Effective Engineering Activities for Out-of-School Time (research to practice)

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Introduction: Why Engineering in OST?

In recent years, interest in the use of science, technology, engineering, and mathematics (STEM) programming in out-of-school time (OST) settings, such as afterschool and camp programs, has grown rapidly. OST stakeholder organizations such as the National Afterschool Association, the Afterschool Alliance, and the Coalition for Science Afterschool have publicly expressed a need for quality STEM activities to be incorporated into OST programming. The National Afterschool Association website underscores this idea, stating: "Considering how science impacts our nation's strategic interests and security, we encourage our members and stakeholders to join forces with school personnel to increase the capacity of afterschool professionals to deliver instruction and engage learners in high quality STEM activities."[i]

At the same time that national OST organizations are calling for increased STEM presence, many OST educators are also expressing excitement about the types of hands-on, creative opportunities afforded by STEM programming; particularly by engineering. This concurrent top-down and bottom-up support provides a strong foundation for introducing engineering activities in afterschool and camp settings.

The increased interest around STEM programming in OST calls attention to the lack of high-quality engineering curricula designed specifically for OST settings. While many engineering activities are posted online or published as activity packets, there are few OST engineering units intended to provide comprehensive, thoughtfully sequenced engineering experiences for young children. To address this need in a way appropriate for OST settings and educators, the Engineering is Elementary Program at the Museum of Science, Boston, began development of Engineering Adventures (EA) in 2010. The main goal of the curriculum is to positively impact the attitudes of children (grades 3-5) about their ability to engineer by providing curricular materials uniquely appropriate for varied out-of-school time settings. This paper will discuss the development and evaluation of Engineering Adventures units, particularly *Bubble Bonanza: Engineering Bubble Wands* and *Hop to It: Safe Removal of Invasive Species*. Both units have gone through many rounds of testing and revision and are now publicly available to download free of charge on the Engineering is Elementary website. The development and evaluation of the units' effectiveness improving children's attitudes and understandings about engineering led to key findings that will inform future EA units, but can also inform other out-of-school time STEM activities.

The dearth of curricula similar to Engineering Adventures may stem from the challenges inherent in developing activities that meet the needs of diverse OST programs. Sites vary in programmatic focus, location, facilities, schedule, and almost every other characteristic. The same children do not necessarily attend every day, and their background knowledge likely differs due to mixed grade level groups being populated by children from different schools or even different districts. Common ground among programs can usually be found, however, around the skills OST programs value and work to foster in children. Many OST programs emphasize the importance of critical thinking, communication, collaboration, and creativity, the types of skills that help children grow into productive, thoughtful adults regardless of their eventual career path. Fortunately, these same 21st century skills valued by many OST programs are also important engineering practices. Engineers need to think critically about problems and possible solutions;

communicate with colleagues and the public; collaborate with other engineers, scientists, and even artists; and be creative enough to think innovatively when approaching problems. In this regard, engineering fits naturally into OST programs, and can be introduced to OST educators in a way that capitalizes on their pedagogical strengths.

Beyond providing a good match for the 21st century skills valued in OST, the introduction of effective engineering curricula provides important opportunities to address the paucity of underrepresented minorities in STEM fields. According to the U.S. Census Bureau, approximately 36% of the population reports as a non-white minority.[ii] While the number of minority scientists and engineers has grown slightly in the past two decades, percentages of minorities in STEM remain low. In 1993, 16% of scientists and engineers self-reported as minorities, and only 28% in 2007.[iii] These statistics point clearly towards the need to encourage more minority youth to consider STEM careers. The racially diverse population served by OST programs provides an opportunity to reach groups often underrepresented in engineering. Across the country, more than 40% of afterschool programs serve a majority of minority youth. Data from a 2009 study conducted by the Afterschool Alliance shows that approximately 15% of the national school-aged population participates in afterschool programs. [iv] In comparison, 25% of Asian, 24% of African American, 21% of Hispanic, and 16% of Native American children attend afterschool programs. Thus, including engineering curricula in OST programs helps to introduce new demographic groups to engineering practices, skills, and career opportunities.

What Can Successful Engineering in OST Look Like?

Before delving into the details of OST engineering curriculum development and evaluation, it is useful to envision what successful engineering activities can look like in OST. The fifth grade engineers at the out-of-school time program Girls Inc., provide a window on the possibilities. The girls participated in the *Bubble Bonanza* unit. After being introduced to the engineering design process (EDP), the steps engineers use to help them solve problems, the girls experimented with materials. Then they had the chance to engineer their own bubble wands. As part of the culminating showcase activity, the young engineers stood at the front of the room and a crowd of girls sat on the floor before them. They were waiting for the Bubble Bonanza—a bubble show put on by the engineers who have just finished designing their very own bubble wands.

Educator Linda Hill holds up a sign that says “I am an engineer because…” and asks the fifth graders, “Why are you engineers?” “We made bubble makers,” volunteers Tanisha. “We asked questions,” adds Jaslene. “Imagined,” says Amanda. The girls are naming the steps of the engineering design process they focused on as they engineered their bubble wands. Other girls add “plan” and “improve.” “What was the most important part for us?” asks Linda. “Create!” the girls cheer.

Linda explains to the audience that over the past several weeks, each girl chose a goal for their bubble wands, deciding what type of bubble (tiny, giant, double, etc.) they would engineer each wand to make. They conducted experiments to learn what bubbles can and cannot do, and conducted testing to learn more about materials they could use in their final bubble wand design. As the Rihanna song the girls chose for background music plays, they demonstrate the range of wands they designed. The crowd “oohs” and claps as the first giant bubble is released (figure 1).

Figure 1. A bubble show at Girls Inc. in Lynn, MA

Critical Components

As evinced by the *Bubble Bonanza* show at Girls Inc., successful engineering curricula for OST empowers kids to feel that they are engineers and guides them to effectively use the engineering design process as a tool. Perhaps most importantly, successful OST engineering activities are fun and engaging for the participants. Development of the first EA units led to the creation of critical beliefs and learning goals about effective engineering materials for OST (Table 1). All Engineering Adventures units are developed, and then later evaluated, based on these criteria.

Table 1. Design Beliefs and Learning Goals

We believe kids will best learn engineering when they:	Kids will learn that:
engage in activities that are fun, exciting, and connect to the world in which they live.	they can use the Engineering Design Process to help solve problems.
choose their path through open-ended challenges that have multiple solutions.	engineers design technologies to help people and solve problems.
have the opportunity to succeed in engineering challenges.	they have talent and potential for designing and improving technologies.
communicate and collaborate in innovative, active, problem solving.	they, too, can be engineers.

The bubble show described at Girls Inc. provides qualitative evidence supporting several of the learning and attitudinal goals developed by the Engineering Adventures team. Participants were able to identify as engineers and to share the steps of the engineering design process they used to help them design technologies, for example. The formal assessment of outcomes in OST, particularly outcomes related to STEM programming, is a fairly new notion. As stated by the Afterschool Alliance in a recent brief, “the research base behind the answers to key questions

like whether, how and under what conditions after-school programs can lead to specific youth outcomes remains thin."[v]

A recent study conducted in Chicago OST settings presents findings related to content impacts and provides insight that can be used to inform future programmatic development. The study analyzed programming resulting in positive academic and socio-emotional outcomes in OST. This study showed that both academic and social/emotional outcomes improved when programs employed "SAFE" activities: Sequential activities that encourage Active youth involvement, are Focused, and have Explicit learning objectives.[vi]

In order to further codify beliefs about teaching STEM in afterschool, the Afterschool Alliance recently proposed a list of developmental outcomes that include: youth develop interest in STEM and STEM learning activities, youth develop capacities to productively engage in STEM learning activities, and youth come to value the goals of STEM and STEM learning activities.[vii] These outcomes closely align with the design beliefs previously articulated by Engineering Adventures. The Alliance further recommends that assessment tools be mapped to these outcomes, or, if needed, new tools developed to assess these outcomes.

The *Bubble Bonanza* unit described above, as well as all other Engineering Adventures units, adhere to these SAFE criteria and the developmental outcomes put forth by the Afterschool Alliance. EA units include 6-10 activities sequenced in a way that allows children to build upon discoveries made in previous sessions. All activities encourage active, hands-on experimentation and engineering. The curriculum developers have found it is particularly important in OST to structure the activities so that children are able to begin touching and interacting with the materials as quickly as possible. Introductory discussion related to an activity is kept to a minimum—five minutes or less. Additionally, all activities are written so that the steps of the engineering design process and the engineering goal are repeated over and over, making children's roles as engineers explicit.

Through preliminary evaluation of EA units, the Engineering Adventures team has seen strong evidence that creating curriculum using our stated design beliefs in can achieve the learning outcomes discussed above. Further, the assessment instruments developed by the EA team (which will be discussed in later sections of this paper) provide ways to evaluate these outcomes.

Unit Development

The process of developing the first several EA units involved multiple revisions based on evaluation data. During this process, important lessons were learned and some large-scale curriculum design principles for OST emerged. The *Bubble Bonanza* unit is used as an example, along with *Hop to It*. This unit introduces children to the problems caused by the invasive cane toads of Australia, and asks them to design a humane trap to catch the toads.

In creating these first units, the curriculum development team drew heavily from the inclusive design principles and structures found to be successful for engineering curricula used in elementary schools. These include ideas such as setting learning in a real-world context, engaging students in active, hands-on, inquiry-based engineering, scaffolding student work, and presenting challenges authentic to engineering practice.[viii] Early testing of EA units showed that

a focus on inquiry, the engineering design process, and hands-on activities remained important in OST. Testing also revealed several key principles unique to OST settings, many echoing the importance of the SAFE (sequenced, active, focused, and explicit) qualities identified by the Chicago study. The principles described below are included in all Engineering Adventures units, and are applicable to other STEM activities that might be created for the out-of-school time environment.

The EA developers have found that any science-focused activities included in the engineering unit must be clearly linked to the culminating engineering challenge. Early EA units included several science activities intended to provide children with background information that would inform their designs. Testing quickly showed these lessons were confusing for both children and educators. In *Hop to It*, for example, first iterations of the unit included simulation games modeling impacts of invasive species. While understanding the negative results of invasive species can be a motivating factor for engineering a successful trap, children and educators found the specific science information related to impacts on food and habitat was overwhelming. Children and educators expressed difficulty understanding why the lessons were included. Rather than removing all science experimentation from the units, the developers tested, and have found success, creating science explorations that are clearly and concretely tied to the culminating engineering challenge. The *Hop to It* unit was changed so that a short video outlined some of the negative impacts of invasive cane toads and reinforced how the engineering design process could be used to engineer traps to stop the toads. The science simulation games were replaced with activity sessions allowing children to manipulate and experiment with the materials available for them to use in their trap designs. Children and educators were still engaging in science practices, but in a way that more directly supported the engineering challenge.

Curriculum developers also found that activities must be structured to quickly allow children to engage with materials. Introduction and discussion prior to beginning the hands-on portion of the activity should be no more than five minutes. During hands-on work, kids should be given parameters to guide their explorations, but should have a degree of autonomy over what they are investigating. In the *Bubble Bonanza* unit, this structured freedom was accomplished by creating Challenge of the Day cards. An example challenge might be: “Can you find out if the shape of a bubble wand affects the shape of the bubble it makes?” Posting these cards reminds participants (and educators) what they should be focusing on for the day, while leaving a great deal of latitude about how to complete the challenge. Supporting participant autonomy is advantageous for the educator, as well, since the onus for directing the lesson is refocused, allowing them to support (rather than direct) children as they investigate. This supportive role is one that most OST educators are already comfortable with.

The engineering design process is a central part of the Engineering Adventures curriculum. The critical thinking strategies and iterative problem solving reinforced by the EDP mesh well with the types of social and 21st century skills often emphasized in OST, making the process particularly appropriate for this setting. First drafts of units used the EDP as a backdrop and directed educators and kids to return to the EDP during reflection portions of each activity. This passive use of the EDP was not particularly effective. More recent versions of units employ the EDP in nearly all sections of a given activity, including the kick-off audio message from the Duo—a brother and sister pair who introduce each adventure. In the *Hop to It* unit, the video used to set the context for the problem presented in the unit also reinforces the engineering

design process steps. Repetition of the EDP has proven to help underscore the importance and utility of the process with children and educators.

Testing also revealed that engineering vocabulary words needed to be introduced clearly and consistently. Early versions of EA units used the verb “design” nearly interchangeably with “engineer.” Introducing more than one new vocabulary word per activity confused children and in some cases barred them from fully engaging with the content. Developers made the choice to highlight the terms “engineer” and “engineering design process” over all other vocabulary in each unit. In *Bubble Bonanza* and *Hop to It* these terms are now woven throughout all activities within a unit, encouraging use of these terms as a matter of course. Observations have indicated that this helps both educators and children deepen their understanding of the words and to become more comfortable using them.

Evaluation Methods

As the Engineering Adventures curriculum is still in development, formative evaluation has been the main focus of assessment efforts. Reliable evaluation instruments for use in OST, particularly quantitative measures around STEM, are difficult to find. For this reason, the EA team has developed and tested several original instruments, for use with both educators and children. Just as EA units have gone through several iterations, so have the evaluation tools that have been created to assess unit goals. These tools are detailed below along with analysis of their level of success.

Engineering Attitudes Survey

The Engineering Attitudes survey is a quantitative instrument used to gauge the success of two of EA’s goals: that children will learn about engineering and learn that they, too, can be engineers. Adapted from an assessment commonly used by the Engineering is Elementary program, this short survey is administered to children both before and after participation in any Engineering Adventures unit. Children are asked to rate their level of agreement with 12 statements (Table 2). The post-survey also includes a short open-ended prompt where children are asked to write about their favorite and least favorite parts of the unit.

Table 2. Engineering Attitudes Survey Statements

#	Statement
1	I would enjoy being a scientist when I grow up.
2	I would enjoy being an engineer when I grow up.
3	I would like a job where I could invent things.
4	I would like to help plan bridges, skyscrapers, and tunnels.
5	I would like a job that lets me design cars.
6	I would like to build and test machines that could help people walk.
7	I would enjoy a job helping to make new medicines.
8	I would enjoy a job helping to protect the environment.

9	I would like a job that lets me figure out how things work.
10	I like thinking of new and better ways of doing things.
11	I like knowing how things work.
12	Engineers help make people's lives better as part of their job.

This survey has been successfully translated into the OST setting. Care and attention were paid to ensure the survey did not contain too many items. Because the survey statements are short, an educator or child participant can easily read them aloud to the group, helping to ensure that reading level does not become a barrier. The open-ended question at the end of the post-survey asking about favorite and least favorite parts of a unit has also been an important tool allowing curriculum developers to hear directly from the children participating in the programs.

Content Assessments

Content assessments unique to each Engineering Adventures unit are administered after the unit has been completed. The content questions are often open-ended and are intended to access children's engineering and technology knowledge and confidence, as well as their interest in future participation in Engineering Adventures.

In order to address understanding of technology, children are asked to select which of 8 items (such as bird, bicycle, video game controller) are examples of technologies. To assess understanding of the engineering design process, children might be asked to give an example of how they used a certain step of the process. End of unit assessments also address some of the science unique to each Engineering Adventures unit. In *Bubble Bonanza*, for example, participants are asked, "Do you think you could poke a bubble with a pin without breaking it? How would you do it?" and "What are some things bubbles can do? What are some things bubbles can't do?" In the *Hop to It* unit, children are asked, "What do you think might happen if cane toads were brought to where you live?"

The success of the content assessment instruments has varied. They have helped developers to identify points at which units needed improvement or further support, but creating written content assessments that are short enough that OST participants will tolerate them has been a struggle (written assessments are necessary to gather input from a large sample). Unlike in classrooms where pencil and paper work is expected, in OST programs these types of assessments are not the norm and it is difficult to convince children to provide written feedback.

EA developers continue to think creatively about less intrusive ways to assess content gains. Collecting and coding text and images from participants' Engineering Journals, which are used throughout the unit, provides one promising possibility discussed below.

Educator Feedback Forms

As part of field testing, all EA educators are required to provide extensive written feedback on the unit as a whole and on individual adventures (i.e., activities). The form asks educators to rate the adventures, provide basic information about facilitation, and contribute any other comments they would like.

Educator feedback forms have been incredibly valuable formative evaluation tools. Especially during early versions of the units, the types of comments received inspired changes (both large-scale and small) that greatly improved the usability of the units. Several educator comments below reflect the wide range of suggestions and comments received.

- "It was great exploration for the students and the items provided made the students be more involved with the different challenges."
- "We will probably not do the unit with all parts, from start to finish. We will probably use a few activities in the future, especially the two prep activities."
- "The unit was fun. I think the kids would have been more creative though if they were given more supplies and time to complete the activities."
- "The concepts of engineering and technology are really broken down to an effective level for this age-range. I would select "7" [highest quality rating] if the kids understood the importance of materials."

All educator feedback is sorted, reviewed, and discussed by the curriculum development team, then incorporated into the revision process. Quantitative data (including overall ratings of the unit and particular adventures) from the forms are consolidated and provided to the team—they typically help to confirm that the changes made based on immediate feedback of focus groups, observations, and the qualitative skimming of feedback forms returned early in the process were appropriate changes to make.

Because educators are given a stipend to thank them for their feedback, securing this feedback has generally not been difficult. Educators are asked to submit feedback following their completion of the unit, which gives curriculum developers a wealth of qualitative information to draw upon during the revision process.

Observations

Another effective evaluation strategy used by the EA team involves site visits. Field test sites located near the Museum provide opportunities for curriculum developers to observe Engineering Adventures in action. Curriculum developers communicate with educators and attend the site's weekly sessions. Notes about these observations are recorded in a standardized format that includes focused questions about facilitation and fidelity of implementation, several ratings of child engagement, and a section in which observers write specifically about what happened during different sections of the adventure.

Observations have proven to be a highly successful formative evaluation tool. The OST educators and children generally enjoy having visitors and OST educators often appreciate having an extra pair of hands available to quickly prep materials before the children arrive. The OST participants often look forward to being asked to comment on the activities and enjoy feeling that their opinion is valued. While the number of observations the curriculum development team can complete is small, the information gathered is extremely valuable and the team has found this type of formative evaluation to be critical in the OST environment. Experiences observing the units in action inform the revision process, helping curriculum developers to quickly change things that are clearly not working and enhance those that are.

Engineering Journals

Each child participating in an Engineering Adventures unit is given an Engineering Journal and examining student work is an extremely important part of evaluation. Unit-specific journals give kids space to record their ideas, including drawing and revising their design ideas. For the EA curriculum and research teams, the journals serve as a useful assessment tool that can provide insights into kids' understanding. At the end of field testing, all journals are returned to the Museum of Science where researchers code individual journal writing and drawings to assess how well students; work in the units reflect EOST's key goals.

The first versions of Engineering Journals were open ended—many pages did not include specific prompts or questions. Although the openness is theoretically appealing, these versions did not prove to be highly successful evaluation instruments. Both children and educators expressed confusion over the purpose of the journals. The Engineering Journals have since been revised to include a prompt on each page, while often still allowing free space for student-generated drawing or writing.

Results

Comprehensive evaluation and analysis has been completed for the *Bubble Bonanza* unit. This section will focus these findings. Testing of *Bubble Bonanza* began in fall of 2011 and continued through the spring and summer of 2012. It was tested in more than 40 afterschool and camp programs and more than 350 children participated. After summer 2012 data were analyzed, the unit was found to be meeting key participant goals and was then made available to the public. Data from pilot test sites are presented below, as well as information gathered from a survey emailed to all users who downloaded the unit once it was made public.

Pilot Test Results

Over the course of field testing the *Bubble Bonanza* unit, educators consistently rated the quality of the unit highly (an average rating of 6 (n=39) out of a 7 point scale, 1 being very low quality and 7 being very high quality). Educator comments often noted the importance of using the Engineering Design Process as a frame for guiding learning, or the fun kids had working on the challenge:

- "The engineering design process was a good learning tool for exploring what steps are required to engineer something. In addition, Prep Activity 1 was good for explaining technology, and Prep Activity 2 was an excellent introduction to engineering."
- "There was such excitement at the first bubbles with a homemade wand. The students also discovered they could make great bubbles with their hands and they were delighted with this."

Bubble Bonanza Engineering Attitudes assessments have shown significant positive effects on child attitudes regarding engineers and engineering careers in their future. Children's more positive agreement with statements like "I would like to be an engineer when I grow up" is notable. The version of the *Bubble Bonanza* unit resulting in these changes included increased use of "engineering" as opposed to the word "design." After completing the *Bubble Bonanza* unit, children are more confident in saying they can see themselves as engineers. This indicates that the *Bubble Bonanza* unit has likely been successful in achieving several of EA's key goals. Figure 2 depicts the statements on which children exhibited significantly more positive attitudes

from pre- to post-survey: “I would enjoy being an engineer when I grow up” (t=-4.133, df=313, p<.001), “I would like a job where I could invent things” (t=-2.156, df=306, p=.032), and “Engineers help make people’s lives better as part of their job (t=-2.576, df=322, p=.010).

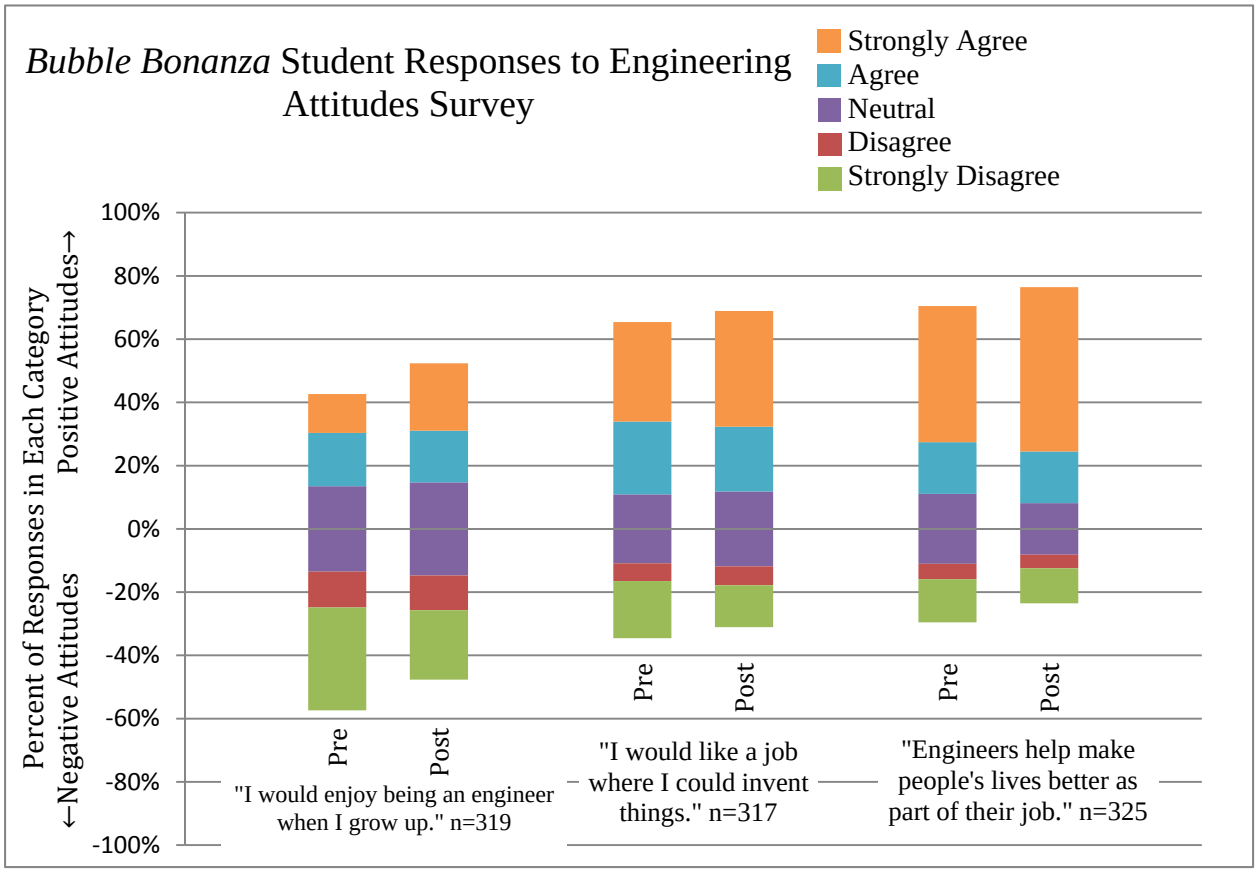


Figure 2. Child Responses to Engineering Attitudes Survey from *Bubble Bonanza*. Statements include only those which exhibited significant change on post-tests compared to pre-tests. Bar represents 100% of responses, broken down by category.

Journals from the *Bubble Bonanza* unit reflect how participants are using the engineering design process as they engineer bubble makers. Students planning designs in their journals set project-based goals, such as to “make big bubbles” or “tiny bubbles”; for the most part, these goals are realistic, as they have been examining and asking questions about the properties of bubbles. The designs the children imagine and plan, including selecting appropriate materials, are appropriately designed to meet these goals. Figure 3 shows an example of a student’s initial design.

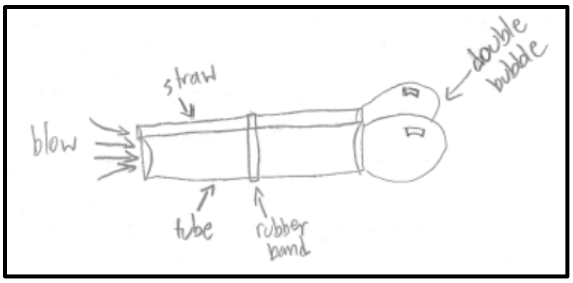
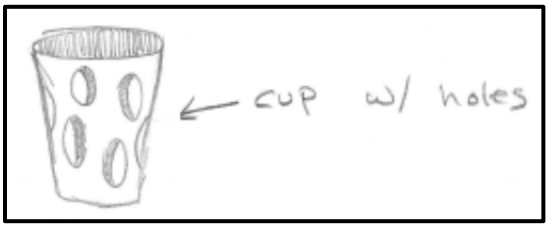


Figure 3. Student design for producing a "double bubble."

Even for individuals or teams who had identical goals, the designs depicted in the journals illuminate the diversity of solutions that EA's open-ended challenges fosters. In many instances, a single journal will document multiple design ideas and shed light on the dynamic design process. One student reports that "first we did just wire then we added pipe cleaners" when trying to make big bubbles . Figure 4 shows another example, this time for making small bubbles. The initial design is on the left, while the improved design is on the right, featuring a balloon and a screen on one end of the cup instead of holes in the sides. These examples show that children are using the engineering design process to solve the problems presented by the context of the unit, and are confident enough to continue in the process and write about their experiences.



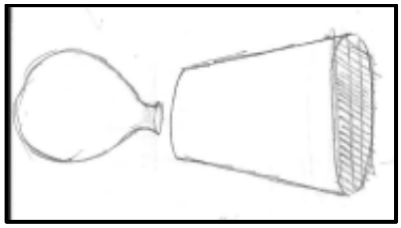


Figure 4. Student's designs for making small bubbles.

Kids were also asked in their journals if they are interested in pursuing an engineering career—specifically a materials engineer in the *Bubble Bonanza* journals—and indeed many children express interest. They supply a range of reasons, including an enjoyment of engineering and the engaging activities they have been doing—"I want to be a materials engineer because it is fun" or "because I would love to solve problems". Some children also express feeling capable of pursuing engineering careers—"I would love to be [an engineer]. Because I'm very inventive and smart" (see Figure 5 for associated picture).

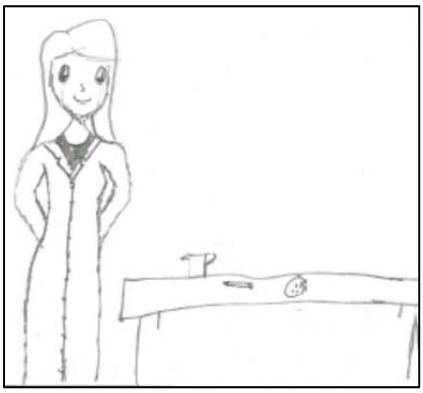


Figure 5. "I would love to be [an engineer]. Because I'm very inventive and smart."

Post-Release Survey Results

The *Bubble Bonanza* unit was made available to thousands of OST programs via online posting in July of 2012. Over the six months that the unit has been publicly available, it has been downloaded over 700 times. A link to an online survey was recently emailed to those who downloaded the unit, with the goal of gathering data related to their thoughts on unit quality, usability, what they believed their children gained from participating in the unit, and their interest in implementing other similar units in the future. A total of 118 educators completed the survey. It is worthwhile to note that educators who helped to pilot test the *Bubble Bonanza* unit were sent prepared materials kits to help facilitate the activities, and were offered email and phone support from EA curriculum developers. The educators who downloaded the *Bubble Bonanza* unit and participated in the survey received none of these supports.

Of those educators who have implemented the *Bubble Bonanza* unit at least once, most indicated the unit was easy to use, with ninety five percent rating ease of use as a 5, 6, or7 on a 7 point scale (with 1 being "not at all easy" and 7 being "very easy."). Survey participants also rated the overall quality of the unit as high, with 100% of survey respondents rating the unit a 5, 6, or 7 (with 1 being very low quality and 7 being very high quality). Ninety-eight percent of respondents indicated they were likely to implement the *Bubble Bonanza* unit again, and 100% of respondents also indicated an interest in implementing other Engineering Adventures units. These results confirm support and interest in STEM programming, particularly engineering programming, within the OST field.

Table 3 shows the results of survey questions related to participant learning and confidence.

Table 3. Educator Assessment of Participant Impacts (n=40)

	1 Strongly Disagree	2	3	4	5	6	7 Strongly Agree	Not Sure
My kids used the engineering design process to help solve problems in the unit	0%	2.5%	2.5%	10%	22.5%	20%	42.5%	0%
My kids have a better understanding of what engineers do	2.5%	0%	0%	7.5%	10%	27.5%	52.5%	0%
My kids have a better understanding of what technology is	0%	2.5%	0%	5%	10%	30%	52.5%	0%
My kids have increased confidence that they can design and improve technologies	2.5%	0%	0%	2.5%	25.6%	25.6%	43.6%	2.5%
My kids better understand failure as an opportunity to learn	2.6%	0%	0%	5.1%	30.8%	41%	20.5%	2.6%
My kids believe they could be engineers when they grow up	2.7%	0%	0%	5.4%	24.3%	32.4%	35.1	8.1%
My kids had fun participating in the Bubbles curriculum	2.7%	0%	0%	2.7%	2.7%	8.1%	83.8%	8.1%
My kids would choose to participate in another EOST activity in the future	5.9%	0%	0%	2.9%	2.9%	8.8%	79.4%	17.6%

Educator responses indicate participation in the *Bubble Bonanza* unit resulted in positive gains in attitude and confidence. Ninety four percent of educators felt their kids had increased confidence in their ability to design and improve technologies. Educators also indicated increased understanding of engineering, technology, and ability to use engineering tools and skills, such as implementing the engineering design process and learning from failure. Eighty-five percent of respondents felt their kids had used the engineering design process to help them solve problems in the unit. Ninety two percent felt their kids had a better understanding of failure as an opportunity to learn. Perhaps most importantly, educators felt their kids had fun participating in the unit (94% rated this statement a 5, 6, or 7) and 95% of educators felt their kids would choose to participate in another unit.

Educators' beliefs that children's engineering skills and attitudes were positively impacted by participation in this unit echo the positive impacts found during Engineering Adventures field testing. This is especially noteworthy given survey respondents were provided only with the downloaded unit; no additional professional development supports were offered by the Engineering Adventures team. In the next several months, a similar survey will be sent to users who downloaded the *Hop to It* unit. EA developers are particularly interested to see if positive content and attitude changes hold across units, as this will further support the notion that the critical components the EA program has identified for OST are indeed crucial for creating positive effects, no matter the science and engineering content highlighted in the unit.

Conclusion

With OST stakeholder organizations and educators voicing positive support for engineering activities, it is critical that high-quality engineering activities created specifically for the OST

environment are available. Engineering curricula that have been thoughtfully designed to introduce children to engineering in a comprehensive, engaging way can positively impact children's engineering attitudes and abilities. Kids should be explicitly encouraged to use the Engineering Design Process, by taking initiative, making mistakes, putting their own unique ideas into action, and improving their designs. Engineering units that thoughtfully sequence activities to help students build on their learning and explicitly focus on children as successful engineers can positively impact children's ideas and attitudes about engineering.

Thoughtfully designing and thoroughly testing engineering activities in OST contexts are critical to their success. Multiple cycles of formative evaluation, feedback, and revision produce activities and units that work for kids, as shown by the examination of student work and surveys from Engineering Adventures. Through their journals, kids demonstrate they are using the engineering design process and applying it to their designs. Both the journals and surveys show that kids' interest in engineering as a future career increases when they participate in EA challenges.

While positively affecting the number of future engineers would be a desirable outcome related to using engineering activities in OST, the opportunities to increase children's confidence in their abilities to engineer and views of themselves as critical thinkers are perhaps the most exciting possibilities. In the case of Engineering Adventures, these positive attitudinal gains were shown after children engaged in only one engineering unit. The potential for OST programs and engineering practices to empower children as problem solvers is the true strength of both the Engineering Adventures program and STEM in OST.

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