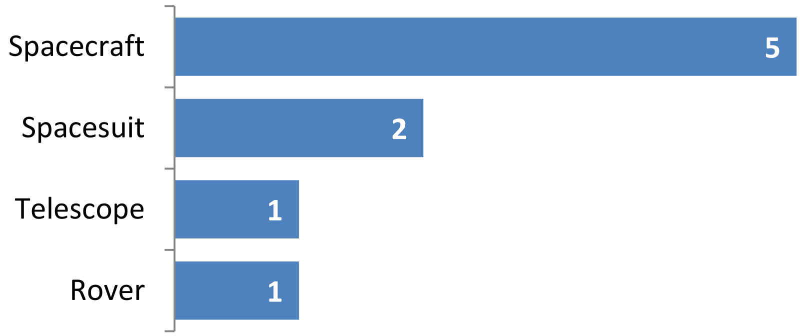


Figure 15. Space exploration tools drawn by respondents (N = 17)

The most frequent items respondents drew were objects in the Solar System, with 12 of the 17 featuring one or more planet. Figure 16 summarizes the object in the Solar System included in drawings. When asked, some children said that objects in their drawings were simply generic planets. These are included in the category *unnamed planets*. Respondents drew Earth far more often than other planets, and 10 included the Sun in their drawing. Saturn with its memorable rings was featured in 4 drawings, and Pluto, Jupiter, and Mars in one drawing each. As I will discuss later, respondents had difficulty naming all the planets.

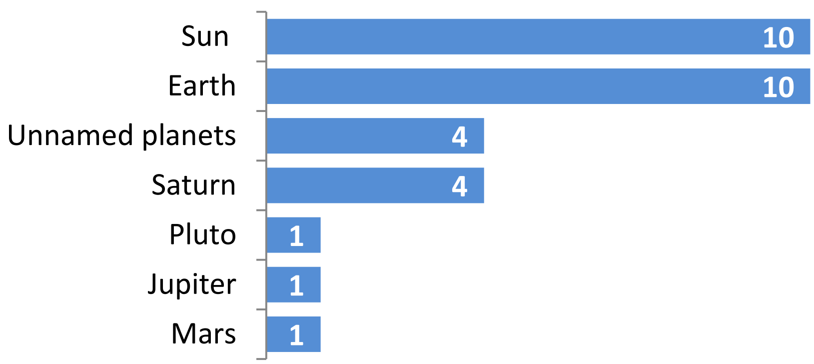
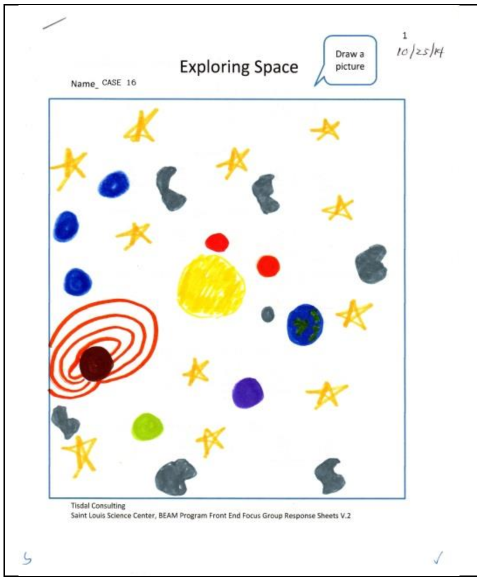


Figure 16. Objects in the Solar System included in drawings (N = 17)

While 6 respondents included some formation of the solar system in their drawings, two of these older respondents provided particularly detailed ideas of how they envisioned the solar system. Their drawings reveal a somewhat higher level of knowledge about astronomy than do other drawings. Yet note that neither includes the tools of space exploration or people. Figures 17 and 18 show these drawings.



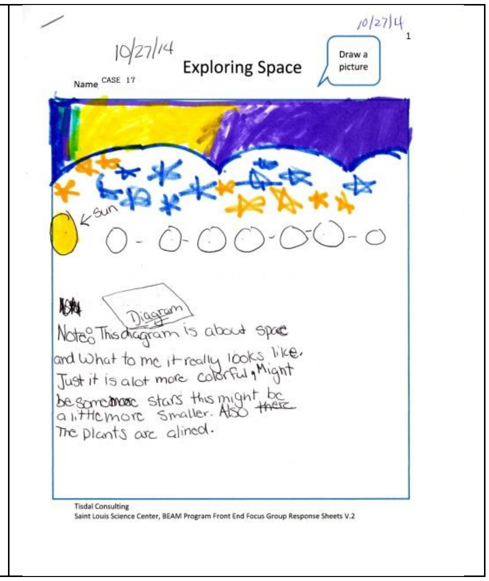


Figure 17. CASE 16, female, 14 years old

Figure 18. CASE 17, male, 11 years old

CASE 16 described her drawing as follows:

> *So I basically drew what I thought space looked like. And that's the sun and the moon, and those are the nine planets. And then the gray things are asteroid and then star. . . . [I arranged the planets in a circle] because they orbit the sun. [This is] Earth, this is supposed to be Jupiter. . . . And the blue ones are the gas giants. There's a whole bunch of different things out in space. (CASE 16, female, 14 years old)*

CASE 17, a bit younger and participating in a different focus group, provided this explanation in his drawing:[1]

> *Note: This diagram is about space and what to me it really looks like. Just it is a lot more colorful. [There] might be some more stars. This might be somewhat smaller. Also, the planets are aligned. (CASE 17, male, 11 years old)*

When asked, CASE 17 explained he knew that the planets orbited around the Sun but had decided to shown them lined up.

Finally, some respondents drew other elements in the universe, with 11 respondents drawing stars, 1 drawing the Milky Way, and another drawing black matter.

[1] Spelling and punctuation have been corrected so mistakes do not distract from his message.

To what extent are children interested in the focus and activities of the program?

Summary of Findings—Interest Levels in the Focus and Activities of the Program
Young people across all three age groups exhibited higher levels of interest the activity-based topics such as *learning to program a robot* and *designing a vehicle to explore Mars* than in knowledge-based topics such as finding out about NASA, Mars, exploring space, and jobs. Respondents of all ages and at both sites expressed high levels of interest in robots in general, which may be the most popular topic to use in eliciting excitement and building positive expectations about the workshops. It also seems that lower levels of interest in several areas appeared to be connected to the lack of familiarity and knowledge about topics. While most respondents connected NASA to space exploration, respondents at all age levels were only vaguely familiar with NASA activities. Respondents showed the least interest in jobs at NASA, which may be due to unfamiliarity with the agency.

Initial levels of interest play a role in the expectations students have as they prepare for field trips as well as in their motivation to initially engage in activities. Knowing initial levels of interest provides information for crafting BEAM field trip workshop descriptions and focusing any pre-trip background and activities.

Early in the focus group, before respondents had time to judge others' ideas about topics, I asked children to rate their interest in various learning content which was to be included in the workshop.   Respondents rated these areas at four levels, from boring to interesting, with an additional option to report they were unfamiliar with the topic. I explained the idea of "thumbs up and thumbs down" ratings, providing examples to allow the respondents to practice before marking ratings on their response sheets. Items were read aloud to account for differences in reading levels. Figure 19 shows the rating scale respondents used.

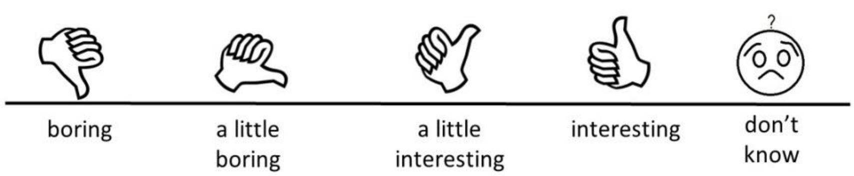


Figure 19. Interest rating scale

Figure 20 shows the mean ratings of interest in items across groups. Though numbers were small, respondents of different ages and genders appeared to rate items in a similar way. There were differences among items and also differences of interest about specific topics. Table 2 shows the mean ratings of content topics. Items with an N less than 21 indicate individuals selecting the "I don't know" option. Differences between items above .25 of a rating point can be considered significantly different based on the largest standard error of the mean among all the items. Table 2 includes the descriptive statistics for each of these items.

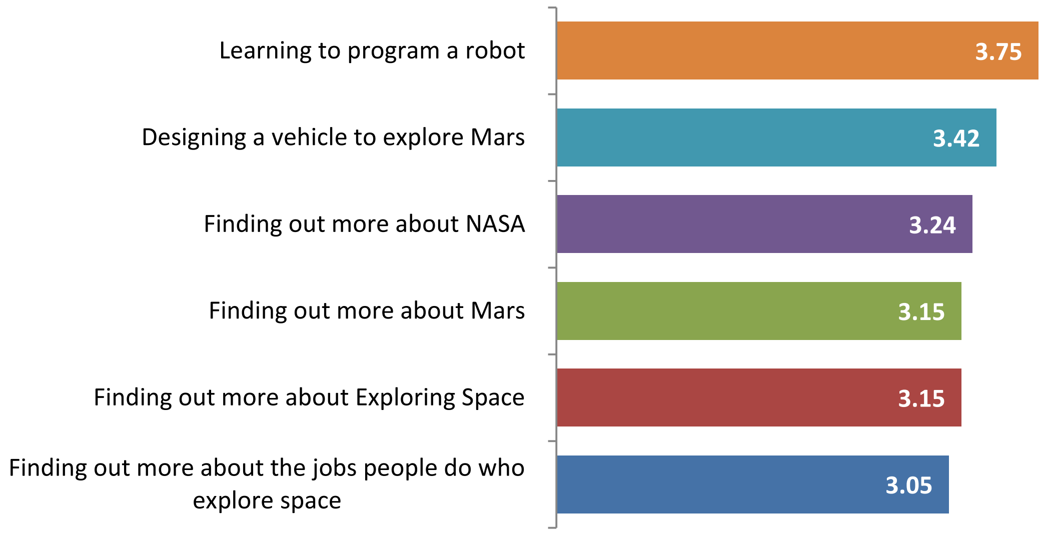


Figure 20. Mean ratings of interest levels (1 = boring to 4 = interesting)

Table 2. Interest Items' Descriptive Statistics

Interest Items	N	Mean	Median	Standard Deviation	Standard Error	Range
Programming a robot	20	3.75	4.00	0.72	0.16	3
Designing a vehicle to explore Mars	19	3.42	4.00	1.02	0.23	3
Finding out more about NASA	17	3.24	4.00	1.09	0.26	3
Finding out more about exploring space	20	3.15	3.00	0.99	0.22	3
Finding out more about Mars	20	3.15	3.50	1.04	0.23	3
Finding out more about the jobs people do to explore space	19	3.05	4.00	1.27	0.29	3

After rating all the items, I asked respondents to give reasons for their ratings. Note that the two activities on the list (*Programming a robot* and *Designing a vehicle to explore Mars*) were rated at higher levels than any of the knowledge areas. In addition, both these areas featured technology, an area that respondents appeared to perceive as familiar. Not all respondents were able to clearly articulate a reason for their ratings, particularly among the younger children.

Learning to Program a Robot

Respondents rated *Learning to Program a Robot* highest among all topics. At the school, children in grades 2 and above participate in robotics class for one hour a week. As one pointed out, "Well, we're doing that in robotics already." Enthusiasm for this class appeared high. One explained:

> *Well, it's really actually fun to experience around with that stuff. . . . I love robots and all that stuff so [much]—love, love, love—and remote control too. (CASE 19, female, 11 years old)*

For school respondents who had experienced the robotics class, the opportunity to work with other people when programming was also appealing. As one explained, "It's fun because you can also tell people and teach people how to program."

Yet even in the Mixed Grade and Older focus groups at the YMCA, all respondents gave this activity higher interest ratings. It appeared that one reason for the high ratings was the opportunity to be creative. As one younger respondent explained:

> *I think it'd be interesting. I would program a homework robot. So it could do the homework for me and things like that. Or I would program a robot to where . . . it could give me a piggyback ride to school. (CASE 3, male, 9 years old)*

A reasonable interpretation of some of these responses is that programming a robot is clearly of interest, but not necessarily within the context of space exploration.

Designing a Vehicle to Explore Mars

The next highest-rated topic was *Designing a vehicle to explore Mars*. A few respondents explained their high rating by connecting it to previous design experiences in class.

> *Oh, like we did a design with marshmallows. And then we had make it stand up and used and some sticks and put it together, and it was like a competition. (CASE 11, female, 13 years old)*

Yet previous experience also influenced some lower ratings:

> *Like I'm not into building stuff. . . . No, it's complicated. Like I don't know what all these parts are doing. That's not me. (CASE 16, female, 14 years old)*

Another, who had rated other areas at lower levels, heard the word "design," connected it to art, and gave this item a high rating:

> *"Art, I love art!" she explained. (CASE 8, female, 6 years old)*

Several of the boys connected this topic to cars and to the idea of exploring:

> *I said design a vehicle for explore Mars is interesting . . . I saw a picture of exploring on another planet, I mean [in] a movie, and I think they was going back into space or something like that and they was in a car. (CASE 15, female, 13 years old)*

> *I really like cars and airplane stuff. Especially things that could help explore. I thought it was interesting. Because like, because like I can like anything I want, so I can build like a car that could do what planes do or what helicopters do and stuff like that, and I'll build and stuff. (CASE 1, male, 12 years old)*

Finding Out More about NASA

Respondents placed *Finding out more about NASA* in the middle of their ratings. Despite this relatively high rating, when I asked for a show of hands, about half the respondents said they unfamiliar with NASA. Among the other half, the term was familiar, but they didn't know the words behind the acronym.

> *I know what it is but I just don't know what it stands for. . . I think it's like, well, what I was saying it's like they have people design space ships and have it go in space. (CASE 15, female, 13 years old)*

At the school where focus groups were held, the children can participate in an afterschool program using NASA materials. Among this group, the term sounded familiar, but some respondents connected it primarily to teaching and learning.

> *They teach people about the, um, universe? (CASE 8, female, 6 years old)*

In one group, respondents tried to guess the words behind the acronym and got a nice laugh from other respondents:

CASE 21*:*	*National uh—Astronautics?*
CASE 18*:*	*Astronaut?*
CASE 17*:*	*Sequencing? Synchronizing.*
CASE 19*:*	*National Astronaut Synchronized Apple?*

Finding Out More about Mars

Finding out more about Mars was ranked in the low-middle of interest items, with a mean rating of 3.15. Respondents who rated this item highly were able to explain their interest. One had recently studied Mars in school and was clearly fascinated by the volcanic activity he had learned about.

> *Because it's like the closest planet you can really study. . . . Mars has a lot of volcanoes. And I saw on the history of it, I think we're doing science, science history is cool. One of Mars'*

volcanoes is almost as big as Texas. You could fit it in—it could barely fit into Texas. (CASE 1, male 12 years old)

Several brought up a theme that appeared throughout the focus groups: If Earth becomes unlivable, then Mars could be an option.

I said finding out more about Mars [was very interesting]. Because I think a few years back, people were talking about like how if the Earth somehow isn't like good enough for humans to live on, then we could move to another planet, and I believe they said Mars, so I want to know about like why they think we could just go Mars in time. (CASE 16, female, 14 years old)

Younger respondents who rated this item at lower levels simply said they thought it was boring. This response appeared to be connected a lack of knowledge and information about Mars. As one eight-year-old explained, echoing some information from another respondent:

Because Mars sometimes it's like a reddish brown planet like as he said, and then Mars is I think it's a little hot or cold. I don't remember but the reason I find it a little boring because there's not, well, like on Mars there's just not a lot of stuff to know about a lot. (CASE 3, male, 9 years old)

Finding Out More about Exploring Space

Finding out more about Exploring Space also had a mean rating of 3.15, among the lower of the ratings. Yet those respondents who rated it higher and lower connected "liking" of this topic to their identity—that is, what kind of people they are.

Because I [have always been interested in] like what happens in space and everything about people living on Mars, like other planet creatures. [I got interested in it] right around kindergarten [from] books and stuff. Like kids' books. (CASE 13, female, 14 years old)

Oh, it's not my thing. (CASE 10, female, 12 years old)

I gave it a "little interesting." I've never really been that excited about learning about space. (CASE 12, female, 13 years old)

Again, some lower ratings appeared to be connected to lack of awareness and knowledge; it was an area in which respondents had little experience. One explained:

I have it interesting because, well, I never been in space, I never been on the moon, I never touched the moon. I never had been out of Earth. I haven't been to a different planet. I haven't been on Jupiter, Mars, other planets, and I love Earth. (CASE 21, male, 10 years old)

Student testing about Earth and space science at the end of grade 3 may have affected this respondent's perception of the topic:

> *I mean since, you know, I'm a sixth grader, I've already learned most of this stuff. (CASE 17, male, 11 years old)*

Yet several other respondents explained their lack of interest by citing space as unwelcoming and a place difficult to survive:

> *I rated it a little boring 'cause I'm just not exactly into space. I am very fine sitting here on Earth with all the beautiful trees and plants and oxygen and life. (CASE 19, female 11 years old)*

> *It's a little bit boring. It's a little bit boring because if you were like, let's say I was living up in space and there was no things or no oxygen—I would just be dead, and I would just look at all the dark stuff and no oxygen. (CASE 20, male, 9 years old)*

Finding Out More about the Jobs People Do Who Explore Space

With a mean rating of 3.05, respondents rated *Finding out more about the jobs people do who explore space* at the lowest level among all the items. Several children said simply that they found this topic "boring." Again, this rating may have been due to the topic being unfamiliar. Another factor is that some respondents were not particularly interested in learning about careers. Among a few children, however, it was a very interesting topic because of the adventure and questions they associated with space exploration. Yet their questions appeared vague and connected to some misinformation and fantasy.

> *I think it would be interesting because like they can like tell they can like go on Mars and see like they can like, like you have the things that can show how hot something is, like a temperature thing, and they can use that to see how hot the sun is. And then they keep the information and bring it back to Earth so a lot of people will know if it's the truth that the moon has holes in it or made out of cheese or, or red or blue cheese or Mars has aliens on it, or yes stuff like—and how hot the sun is. Stuff like that. (CASE 2, male, 8 years old)*

> *I said interesting because I would like to know [how] they make suits 'cause the sun is really hot so a person if they try to go on the sun they're probably melt, so I think if they made suits so they could study the sun, seeing what it's like, they could see the core of the sun and some things like that, the sun formation to see if the suit can last on the sun. (CASE 3, male, 9 years old)*

> *I put real interesting . . . . Because you can't know about space if you don't have any jobs. And especially for the designers—without designers and you can't do anything in space. You could building the telescope, but if you didn't have any machines or anything, [you couldn't] to go into space. (CASE 1, male, 12 years old)*

To what extent and in what ways are children familiar with Mars?

Summary of Findings
Most respondents appeared to know that Mars is one of the planets in the Solar System and most identified it as one of the planets closer to Earth. Yet they often confused Mars with other planets when trying point it out in a model Solar System. On the other hand, when shown a photo, most identified the planet by the predominate color and used the phrase "the red planet." Respondents agreed that Mars was rocky and that there was no air to breathe, but there was little agreement about the temperature. Among both younger and older respondents, knowledge of Mars was very rudimentary at best.

Most respondents appeared to know that Mars was one of the planets in the solar system and most identified it as one of the planets closer to Earth. Yet, when shown a model Solar System many were not clear which planet was Mercury which was Mars and which was Venus. On the other hand, when shown a photo most identified the planet by the predominate color and used the phrase "the red planet."

Respondents agreed that Mars was rocky and there was no air to breath. But there was little agreement about the temperature.

> *It's like hot, makes you sweat a little bit, and then it's really red, (CASE 8, female, 6 years old)*

> *I was starting to say your head would freeze up, (CASE 4, female, 6 years old)*

As I discussed earlier, one respondent was very interested in the volcanoes on Mars. Two other older respondents appeared more knowledgeable than others about the place of Mars in the Solar System and its surface characteristics. One explained:

> *I just remembered that the Earth is the third planet from the sun like Mercury, Venus, and Earth; also, like I can remember that these are the four terrestrial planets and then we have the asteroid belt and the asteroids. (CASE 17, male, 11 years old)*

When asked by a show of hands, about half the younger children thought there were humanlike aliens living on Mars. None of the girls in the oldest group believed this was the case, although some mentioned aliens in a fanciful way connected to TV and movies.

To what extent are children familiar with NASA's unmanned missions to explore Mars and with Mars rovers?

Summary of Findings About half of respondents in all age groups had the misperception that humans had already landed on Mars, and only half the older respondents and none of the younger respondents were familiar with the Mars rovers. Most respondents of all ages had a basic understanding of what a rover might do (e.g. collect rocks, take photos) but only a sketchy connection to the underlying scientific question about Mars the rovers could be used to answer.

When asked by a show of hands, about half the children in all the groups thought people had already landed on Mars and about half knew only rovers thus far had visited Mars. None of the children in the youngest group (ages 6 to 8) recognized a photo of a Mars rover and about half of those in the intermediate (ages 9 to 11) group recognized it, while most of the respondents in the oldest group (ages 12 to 14) recognized a Mars rover. Some respondents commented that the photo of the Mars rover reminded them of film characters in *E. T.* and *Wall-E*. When asked for the names of the rovers, one guessed "Land Rover?"

Most respondents familiar with rovers had a basic understanding of what a rover might do but only a sketchy connection to the underlying scientific question about Mars the rovers could be used to answer:

> *Like [it] takes pictures of Mars and it goes around in circles. (CASE 11, female, 13 years old)*
>
> *I'm gonna say probably because I don't know, they probably found out if they have volcanoes and they . . . like observe rocks. The scientists observe the rocks and they can see if—and maybe, maybe they found out if there are aliens. (CASE 2, male, 8 years old)*
>
> *Maybe when it grabs those rocks, I think maybe it puts it lightly on its solar panel because when it goes back to Earthy or when—'cause when the people come and get it—they'll see lots of rocks and they'll be like, good job, 'cause you found lots of rocks. And now we can bring it back to Earth. (CASE 20, male, 9 years old)*

To what extent and in what ways do members of these target audiences consider the exploration of Mars as valuable?

Summary of Findings
Overall, respondents appeared to rank the importance of Mars exploration at lower levels of importance than social concerns such as stopping war, reducing homelessness, curing disease, and stopping violence, but at a higher level than personal interests such as getting tattoos or having fun. Personal interest among scientists and explorers was cited as the primary rationale for Mars exploration, and a few gave examples of scientific questions that could be explored. A few said that finding a place to live and grow food should Earth become unlivable as a rationale for exploration.

To get a better understanding of the extent to which respondents considered the exploration of Mars as valuable, I asked them to tell me what things they thought were more valuable and what things they thought were less valuable. Among younger children, even this request appeared difficult, and they focused on more personal matters such as getting their education and praising God. One respondent responded that, personally, she did not think she needed to go to Mars:

> *Because like it's fun because you can learn planets like in school you don't have to go to Mars and look at Mars and see what—and learn about it. Like if the teacher knew, the teacher could tell you about Mars and all about it. (CASE 6, male, 6 years old)*

Older respondents cited a range of social issues as more important priorities for them than exploring Mars:

> *More important would be like you know, what CASE 13 said about the homeless people. Like trying to make sure [they have somewhere to go] get 'em off the street. And less important would be going to war, interfering with other countries. (CASE 16, female, 14 years old)*

> *I think more important would be like curing diseases that they don't have cures for now. And less important would be having a tattoo for every person. (CASE 15, female 13 years old)*

> *More important is stop all the violence, it's so stupid. And less important, I don't know. (CASE 10, female, 12 years old)*

Mars exploration being rated as somewhat less than a top priority may have been due to respondents' lack of awareness about any good reasons for people to explore Mars. One conjectured that it was a personal interest of people doing the exploring:

> *[They explore Mars] 'Cause they like—they like space. (CASE 10, female, 12 years old)*

A few older respondents gave some reasons to explore Mars, but they presented these reasons as guesses. A few noted scientific questions:

> *So we can find out more from that, like how that other planet was formed and what caused it to be this way and all that stuff. (CASE 19, female, 11 years old)*

Others thought exploring Mars might be important as an option to Earth as a place for people to live and one more likely to be habitable than other planets:

> *Because we would die if we went to Mercury or Venus to live. We would die if we went to Jupiter. (CASE 19, female, 11 years old)*

> *I think [people would explore Mars] to build more towns where people can live . . . . Maybe to be able to grow food and be able to farm food. (CASE 18, male 10 years old)*

Given a design challenge, to what extent and in what ways do members of the target audience use the engineering design process to guide their efforts?

Summary of Findings In general, younger children (6 to 8 years old) appeared to be less able to develop a set of sequential, progressive steps to reach a goal—that is, to articulate a multi-step process that portrays their own thinking and behavior. These younger children focused on the characteristics of the rover or robot itself rather than the process they would use to design the robot. One theme among these younger children was that robots need to protect themselves from attack physical attack similar to fight scenes in cartoons.

Several older children (8 out of 10) did present sequential, progressive processes. *Design* (*n* = 9), which included sketching and developing blueprints, and *Building* (*n* = 8) were the two most frequently cited steps and appeared to be the most clearly understood by the respondents. Yet few of these 12- to 14-year-olds clearly defined the engineering problem or identified constraints. These steps are the points in the process where existing scientific information can be used to guide the design, so given the goals of the project; they need to be explicitly included in the design process. In addition, only a few respondents (*n* = 3) presented the step *Conceptualizing or Thinking*.

It appeared that respondents focused on the mechanical design of the rovers and gave less attention to communication, transporting the vehicle, and transportation. Finally, about a third (*n* = 4) of the children providing written responses (*N* = 10), included the idea of testing and revising their designs, and only two of these respondents clearly indicated they would carry out empirical testing. Only one presented the idea of iterative testing.

Children in the two focus groups were asked the following question and asked to respond on paper:

> *I want you to imagine that you are designing or planning a rover to explore Mars. (Slide 13) Tell me about HOW you would go about planning and putting together a rover to Explore Mars. What steps would they go through? Use the sheet provided.*

Written steps in the process were obtained from only 10 of the 21 respondents due to a variety of factors. It was never planned to ask the younger group (6 to 8 years old) to write down steps; they were to respond aloud because of the limited writing skills of children this age. Yet these younger respondents also appeared to have difficulty in talking about steps in a process. So I asked them to draw a picture of a robot they would send to Mars and to think about what they would do to design it.

The other factor was an issue of communication between the school site and the parents or guardians. The school changed the date of this focus group, but apparently had not communicated this information to the adults. Parents and guardians began picking up students 10 minutes into the focus group, and most respondents had left by the time we reached this section of the interview. This focus group was shortened, and none of these respondents were able to provide written responses.

Younger Respondents—Pictures

As explained above, in the focus group of 6- to 8-year-olds, respondents seemed to have great difficulty in describing a step-by-step process. In response to this difficulty, I asked them to draw pictures of the robots they would send to explore Mars and to talk about their drawings. The children were able to draw and talk about their designs, but they did not seem to be able to abstract the process by which they created their designs. The pictures are shown in Figures 21 to 26. Drawings show patterns that provide some insights into how some children think about robots. (Note that none of the pictures look like the designs of the current Mars rovers.) Cases 4, 5, 7, 8, and 9 clearly show robots with human features such as heads, eyes, a mouth, arms, and legs. When asked to describe his robot, Case 6 pointed to features in the drawing that were ears, the head, and the neck. Two of drawings, those of Cases 4 and 7, feature devices for external communication so that someone can tell the robots what to do. As a whole, these drawings seem to portray robots as walking and talking creations that may be similar to robots in films and television.

When asked questions to probe their understanding, the children knew that some robots did not have legs but moved on wheels. As they described their drawings, all pointed out that their robots communicated with someone who told them what to do. The children did not appear to make a distinction between remote control and programming.

Figure 21. CASE 4 Robot Drawing, male, 10 years old

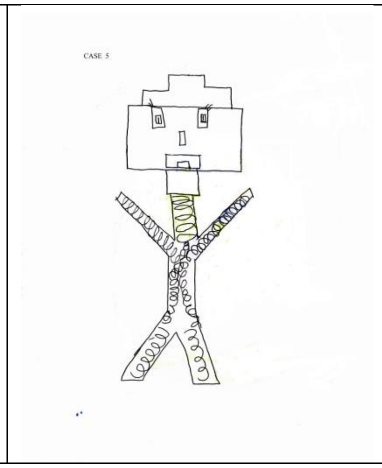


Figure 22. CASE 5 Robot Drawing, female, 8 years old

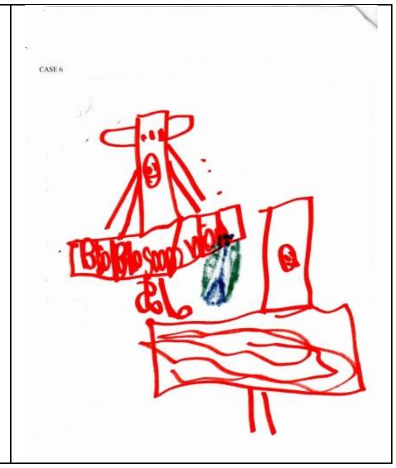


Figure 23. CASE 6 Robot Drawing, male, 6 years old

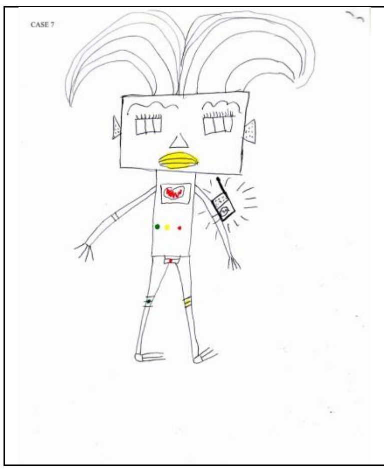


Figure 24. CASE 7 Robot Drawing, female, 7 years old

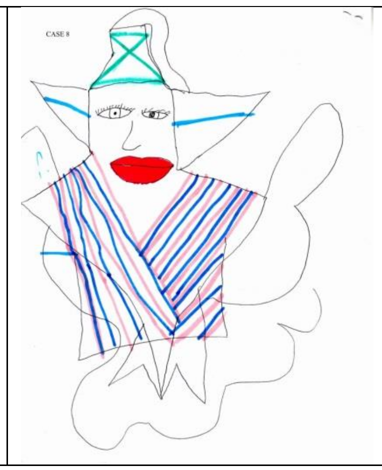


Figure 25. CASE 8 Robot Drawing, female, 6 years old

Figure 26. CASE 9 Robot Drawing, female, 6 years old

Another theme apparent in the children’s descriptions was the idea that robots need to protect themselves from attack. Case 5 explained that her robot could do karate in order to protect itself. Case 4 said that her robot had arms so if something “went wrong, he could take care of it. He has strong arms, so he could pick it up and throw it somewhere else.” She described her robot as “powerful.” In summary, the children appeared to consider challenges and dangers in designing their robots, but the challenges considered appeared to focus on physical attack of the robots.

Older Respondent—Written Steps

Written responses to the question about designing a rover to explore Mars were obtained from 10 respondents, ages 8 to 14, from the mixed-aged focus group (September 27, 2014) and the respondents in the older focus group of 12- to 14-year-olds (October 25, 2014). Readers should remember the responses presented are probably more characteristic of older than of younger children. Appendix F includes the respondents' written engineering design steps, along with my coding of the steps that are discussed in this section. I developed the codes from the responses and then looked at the engineering design process models discussed in the introduction for names and sub-steps.

Among the written responses, 8 of the 11 children who wrote down steps displayed a logical, progressive sequence to reach an outcome. Examples of responses showing a logical sequence of steps included the following:

> *Think on what I want to build*
> *Then learn or search about it*
> *Draw what I think I want to make*
> *Do a rough draft/program it*
> *Revise or change anything I need or want to*
> *Build it (CASE 10, female, 12 years old)*

> *Hire someone*
> *Design*
> *Collect*
> *Build*
> *Send To Mars*
> *Explore (CASE 1, male 12 years old)*

I also classified as a logical sequence a series of steps based on a false premise. A 14-year-old girl stated in her explanation of the picture that humans were already on Mars. She started her process with having these people explore to give her ideas about what a rover would explore. Despite this misconception, however, her steps were logical and sequential.

> *Have people explore Mars*
> *Think about some things you would like to see*
> *Make a blueprint of what you want it to look like*
> *Get the materials*
> *Make the rover*
> *Name it*
> *Send it to Mars (CASE 16, female, 14 years old)*

Examples of processes that were not classified as logical sequences included those of the youngest respondent, age 8, who made his robot before designing it:

Make robot with iron.
Design the head.
Make the body.
My rover would be done. (CASE 2, male, 8 years old)

Another example of steps that were not logical and progressive came from a 14-year-old girl who asked a series of questions but never proceeded beyond that point in the process:

To find out how a rover would get a connection from Earth to Mars
How would we get the rover to Mars?
How would the rover be shaped?
What would it be made of?
What elements could be part of it?
What color should it be?
How would I program it to do what I want it to do? (CASE 12, female, 13 years old)

None of the respondents submitting written responses included a step that could be clearly classified as *Identifying the Problem* to be solved through an engineering design. In addition, only three respondents included steps that appeared to be the process of Identifying Constraints. Note that these constraints have to do with vehicle delivery or Earth-to-Mars communication. None of the respondents identified constraints that had to do with the climate or topography of Mars. Responses classified as identifying constraints included:

Make create a way to send it to planet. (CASE 11, female 13 years old)

To find out how a rover would get a connection from Earth to Mars. (CASE 12, female 13 years old)

Find a way to get a connection. (CASE 15, female, 13 years old)

Note that almost all the respondents interpreted the problem or task I had given them as designing the mechanics of a rover to explore Mars. Constraints considered often appeared add-ons about communication or transporting the vehicles. Only three respondents included the idea of programming the rovers, which indicates these respondents were aware of both the mechanical and the programming areas in the design of rovers to be sent to Mars. Yet, like the constraints, for Cases 11 and 12 the idea of programming appeared secondary to the physical design. Here is how the three respondents included programming in their process, indicated by asterisks:

Think on what I want to build
Then learn or search about it
Draw what I think I want to make
**Do a rough draft/program it*
Revise or change anything I need or want to
Build it. (CASE 10, female, 12 years old)

Hire people to help.
Start construction. Finish construction.
Make it presentable. Perfect it.
**Program it to do its job.*
Make/create a way to send it to planet.
Send it to do research about planet (CASE 11, female, 13 years old)

To find out how a rover would get a connection from Earth to Mars
How would we get the rover to Mars?
How would the rover be shaped?
What would it be made of?
What elements could be part of it?
What color should it be?
**How would I program it to do what I want it to do? (CASE 12, female, 13 years old)*

About one-third of the children submitting written responses included steps that involved conceptualizing or thinking prior to designing, sketching, or building the rover. Examples of steps classified as conceptualizing or thinking included:

Think on what I want to build. (CASE 10, female, 12 years old)

Think of a plan. (CASE 2, male, 8 years old)

Thinking like what type of structure do I want. (CASE 15, female, 13 years old)

Several of the engineering design models include steps about finding out what others, or doing or collecting more information about the nature of constraints. I called this step *Research*, referring to the process of looking for existing knowledge as opposed to the process of carrying out original research. In general, only a few of the respondents included steps that could be classified as *Research*. Case 12, who posed all of her steps as questions, is included in this group. In addition, Case 1 noted that he would “collect” information, and Case 10 said she would:

Think on what I want to build
Then learn or search about it (CASE 10, female, 12 years old)

The step included by the highest number (n = 9) of the respondents was *Design*. I classified responses that explicated stated design of the vehicle and also included steps involving drawing, sketching, and developing blueprints. Examples of these responses included:

> *Draw*
> *Blue print (CASE 3, male, 9 years old)*
>
> *Draw what I think I want to make*
> *Do a rough draft/program it (CASE 10, female, 12 years old)*
>
> *Sketch it out (CASE 15, female, 13 years old)*
>
> *Make a blueprint of what you want it to look like (CASE 16, female, 14 years old)*

The next most frequent step was *Build*; 8 of the 11 respondents included this step. What varied among these respondents was where they place the *Build* step in their process. The youngest respondent included building as both his first and third steps.[2]

> **Make robot with iron.*
> *Design the head.*
> **Make the body.*
> *My rover would be done. (CASE 2, male, 8 years old)*

Cases 1 and 3 included *Build* as their fourth step, and Case 11 included it as his third. Case 13 included the idea of building at multiple steps and intertwined it with the next step, identified *Test*:

> *Create blue print*
> **Invent your prototype*
> *Take it out.*
> *Take it to space.*
> **Keep trying to rebuild it if it stops working or messes up*
> *Be creative.*
> *Make sure it is all good. (CASE 13, female, 14 years old)*

Only 4 of the 11 written responses contained a step that indicated they would *Test* and then revise the design or vehicle. Some of these steps did not clearly indicate empirical testing but may have indicated mental review and revision:

> *Revise or change anything I need or want to (CASE 10, female, 12 years old)*

---

[2] An asterisk precedes steps classified as *Build*.

Make it presentable. Perfect it. (CASE 11, female, 13 years old)

But two others, including Case 14, which follows, clearly understood empirical testing:

Think of a plan
Sketch design it
Test it
Fix mistakes
Do a final plan
Find way to get it to Mars
Send it to Mars. (CASE 14, female, 14 years old)

Yet only Case 13, who said she would "Keep trying to rebuild it if it stops working or messes up," appeared to have a clear idea of iterative testing.

To what extent and in what ways do members of the target audience consider the surface characteristics of Mars and the communications time lag between Mars and Earth in their design process?

Summary of Findings
None of the respondents included the characteristics of Mars or the communications time lag between Mars and Earth in their design process. This may have been due to how the design task was presented, but it is likely to have been influenced also by little awareness of the processes of identifying problems and constraints as well as a lack of awareness about either of these topics.

Data relevant to this question are embedded in the data presented for the engineering design process. As shown in the analysis steps presented by the respondents, none considered the surface characteristics of Mars in their designs. This may have been due to their focus on developing a process, but since the ideas of Identifying the Problem and Identifying Constraints were included by so few, it is more likely that very few have the idea that good designs emerge from careful consideration of problems and constraints.

Case 13 provided the only instance among written responses where a communications connection was explicitly mentioned; in most of the written responses, the focus was on the mechanical design of the rovers. Only three respondents mentioned programming. Among the younger children who drew pictures of robots, two explicitly included communications devices, while all indicated orally that their robots communicated with and were controlled by humans. These responses may have been due to the robotics program at the school where children in second grade and above have a weekly lesson in robotics that includes programming. So while none of the respondents included the time lag in their designs, the younger children with more exposure to robotics appeared to have a greater understanding of communications and programming.

As discussed previously, all respondents of all ages appear to have rather low levels of awareness and knowledge about the physical characteristics of Mars or the communications time lag from Earth. This lack of awareness may have been a reason they did not consider these elements in their design process.

To what extent do members of the target audience see themselves as someone who could be a NASA engineer?

Summary of Findings
In a photo selection activity designed to see if respondents thought that people like themselves, in terms of race and gender, work at NASA, respondents most frequently selected white or Asian men. The majority of respondents were African-American females ($n = 8$). The four least selected photos included those showing three females and three people who appeared to be people of color. Male respondents ($n = 4$) selected very few photos showing females as those they thought to work for NASA on the Mars rover projects. Based on follow-up conversations, this tendency to think people working at NASA are white or Asian men appeared unconscious.

I presented the pictures on a PowerPoint slide, four per page, and told the children that any number of people on each page could work on the Mars rover projects. Most of the photos were obtained from the Jet Propulsion Lab webpage (2014). A few additional pictures of models were obtained from non-copyrighted photo collections. This task was designed to see if the boys and girls in the focus groups had perceptions about who would or would not be involved in this type of work and whether the people they selected would be like themselves in terms of race or gender.

Despite the concentration of female and African-American respondents, the top four most-selected photos show males three of whom appear white or one who appears Asian in ethnicity. Among the four least-selected photos, three are female and three appear to be people of color.

Table 3 shows the responses of 12 children who were asked to look at pictures and "guess" which of the individuals shown worked on the Mars rover projects at NASA. Only about half the children attending focus groups responded to this question, due to a variety of issues that included a projection problem in the October 13, 2014, group and the early pickup of children by parents and guardians during the October 27, 2014, group. Both these issues occurred at the school site. Among the children responding to this question, 4 were male and 8 were female. Ages ranged from 8 to 14, with a concentration (7) from the focus group of 12- to 14-year-olds. All identified themselves as African-American.

Table 3. Which of these people worked on the Mars rover projects at NASA? (*N* = 12)

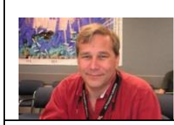
Photo	**Item Number**	**Actual Position**	**Males (*n* = 4)**	**Females (*n* = 8)**	**TOTAL (*N* = 12)**
	2B	Computer Engineer	2	8	10
	4C	MSL Chief Engineer	3	7	10
	2A	Engineer but not at NASA	2	6	8
	1D	Chairman, Division of Sciences *Salish Kootenai College*	2	5	7
	3B	Ph.D. Candidate Washington University in St. Louis	0	6	6
	2C	Mission Manager	1	4	5
	3C	Staff Mechanical Engineer	1	4	5

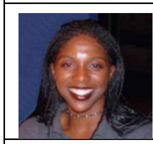
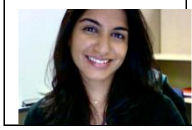
Photo	Item Number	Actual Position	Males ($n = 4$)	Females ($n = 8$)	TOTAL ($N = 12$)
	1A	Astro- dynamics Team Lead	3	2	5
	3 D	Model	3	1	4
	1C	Surface Sampling System Activity Lead	0	3	3
	2 D	Thermal Engineer	1	2	3
	4A	Database Administrat or	1	2	3
	1B	Systems Engineer	0	2	2
	4 D	Systems Engineer	0	2	2
	4B	Senior Robotics Engineer	1	1	2

Photo	Item Number	Actual Position	Males (*n* = 4)	Females (*n* = 8)	TOTAL (*N* = 12)
	3A	Tactical Uplink Lead	0	1	1

It is a very small sample, yet respondents answering this question, a majority female, appeared to think that people *less like* themselves in gender and ethnicity would work for NASA. Note from the numbers selecting photos showing females (3B, 1C, 2D, 1B, 4D, and 3A); however, that very few males selected any female photos. This finding may mean that while some girls' ideas of what jobs are open to them has expanded these ideas about girls and women as engineers and scientists may have changed less among boys.

Many of the respondents who completed this activity stayed after the conclusion of the focus group to see if they had "guessed" correctly. From the general conversation, it appeared that the children were unaware they had selected photos of people the least like themselves. In addition, they were unfamiliar with the job titles that were displayed at that point with the photos. They asked "What's that?" about several jobs while laughing and guessing what the long names might mean. This lack of familiarity, along with other discussion, appeared to indicate that respondents had little knowledge about the range of careers and fields involved in developing the Mars rovers. This lack of knowledge may affect initial interest.

What are children's perceptions and misperceptions about space exploration?

Summary of Findings The most important misperceptions I identified were that respondents were less likely to identify photos of women and people of color as working for NASA on the Mars rover projects and more likely to identify white and Asian men. This process of developing identity is essential in young people selecting education and career paths. In other areas, rather than being peppered with misperceptions, most respondents' knowledge can be described as somewhat rudimentary, vague, and not well-connected. There were two other uncertainties across all age groups: (1) Many were unfamiliar with the acronym NASA, and some were not aware of the agency or its mission at all; and (2) some respondents, both older and younger children, were unclear about whether human beings had traveled to Mars. Younger respondents in general had less knowledge about the Solar System and space exploration. A few younger respondents appeared to believe there could be aliens on Mars.

Findings about misperceptions reflect a synthesis of findings across other areas relevant to this question. The most important misperceptions I identified are that respondents were less likely to identify photos of women and people of color as working for NASA on the Mars rover projects and more likely to identify white and Asian men. Information about career opportunities will not "stick" if young people do not see themselves as those for whom an educational and career path is open.

Among other topics explored in this study, respondents showed only a few misperceptions. Rather than being peppered with misperceptions, most respondents' knowledge can be described as somewhat rudimentary, vague, and not well-connected. For example, older respondents exhibited some knowledge about the Solar System in discussion, and some could identify a Mars rover. These respondents had a general idea about programming. Yet only one could and did talk about rovers as a robot in the context of Mars exploration. Some of these same older respondents could identify Mars from the order of planets in their distance from the Sun. Yet only one identified the underlying connection that further distance from the Sun influenced the overall temperature on the planet's surface. In other words, these older students had a good deal of existing knowledge, but this knowledge was not connected in context or through underlying principles.

Younger respondents in general had less knowledge about the Solar System and about space exploration. They knew their own planet Earth and the Sun. Unlike the older children, most had not encountered factual information about these topics in school to any great extent. Yet the younger children at the school site had much greater understanding of robots and programming, probably because a special class is offered on this topic at their school

There were two common uncertainties across all age groups:

- Many are unfamiliar with the acronym NASA, and some were not aware of the agency or its mission at all. Most others connected NASA with space, but none of the respondents knew the terms for which the letters stood.
- Some respondents, including both older and younger children, were unclear about whether human beings had traveled to Mars.

One misperception appeared only among younger children, a few of whom appeared to believe there could be aliens on Mars. While older respondents mentioned aliens, they did so in an ironic way or in reference to television or films.

Conclusions and Recommendations

In this section, I am going to focus on what the findings mean for the operation and design of workshops and materials. Conclusions and recommendations encompass how the findings become the basis for action—in this case, the design of engaging through productive workshop experiences for young people from lower-income households and among ethnic communities.

First, respondents across all age groups rated *programming a robot* and *designing a vehicle to explore Mars* at the higher levels of interest. Program designers can use these topics as a "hook" to pique young learners' expectations for an engaging and interesting program. Since these activities are at the heart of the workshop experience, this is good news for the BEAM team. Stressing these topics in the program description for teachers, and designing pre-visit activities focusing on these topics, is recommended. Other focus areas of the program, including several related to the acquisition and application of knowledge, can be integrated into these activities. This strategy should provide relevance and connections to topics with high levels of initial interest among most young people.

Second, respondents in all age groups appeared to have sketchy and disconnected knowledge about several topics, including the place of Mars in the Solar System, the climate and geology of the planets, and NASA and its manned and unmanned missions. For example, young people not only were unsure about the temperature on the surface of Mars but also appeared unaware that the relative distance to the Sun would be connected to the temperature on the surface of a planet. This finding means respondents did not appear to be making connections among areas of knowledge and deeper principles. A teaching-learning practice recommended to help people make deep connections to concepts is reflective practice. I recommend that program designers look for opportunities to include this strategy before, during, and after the workshop experience.

Reflective practice was first used by Schön in 1987 to describe how practitioners build knowledge from their own work experiences. Since then, teachers at all levels of education—and particularly those in practical fields such as medicine and engineering—apply this method to help students construct knowledge. Murphy (2011) provides this definition:

> *Reflective learning is defined as 'a great or deeper degree of processing of material to be learned' (Herod, 2002). Compared to nonreflective learning, where 'material is simply taken in with little or no active thinking or understanding (e.g., memorization), reflective learning engages a large amount of the learner's thinking or cognitive capacities' (Herod, 2002). Reflective learning is engaging in reflection for the goal of producing learning out of the process, and it is the central tool for deriving knowledge formed through the experience.*

As Murphy points out, "For many students, doing swallows up learning. Even staying aware of what we are doing does not itself create learning." Therefore, specific reflective activities need to be built into the program design. Murphy suggests reflective blogs, structured reflective journals, and portfolios. These ideas suggest the creation of an online blog with structured prompts for students to take part in after their experiences. Debriefing discussions after lab experiences are another popular form of reflection.

Yet reflective practice can also be used prior to an experience to help students bring existing knowledge and experiences to mind and make connections among things they already know. Drawings, concept maps, and peer discussions can be used with older children as well as younger children who have more limited writing skills.

Murphy (2011) provides a nice example of reflective practice from her own teaching experience:

> *Suddenly a student calls out, 'Oh, I get it, Ms. Murphy! I just had an aha moment.' The other students stop and look up at her.*
> *'What do you mean by that?' I ask.*
> *'This lab makes so much more sense now. Now I get what it was all about,' she responds. 'Writing this reflection made me realize why planets go faster when they are closer to the sun. It all has to do with more gravity! I mean, I know you told us that before, but I didn't really get it.'*

Yet findings also show some important differences among children of different ages. Younger respondents, as well as a few of the older respondents, had difficulty thinking about their own cognition and behavior to produce sequential, coherent steps in the engineering design process. A strategy used to make learning more productive for learners who have not quite mastered this thinking behavior is call scaffolding. McLeod (2008) characterizes scaffolding as follows:

> *Scaffolding involves helpful, structured interaction between an adult and a child with the aim of helping the child achieve a specific goal. . . . '[Scaffolding] refers to the steps taken to reduce the degrees of freedom in carrying out some task so that the child can concentrate on the difficult skill she is in the process of acquiring.' (Bruner, 1978, p. 19)*

Materials as well as adults can provide scaffolding. Younger students may need to be provided with a step-by-step outline to move through the engineering design process, or experience the steps one by one and then be asked to reflect on what they did. Even older children may need to initially encounter very clearly designed engineering problems as well as devise a simple, clear list of constraints and possible solutions. For example, they may need to be start with the challenge of moving a rover from one point to another and then, after that task is mastered, move on to selecting wheels to move over a rocky surface. Devising solutions for engineering problems with multiple constraints involved may be difficult, however, for younger children.

In articulating how they would design a rover to explore Mars, older children seemed to omit steps involving cognitive activities such as identifying the engineering design problem, identifying constraints, and thinking about and planning before they started to build their rover.

These are the parts of the process where scientific information connects to the engineering design process. Clearly, these steps in the engineering design process are critical to the accomplishing the BEAM workshop and project goals. Based on these findings, the Engineering Design Model used by NASA (Marshall Space Flight Center & Johnson, 2013, June 5) appears well-suited to call attention to these important steps and provide a framework for scaffolding.

BEAM team members may want to brainstorm interesting ways to scaffold young people accomplishing these steps. Ideas could include role plays with the workshop instructor, discussing what he or she wants to learn with one of the student engineers. Short videos of such role plays could be use as pre-workshop activities. In addition, program designs might include using design teams with different roles and providing one-paragraph scripts to help students clearly identify these steps and accomplish these tasks. Finally, some of the exhibits in the planetarium area may provide information that students could be assigned to “collect” and bring back to the team, with clear instructions to use it to identify constraints for the design.

These ideas for scaffolding are general suggestions based on findings. BEAM team members may find stronger scaffolding applications by considering specific design tasks. It is highly recommended that the formative evaluation of programs (study of the effectiveness of initial offerings) explores the degree to which the scaffolding strategies are effective.

These findings indicate that workshops will need to be carefully planned to scaffold the engineering design process, particularly the steps that involve more mental activity and less physical activity, such as identifying the problems and constraints, and conceptualizing the design.

Another set of findings relevant to program design concerns the different levels of knowledge among age groups and overall. Younger children had less knowledge about Mars, the Solar System, and NASA and its missions than did older children. Yet older children’s knowledge, while greater, was not deep or detailed. Pre-visit activities could include directing classes to online resources that let them “Find out what we already know about the Mars landscape your rover will explore.” On site and prior to design activities, using exhibits focusing on the Solar System and orbits to introduce the idea of a time lag may help provide this important context and knowledge base for design.

Respondents across all ages found exploring space and Mars as less important priorities than solving some social issues. In addition, they lack clear reasons as to why it is important to explore Mars—that is, what can be learned and how exploration could benefit human beings. This finding is of real concern because it points the extent to which young people will perceive their learning about Mars, their designing of rovers, and their view of space exploration in general. Relevance is a key element of motivation for learning for people this age.

I strongly recommend the BEAM design team, with the help of advisors, identify three important practical benefits to humans from Mars exploration that would be understandable and relevant to young people. Then finding ways to introduce and stress these benefits throughout the programming needs to be considered. Among respondents in these focus groups, programming robots and designing vehicles are highly attractive activities. The exploration of space appears interesting to them but not compelling, important, and essential. Making this case to younger learners—particularly those from lower-income and minority communities whose immediate focus is on homelessness, curing disease, and violence—may be essential to the success of these workshops.

Finally, respondents did not recognize that people like themselves, particularly in terms of ethnicity, work at NASA on the Mars rover projects. This is clearly a misperception. The Jet Propulsion Laboratory (JPL) website (2014) provided most of the photos for this exercise and showed people of a wide range of ethnicities and many women. Face-to-face visits to the workshops by scientists and engineers need to reflect this type of diversity. In addition, JPL and other NASA connections to the diverse, enthusiastic group of people working on NASA's Journey to Mars need to be mined for online visits, videos of work, and communication with students where ethnicity and gender diversity are apparent. Respondents' perceptions appeared to be unconscious, and repeated exposure to the reality of this diversity is strongly recommended.

Summary

Based on findings in this study, it appears that a one-size-fits- all workshop design is not appropriate for this audience. Children in the younger age range need scaffolding to follow steps of the engineering design process. Even among older students, problem definition and the identification of design constraints will be steps where participants will need help to learn new skills by having examples or explicit problem statements. Students at all age levels may have very wide range of existing knowledge. Workshop design will need to include opening activities to allow the instructor to assess levels of knowledge and understanding on the spot to flexibly adjust to different groups and individuals. If the workshop design tasks are to benefit from being presented in a context of Mars exploration, care needs to be taken to make certain children have an opportunity to learn about this context. The exhibits surrounding the workshop area, as well as pre-visit experience such as NASA videos, can help provide this knowledge and context.

Finally, these conclusions and recommendations are mine as the evaluator. BEAM team members are invited to review the findings and connect them to their own experiences as designers and informal educators. They are also invited to draw alternate conclusions and to raise questions related to these findings at later points in the evaluation. By reflecting on these findings and conclusions, I hope these findings can be put to work, along with the ideas and creativity of the team, in designing experiences that connect with lower-income and minority youth as well other young people throughout the St. Louis community.

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Appendix A: Focus Group Script

BEAM
Front-end Program Evaluation
Focus Group Script

Room Set Up: Table near the door for sign-in sheets, name tags, and table tents.
During the focus group the researcher will sit at the table with a computer and the projector for the PowerPoint.

Timeframe: The will arrive at 45 minutes to check room setup and equipment. The researcher will greet parents and children. At sites such as the Monsanto YMCA, where Informed Consent and Assent have not been obtained prior to the day of the focus groups, she will explain research and ask for Informed Consent from parents/guardians and Assent forms from children. Parents/guardians who wish to observe will be welcomed and seated at the back of the room. Children will asked to sit at the table, and they be given paper and markers to design a table tent while others arrive.

Introduction
Thank you for being here. My name is Carey Tisdal, and I do studies with people like you to help museum and science centers make good decisions. You were invited to tell me how interested you are and share your ideas about some topics related to space exploration. The Saint Louis Science Center (SLSC) is building some new exhibits and planning new programs about space exploration. Some of the programs will be offered as field trips for schools like yours or for [name of Community Partner Organization]. I want you to know you are not expected to know everything about the topics—and you may not even be interested in them. There are no right or wrong answers in this focus group as long as you tell me what YOU think. That why you are here this afternoon—so I can better understand your interests and ideas. This isn't like school—if you don't know something, that is very helpful. People planning the programs need to know what ideas kids like you have about these topics to make the program better.

Just a little more information about me. I am not a staff member at SLSC. They arranged with me to collect information to help make good decisions in designing the program. I will write a report, but I won't use your name when talking about what you say. But some members of the team and some parents/guardians are listening in to hear what you have to say this afternoon. (Slide 1 of project is not used on the title slide to prevent cueing subsequent responses.)

I will be taking notes, but I am also going to audio record so I can remember your answers. I'm going to turn on the audio recorder.

Here are some rules of the road that will help me make sure to record and understand what you say:
+ I would like to ask that only one person talks at a time —please wait until the person is finished before you talk—that way we get everyone's answer on the audio recorder.
+Everyone's answers are good ones, listen respectfully—and we will take turns answering.

Finally, you'll notice markers and papers around the table. At some points tonight, I'll be asking you to mark something, draw on something, and then share what you did. Please put your first name on items—I won't use your name in any report, but it really will help me match up what you do with your explanations. Thanks for your help on that!

Do you have any questions before we start?

Establish Rapport and Response Set

1. (Slide 2) Just to get started, let's go around the circle. Please tell me your name, what grade you are going to be in next year, and the name of your favorite movie and why you like it. X, let's start with you. [Go sequentially around the group to establish longer answers and everyone contributing.)
2. How many of you have been to the SLSC? Show of hands? [Say names aloud for observers and recording.]

Big Ideas

3. (Slide 3) You have a set of papers in from of you. Use the markers on the table and on the top sheet, I want you to draw me a picture about *Exploring Space*. Please write your name first. [three to five minutes for drawing]

4. So, let's go around the circle again. This time we'll start with Y.
   Probes:
   - Are there people in your picture? Who are they?
   - If so, where are they doing? [Probe if they are traveling: Where are they going? Where?)
   - What are the ways you drew to explore space?
   - Tell me about who people work for who explore space?
   - Are there any names you can think of for the jobs they do?

How Interesting?

5. The Science Center wants to know how interested you are in some different things you might find out more about or DO in this program. Look at the slide—here's how you will tell me. Sometimes people use thumbs up and thumb down signs to say how much they like something. For example, ice cream, would you rate that thumbs up or thumbs down? [Wait for responses.)

(Slide 4) On the second page of your handout, I am going to ask you to draw a circle around the thumb that best describes how interested you are in a topic. [Read the four options aloud.) See the face at the end? That means you are not familiar enough with the topic to tell me how interested you are. For example, if someone asked me to tell them how interested seeing a movie I had never heard of, I would circle the face.

So, let's get started. How interested are you in . . . (Slide 5)

Finding out more about Exploring Space
Finding out more about Mars
Finding out more about NASA
Finding out more about the jobs people do who explore space
Designing a vehicle to explore Mars
Learning to program a robot

6. Let's go around the circle again. Tell me which of these things you were most interested in? What were things you were least interested in?

7. Next, I am going to show you a picture, and we're going to talk about it.

   What do you see in this picture? (Slide 6)
   Probes:
   - What is the big red object?
   - What are the smaller objects called?
   - Why are those curved lines in the picture? What do they mean?

8. Which of the planets is this? (Show Slide 7)
   Probes:
   - How do you know it is *[name of planet they say]*?
   - What's important about this planet?
   - What kind of things can you tell about this planet from looking at the photo?

9. What planet is this? (Show Slide 8)
   Probes:
   - How do you know it is *[name of planet they say]*?
   - What do you think it might be like on the surface of this planet?

10. [Set the Solar System model in the middle of the table.] (Slide 9) Here is a model of the Solar System. Notice that these planets are **NOT** all lined up like in the drawing we saw. Why do think that might be?

Probes:

- What's an orbit?
- Do all the planets take the same length of time to orbit around the sun?

Exploring Mars (Slide10)

11. Right now, is anyone exploring Mars? Who? (Probe for NASA)
12. If so, what types of things are these people trying to find out?
13. What are some of the ways that people can study Mars?
    Probes:
    - What tools do they use?
    - How do they get those tools to Mars?

14. (Slide 11) So tell me, how important do you think it is to explore Mars?
    Probes:
    - What would be some useful things we could find out?
    - Are there any reasons people shouldn't explore Mars? What do you think?

Designing a Rover

15. (Slide 12) Here is a vehicle NASA uses to explore Mars. What is it called? [If no one knows, call it a rover.)

16. How do you think the rover knows how and where to move on Mars?

17. A car uses gas for power. Some newer cars use electricity. How is the rover powered?

18. What are some of the challenges in planning and building a rover to explore Mars? [Follow up and probe: Listen for a follow-up on terrain, climate, distance in communicating, time lag.)

19. I want you to imagine that you are designing or planning a rover to explore Mars. (Slide 13)
    [Two older groups) Tell me about HOW you would go about planning and putting together a rover to Explore Mars. What steps would they go through? Use the sheet provided.
    [Younger Group) Tell me about HOW you would go about planning and putting together a Rover to Explore Mars.
    - What would the first step be?
    - What would the next step be?

20. How would you know that you had a good design?

Programming

21. (Slide 14) If you heard on TV a person from NASA say, “NASA scientists have observed an interesting rock near the rover on Mars, and they are working on a program to have the rover look at it more closely.”” What would the scientists on Earth DO to move the Rover closer to the rock?

One way NASA scientists tell the rovers what to do is by sending them instructions in a radio signal. This is similar to how information gets sent from one person to another on a cell phone.

22. If someone talks to you on a cell phone, how long does it take for that information to get from the person talking to you?
23. So if a NASA scientist sent a radio signal to tell a rover on Mars what to do, how long do you think it would take to get there? [Probe: What is the difference?)

24. Is a rover a robot? What do you think?

Engineers and Jobs and NASA

25. What do we call the jobs of the people who plan and build a rover?

26. I am going to show you a set of pictures. There will be four people on each page. I am going to ask you to “guess” which of the people on the page work for NASA in designing Mars rovers. All **four may work for NASA** on a page or **NONE** of them. I want you to write down on your response sheets which of the people you think work for. Don’t say them aloud because we want everyone to just answer for themselves. I am going to show them to you quickly. Ready to guess?

    Follow up: Who did you pick? Why?

Wrap Up

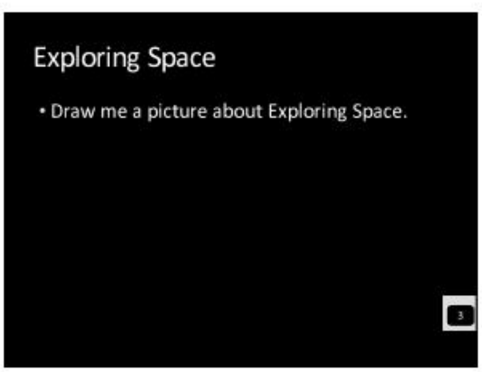
27. You have seen many of the topics and ideas that people planning this program are thinking about. What did you hear about that you thought was the MOST interesting, and would make you want to come to this program on a school field trip?

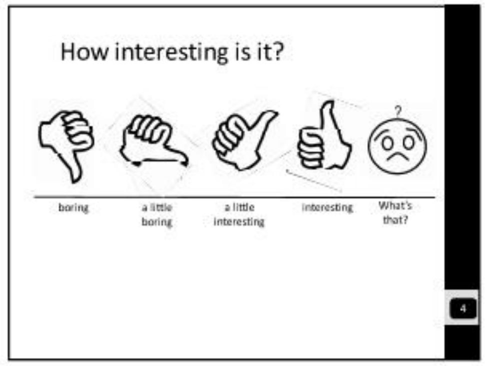
Observers

28. I have been asking questions all afternoon. While I’ve been doing that, our observers have heard some things they’d like to hear more about. They wrote them on cards so I can follow up with you. Let’s see what they want to hear more about.

Close--Thank you for your time

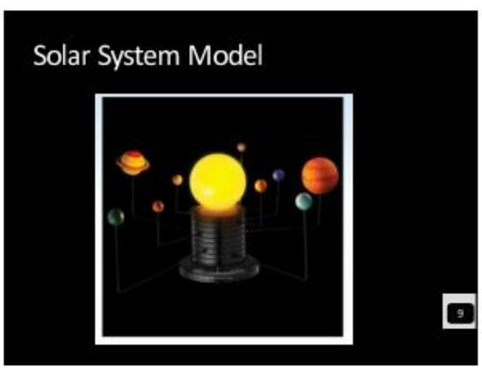
Appendix B: Focus Group PowerPoint






What planet is this?
7


Which planet?
8

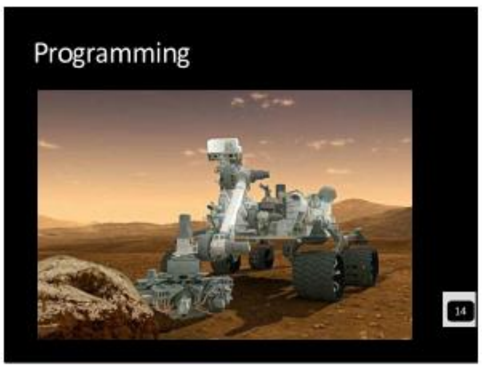

Solar System Model
9

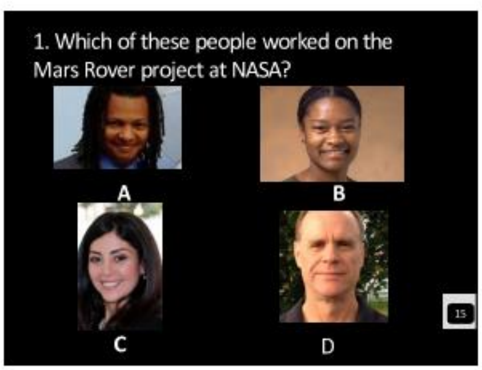

Exploring Mars
10


Mars Exploration
• Why explore Mars?
11


Exploring Mars
12


What steps would someone go through to plan and build a Rover to Explore Mars?
• STEP ONE
• STEP TWO
• STEP THREE
• STEP FOUR (as many as you need)
13

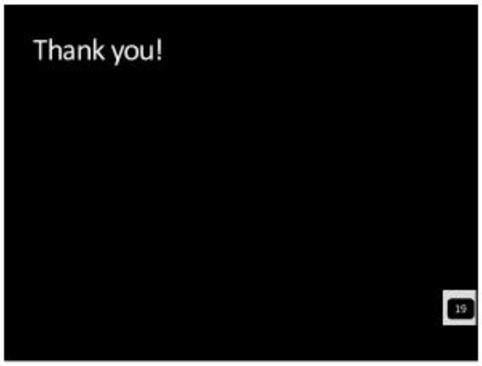

Programming
14


1. Which of these people worked on the Mars Rover project at NASA?
A
B
C
D
15

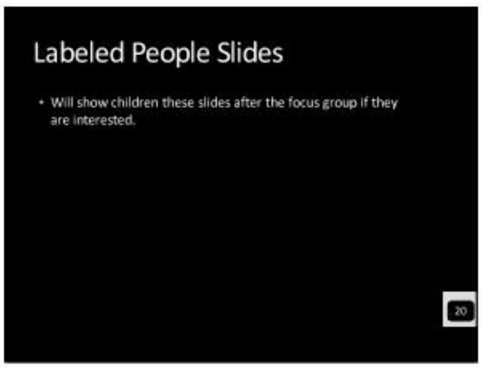

2. Which of these people worked on the Mars Rover project at NASA?
A
B
C
D
16


3. Which of these people worked on the Mars Rover project at NASA?
A
B
C
D
17


4. Which of these people worked on the Mars Rover project at NASA?
A
B
C
D
18



Thank you!
19



Labeled People Slides
• Will show children these slides after the focus group if they are interested.
20

1. Which of these people worked on the Mars Rover project at NASA?
Astrodynamics Team Lead
Systems Engineer
Surface Sampling System Activity Lead (SSS AL)
Chairman, Division of Sciences
21

2. Which of these people worked on the Mars Rover project at NASA?
Engineer but not at NASA
Computer Engineer
Mission Manager
Thermal Engineer
22

3. Which of these people worked on the Mars Rover project at NASA?
PhD Candidate
Tactical Uplink Lead
Staff Mechanical Engineer
Model
23

4. Which of these people worked on the Mars Rover project at NASA?
Database Administrator
Senior Robotics Engineer
MSL Chief Engineer
Systems Engineer
24

Appendix C: Response Forms

Exploring Space

Draw a picture

Name________________

How interested are you in . . . ?

1. Finding out more about Exploring Space

boring	a little boring	a little interesting	interesting	don't know

2. Finding out more about Mars

boring	a little boring	a little interesting	interesting	don't know

3. Finding out more about NASA

boring	a little boring	a little interesting	interesting	don't know

4. Finding out more about <u>the jobs people do</u> to explore space

boring	a little boring	a little interesting	interesting	don't know

5. Designing a vehicle to explore Mars

boring	a little boring	a little interesting	interesting	don't know

6. Learning how to program a robot

boring	a little boring	a little interesting	interesting	don't know

What steps would someone go through to plan to build a rover to Explore Mars?

Step One: ____

____

Step Two: ____

____

Step Three: ____

____

Step Four: ____

____

Step Five: ____

____

Step Six: ____

____

Step Seven:____

1. Which of these people worked on the Mars Rover project at NASA? (Circle to answer)

   A

   B

   C

   D
2. Which of these people worked on the Mars Rover project at NASA? (Circle to answer)

   A

   B

   C

   D
3. Which of these people worked on the Mars Rover project at NASA? (Circle to answer)

   A

   B

   C

   D
4. Which of these people worked on the Mars Rover project at NASA? (Circle to answer)

   A

   B

   C

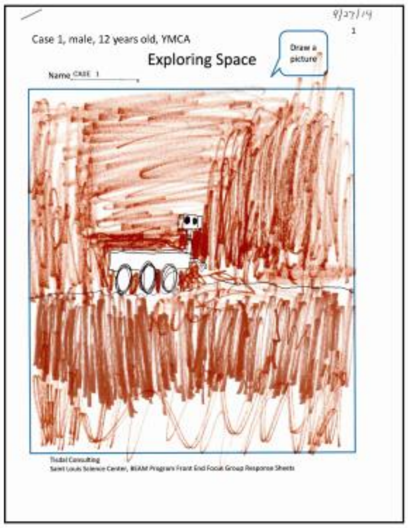
   D

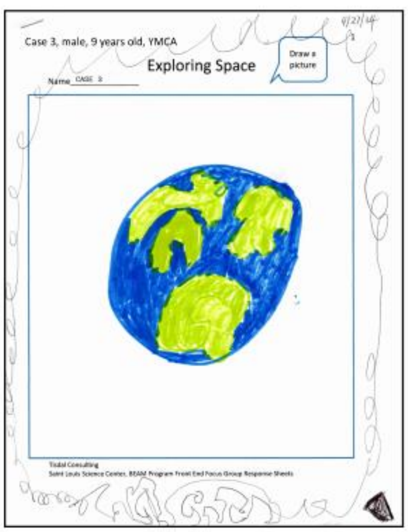
Appendix D. Data Source Table

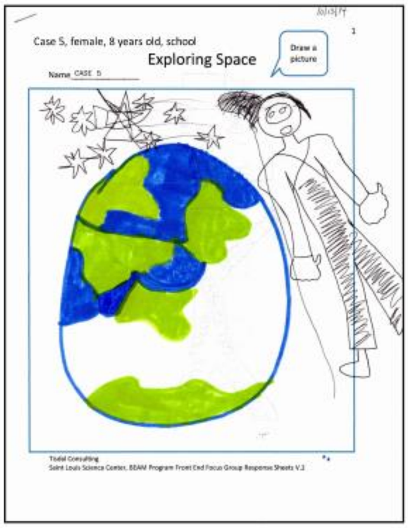
Table D1. Data Source Table

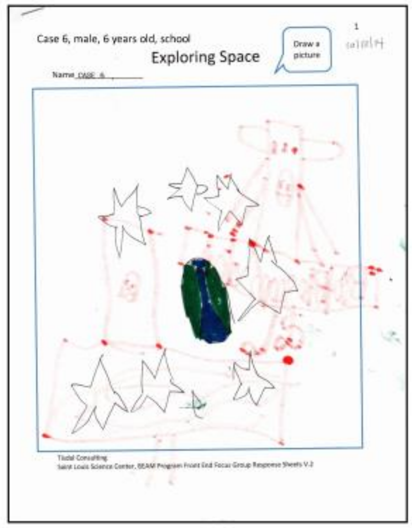
CASES	FOCUS GROUP DATE	GENDER	AGE	GRADE	ETHNICITY	FOCUS GROUP SITE
CASE 1	September 27, 2014	1	12	6	AA	YMCA
CASE 2	September 27, 2014	1	8	3	AA	YMCA
CASE 3	September 27, 2014	1	9	4	AA	YMCA
CASE 4	October 13, 2014	2	6	1	AA	School
CASE 5	October 13, 2014	2	8	2	AA	School
CASE 6	October 13, 2014	1	6	1	AA	School
CASE 7	October 13, 2014	2	7	2	AA	School
CASE 8	October 13, 2014	2	6	1	W	School
CASE 9	October 13, 2014	2	6	1	AA	School
CASE 10	October 25, 2014	2	12	7	AA	YMCA
CASE 11	October 25, 2014	2	13	7	AA	YMCA
CASE 12	October 25, 2014	2	13	7	AA	YMCA
CASE 13	October 25, 2014	2	14	8	AA	YMCA
CASE 14	October 25, 2014	2	14	8	AA	YMCA
CASE 15	October 25, 2014	2	13	7	AA	YMCA
CASE 16	October 25, 2014	2	14	9	AA	YMCA
CASE 17	October 25, 2014	1	11	6	AA	School
CASE 18	October 25, 2014	1	10	4	AA	School
CASE 19	October 25, 2014	2	11	5	W	School
CASE 20	October 25, 2014	1	9	3	AA	School
CASE 21	October 25, 2014	1	10	5	AA	School

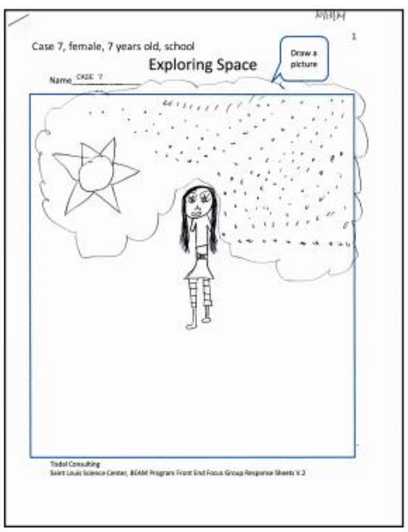
Appendix E: Exploring Space Drawings

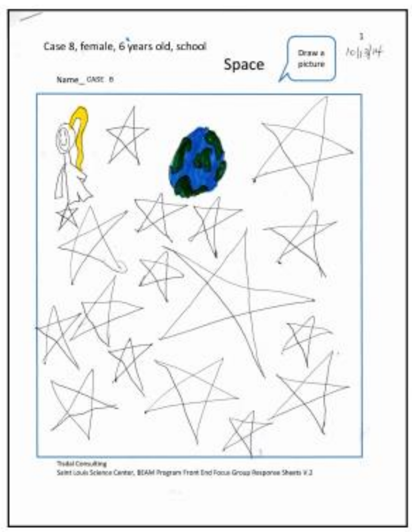


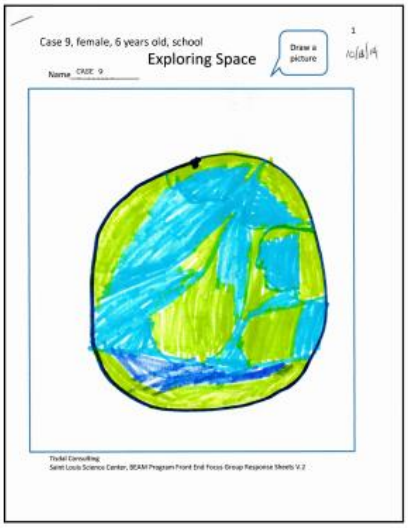



Case 5, female, 8 years old, school
Exploring Space
Draw a picture
Name CASE 5


Case 6, male, 6 years old, school
Exploring Space
Draw a picture
Name CASE 6

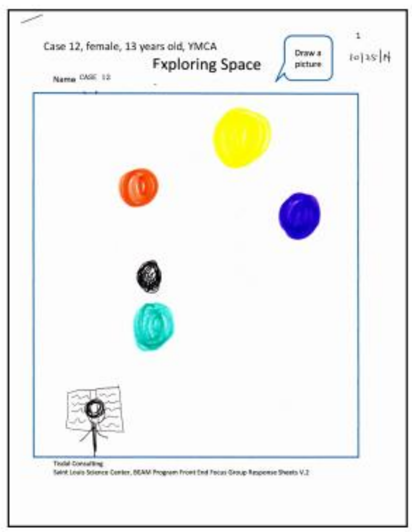

Case 7, female, 7 years old, school
Exploring Space
Draw a picture
Name CASE 7

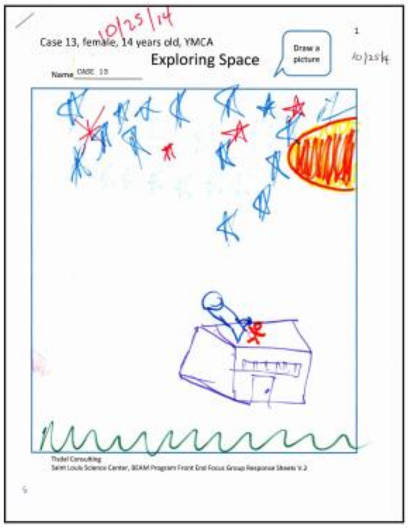

Case 8, female, 6 years old, school
Space
Draw a picture
Name CASE 8


Case 9, female, 6 years old, school
Exploring Space
Draw a picture
Name CASE 9
Tisdal Consulting
Saint Louis Science Center, BEAM Program Front End Focus Group Response Sheets V.2


Case 10, female, 12 years old, YMCA
Exploring Space
Draw a picture
Name CASE 10
Tisdal Consulting
Saint Louis Science Center, BEAM Program Front End Focus Group Response Sheets V.2


Case 11, female, 13 years old, YMCA
Exploring Space
Draw a picture
Name CASE 11
Tisdal Consulting
Saint Louis Science Center, BEAM Program Front End Focus Group Response Sheets V.2

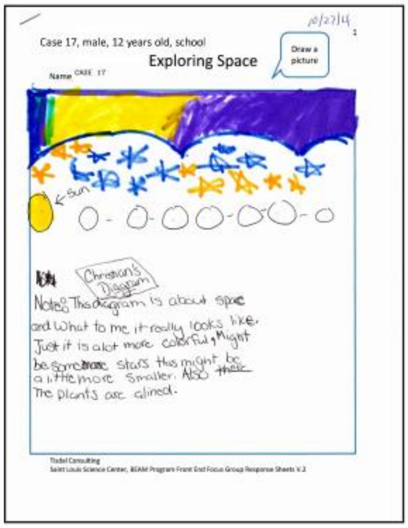

Case 12, female, 13 years old, YMCA
Exploring Space
Draw a picture
Name CASE 12
Tisdal Consulting
Saint Louis Science Center, BEAM Program Front End Focus Group Response Sheets V.2


10/25/14
Case 13, female, 14 years old, YMCA
Exploring Space
Draw a picture
1
Name CASE 13
Tisdal Consulting
Saint Louis Science Center, BEAM Program Front End Focus Group Response Sheets V.2


10/25/14
Case 14, female, 14 years old
Exploring Space
Draw a picture
1
Name CASE 14
Tisdal Consulting
Saint Louis Science Center, BEAM Program Front End Focus Group Response Sheets V.2


Case 15, female, 13 years old, YMCA
Exploring Space
Draw a picture
1
Name CASE 15
Tisdal Consulting
Saint Louis Science Center, BEAM Program Front End Focus Group Response Sheets V.2


Case 16, female, 14 years old, YMCA
Exploring Space
Draw a picture
1
10/25/14
Name CASE 16
Tisdal Consulting
Saint Louis Science Center, BEAM Program Front End Focus Group Response Sheets V.2


10/27/14
1
Case 17, male, 12 years old, school
Exploring Space
Draw a picture
Name CASE 17
← Sun
Christian's Diagram
Note: This diagram is about space and What to me it really looks like. Just it is alot more colorful, Might be some stars this might be a little more Smaller. Also ~~their~~ The plants are alined.
Tisdal Consulting
Saint Louis Science Center, BEAM Program Front End Focus Group Response Sheets V.2


10/27/14
1
Case 18, female, 10 years old
Exploring Space
Draw a picture
Name CASE 18
Sun
Stars.
Milky Way
EARTh
Rocket Ship
Jupiter
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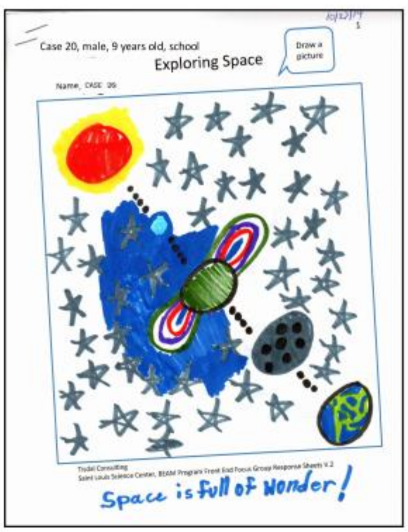
Case 20, male, 9 years old, school
Exploring Space
Draw a picture
Name CASE 20
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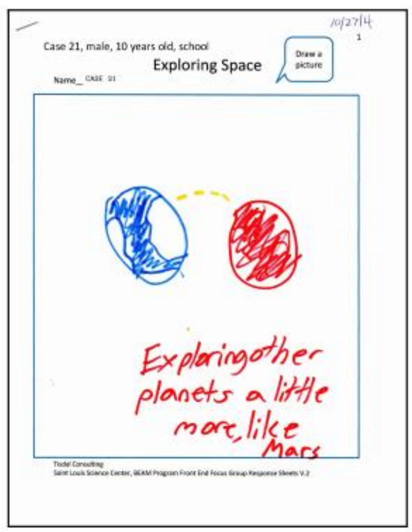
Space is full of Wonder!


10/27/14
1
Case 21, male, 10 years old, school
Exploring Space
Draw a picture
Name CASE 21
Exploring other planets a little more, like Mars
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Appendix F: Engineering Design Steps with Codes

CASE	GENDER	AGE	STEP1	STEP2	STEP3	STEP4	STEP5	STEP6	STEP7	Logical Sequence	Identify Problem/ Constraints	Conceptualize	Research	Plan–Design	Build	Test	Programming
CASE 1	**1**	**12**	Hire someone	Design	Collect	Build	Send To Mars	Explore		1	0	0	1	1	1	0	0
CASE 2	**1**	**8**	Make robot with iron.	Design the head.	Make the body.	My rover would be done.				0	0	0	0	1	1	0	0
CASE 3	**1**	**9**	Think	Draw	Blue print	Build	Make satlige [?] plate	Send to a planet	Explore the planet	1	0	1	0	1	1	0	0
CASE 10	**2**	**12**	Think on what I want to build	Then learn or search about it	Draw what I think I want to make	Do a rough draft/ program it	Revise or change anything I need or want to	Build it.		1	0	1	1	1	1	1	1
CASE 11	**2**	**13**	Decide on design and materials	Hire people to help.	Start constructio n. Finish construc-tion.	Make it presentabl e. Perfect it.	Program it to do its job.	Make/ create a way to send it to planet.	Send it to do research about planet.	0	1	0	0	1	1	1	1

CASE	GENDER	AGE	STEP1	STEP2	STEP3	STEP4	STEP5	STEP6	STEP7	Logical Sequence	Identify Problem/ Constraints	Conceptualize	Research	Plan–Design	Build	Test	Programming
CASE 12	**2**	**13**	To find out how a rover would get a connection from Earth to Mars	How would we get the rover to Mars?	How would the rover be shaped?	What would it be made of?	What elements could be part of it?	What color should it be?	How would I program it to do what I want it to do?	0	1	1	1	1	0	1	1
CASE 13	**2**	**14**	Create blue print	Invent your prototype	Take it out.	Take it to space.	Keep trying to rebuild it if it stops working or messes up.	Be creative.	Make sure it is all good.	1	0		0	1	1	1	0
CASE 14	**2**	**14**	Think of a plan	Sketch design it	Test it	Fix mistakes	Do a final plan	Find way to get it to Mars	Send it to Mars.	1	0	1	0	1	0	1	0
CASE 15	**2**	**13**	Thinking like what type of structure do I want	Sketch it out	Start building it	Get cameras	Find a way to get a connection	Find a way to get it up to Mars		1	1	1	0	1	1	0	0
CASE 16	**2**	**14**	Have people explore Mars	Think about some things you would like to see	Make a blueprint of what you want it to look like	Get the materials	Make the rover	Name it	Send it to Mars	0	1	1	0	1	1	0	0
TOTAL										6	4	6	3	10	8	5	3

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