Extending Science Education with Engineering and Technology: *Junk Drawer Robotics* Curriculum

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Increasing youth science, engineering, and technological literacy constitutes a continuing challenge in the United States. The 4-H Youth Development Program is helping to address this need with nonformal science, engineering, and technology youth education programs. The article describes the benefits of engineering and technology education, often missed in science, technology, engineering, and mathematics (STEM) education, and highlights the *Junk Drawer Robotics* curriculum. *Junk Drawer Robotics* extends science education into engineering and technology domains using experiential learning, cross-age instruction, and small group learning. Evaluation efforts show promise in helping youth increase their content knowledge in engineering and technology.

The prosperity of the United States relies upon our investment in educating and preparing future scientists and innovators to provide solutions to vexing environmental, economic, and social problems. Momentum for coordinated science, technology, engineering, and mathematics (STEM) education has grown over the past decade. However, even with increased focus, new curricula, and state education standards, K-12 student science and mathematics proficiencies consistently show stagnation (National Academy of Sciences, 2006). In addition, engineering and technology remain the underrepresented domains in STEM educational priorities and curricula.

While the United States is still the undisputed leader in basic and applied research, over the last two decades, youth science and math academic performance have stagnated and in some cases declined (Fleischman, Hopstock, Pelczar, & Shelley, 2010; Gonzales, et al., 2008; National Center for Education Statistics, 2011). While the field of engineering is vital in the modern world, there have been few studies on engineering proficiencies and no comparisons of US students' engineering knowledge and skills to those of students in other countries. No national engineering education standards exist to help guide school or out-of-school programs, although there is discussion on developing such standards for K-12 schools. The few studies on youth attitudes towards engineering indicate youth are confused about the field, the engineering process, types of engineering professions, and the value of engineers to society (Robinson, Fadali, Carr, & Maddux, 1999; Robinson & Kenny, 2003).

Technology plays a vital role in our society and is a required 21st century skill for those entering today's workforce. Educational technology can enhance the teaching and learning process while technology literacy addresses skills youth need to problem solve, operate, test, and maintain equipment and systems. Few comprehensive studies compare U.S. student understanding of technology processes to those in other counties. U.S. youth spend over seven hours a day consuming media delivered by technological innovations, two-thirds own a cell phone, and over 80% have Internet access at home (Rideout, Foeher, & Roberts, 2010). However, the mere use of technology devices is not enough for youth to succeed in the workforce. Youth not only need to be consumers of technology, but understand and be able to apply technological processes. Youth tend to have a poor understanding of the characteristics of technology,

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how new innovations influence society, and how technology is created and adapted (Pearson & Young, 2002). Youth need a basic level of technological literacy in order to make decisions and engage in civic debates pertaining to technology.

Why Engineering and Technology?

Science and mathematics, and to some degree, technology, have found a place in formal K-12 education. While engineering education has seen growing interest, structured engineering programs are still rare within K-12 school walls. Both engineering and technology, however, have a vital role in ensuring the prosperity of our nation. Scientific knowledge informs engineering designs while many technological innovations allow for new scientific advances. Science and technology/ engineering education can be successfully connected in K-12 educational settings and may have strong synergistic effects. Specifically, fields of engineering and technology contain similar processes and both may benefit greatly from a combined effort and focus on processes that overlap (Wicklein, Smith & Kim, 2009).

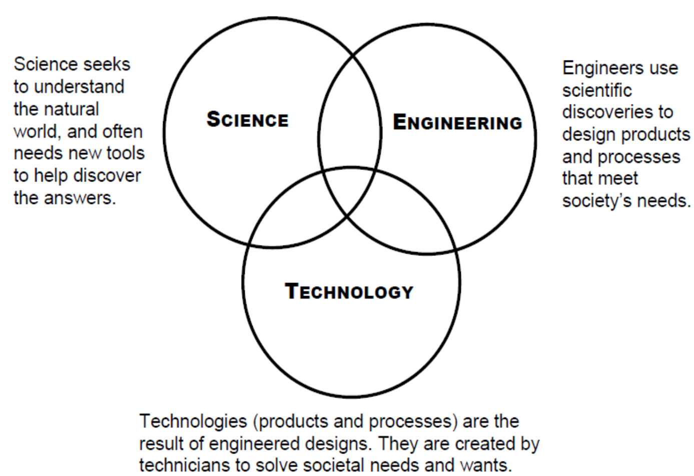
A few studies suggest engineering education may improve science and mathematics learning and achievement (Katehi, Pearson, & Feder, 2009). As youth work on an engineering design challenge, this application helps reinforce science and mathematics concepts. Engineering education programs serve to increase awareness of engineering and the work of engineers, understanding and ability of youth to engage in engineering design, and improvement of perceptions towards engineering (Katehi et al., 2009).

Technology, while encompassing a broad range of concepts and processes, tends to generally be classified into just computer and information technology. However, the processes of innovation, selection, and implementation are important concepts when referring to technological literacy. The argument in favor of technology literacy is similar to that used for science literacy: many of our personal choices and public policy debates center on issues involving technological innovations (which are in turn, based on scientific facts). Everyone needs a basic level of understanding of technology in order to fully participate in a democratic society (Pearson & Young, 2002). In addition, studies on improving technological literacy suggest learning with technology can improve student's cognitive and affective outcomes (Waxman, Lin & Michko, 2003).

Science, engineering, and technology serve a mutually beneficial arrangement. Scientists use inquiry to investigate the world and generate new knowledge while engineers use these discoveries to design new technologies. Technologists apply the research from scientists and engineers in fabricating, testing, and maintaining systems (Horton, Gogolski, & Warkentien, 2007). As depicted in the Venn diagram below, science, engineering, and technology connect in a natural and overlapping manner as all three provide to and receive from the other realms.

FIGURE 1

The Relationships Among Science, Engineering, and Technology



Courtesy of the Massachusetts Department of Education (2006: 81).

While scientific inquiry and engineering design share similar features, the two approaches diverge in several important aspects. Engineering incorporates the role of constraints, tradeoffs, failure, context, and dependence on iteration. Engineering design is grounded in both the natural and human world, focusing on producing a tool or product. Engineers must deal with constraints of time, costs, law, and aesthetics – practical boundaries – within their search for a solution. Within the design process, engineers must make choices on trade-offs between functionality, costs, and safety. Solutions must be safe and engineers must factor failure into the design principle. Whereas science strives to be generalizable, engineers must contend with the context of the environment, human needs, and aesthetics. These constraints allow for a myriad of solutions, promoting creativity and new ways of thinking. Science education can bridge with technology and engineering education by connecting science concepts to the real world. By connecting education with the world, education is more appealing to young people (Lewis, 2006).

4-H Youth Development STEM Education

The field of out-of-school-time (OST) programs continues to grow while an emerging body of research suggests OST educational programs can supplement school-based instruction. Structured and properly facilitated nonformal science programs can increase interest, positively influence academic achievement, and lead youth to future career options (Bell, Lewenstein, Shouse, & Feder, 2009). One such program, 4-H Youth Development, offers research-based science, engineering, and technology programming for youth. The 4-H Youth Development Program, a national nonformal youth education organization has engaged youth in science-based programming for over a hundred years. The 4-H positive youth development environment is ideal for science education through emphasis on nonformal learning and learner-centered pedagogies (Russell, 2001). 4-H has an extensive history of providing research-based programming with youth ages five through nineteen, and as such is well positioned to educate young people in science, engineering, and technology.

The UC 4-H Youth Development Program was one of the first to build momentum for nonformal science education. In 1988, Cooperative Extension specialists at UC Berkeley, funded by National Science Foundation, developed a curriculum to address science literacy programs in nonformal settings. This curriculum, titled *Science Experiences and Resources for Informal Education Settings* (SERIES), was designed to help youth develop competence in science processes (Ponzio, 2006). Over the next decade, multiple science-based curricula were developed for youth ages nine to thirteen on various science content domains. Each curriculum module built knowledge and processes upon each other, building towards advanced concepts. The learning cycle was completed when youth were challenged to complete a service project in their community. Unlike many other 4-H science curricula of the time, SERIES also emphasized science process skills – observing, communicating, comparing, organizing, relating, inferring, and applying. A future outgrowth of SERIES was the *4-H Youth Experiences in Science* (YES) project. Started in 1994 and published in 2000, the YES project added a nonformal science education curriculum for five to eight year olds (Ponzio, Junge, Manglallan, & Smith, 2000).

In 2001, coordinated through the UC ANR Science, Technology, and Environmental Literacy Workgroup, an Action Group was formed to explore prospects for a technology-based curriculum. The action group decided to adapt the successful SERIES model with engineering and technology content and processes. The project focused on robotics and began using the title *S.E.T. Robotics* to highlight science, engineering and technology processes. Robotics was selected as the content domain due to the interdisciplinary connections between scientific principles, engineering design, and technological processes.

As part of the Action Group process, the field of robotics was reviewed and the major systems and elements were identified and defined as topics to be covered in a curriculum. To match the model used in 4-H SERIES, activities on these topics were developed using the learning cycle where there were exploration, concept introduction, and concept application phases. The extension of this model was in adding the engineering and technology process aspects. To do this, the learning cycle was used again as a cycle within a cycle at this next level. Activities were grouped into science based, engineering design based, and in technology building phases. This allows exploration of new knowledge using a science-based activity, then to take that new knowledge as an introduction via an engineering design activity, and apply using a technology building activity. In addition to this concept of focused activities, testing revolved around the use of various commercial robotics kits or building systems. While the building sets could work for the focused learning activities, the kits did not fully meet the learning objectives of the 4-H SERIES model.

In 2004, the concepts and outline for *S.E.T. Robotics* was presented at the California Industrial Technology Education Association conference. The outcome was a reflection on the concepts and delivery of the SERIES curriculum and refocusing the direction of the *S.E.T. Robotics* on using everyday items in place of commercially packaged robotics kits. With these revisions, the curriculum was retitled *Adventures in Robotics*. The new activities were presented at statewide and regional 4-H workshops with teens and adults which provided opportunities for informal formative data collection.

In 2007, the NPASS (National Partnerships for Afterschool Science) partnership project requested a robotics curriculum fitting the needs of afterschool programming. To provide a more useful delivery in the time allotments of afterschool settings targeted by NPASS, robotics modules were sequenced to allow 45 minute sessions. The overall curriculum activities were sorted and grouped into three subsets on arms, movement, and sensors. The curriculum, with these major revisions in sequence and duration of sessions, was renamed *Ventures in Robotics*. These new modules were tested at NPASS regional conferences and other 4-H workshops for feedback to improve the curriculum.

In 2009, as part of the National 4-H Science Initiative, 4-H National Headquarters brought additional resources to support the development of a comprehensive 4-H robotics curriculum. A multistate collaboration was formed between the University of Nebraska, University of California, University of Idaho, Global Challenge Award (a Vermont-based non-profit organization) and others, to develop the curriculum, *4-H Robotics: Engineering for Today and Tomorrow*. The California 4-H component, named *Junk Drawer Robotics*, comprises one of three tracks in this national curriculum effort. Curriculum development efforts included refinement, reconfiguration, expansion, and evaluation of the earlier works on robotics. In addition, a youth robotics notebook component was added, modeled after an engineering notebook.

Junk Drawer Robotics

The *Junk Drawer Robotics* curriculum engages youth in understanding scientific concepts and processes, the engineering design process cycle, and technology creation and building. *Junk Drawer Robotics* provides youth these experiences by working with household items to complete simple design challenges. These robotics activities emphasize science, engineering and technology process skills, cross-age instruction, the experiential learning cycle, and small group learning. Activities are designed to be led by an adult or teen facilitator following the experiential learning cycle and promoting inquiry.

Each module contains the desired big ideas (concepts) and key science processes youth should achieve through the activities. Each activity outlines success indicators to help the facilitator ascertain whether youth have grasped these desired outcomes. This framework guided the development process to ensure activities would achieve the desired result and provide the presenter with acceptable evidence. During curriculum development, many activities underwent modifications to ensure the youth were guided to the desired result.

The curriculum incorporates four practices in nonformal educational curricula design: 1) focus on science, engineering, and technology process skills; 2) use of cross age teachers; 3) frame activities in the experiential learning cycle and promote inquiry; and 4) small group learning.

Focus on science, engineering, and technology process skills

Science processes are used to help youth identify, frame, and explore concepts. Youth then apply these in application activities of design and construction.

This application phase helps youth develop critical thinking skills and ensures participants scaffold their knowledge. The youth build towards advanced concepts as they continue to participate in the curriculum. Engineering and technology skills are enhanced when incorporated with communications, teamwork and hands-on activities and include science applications (Wicklein, Smith, & Kim, 2009).

Use of cross age teachers

Junk Drawer Robotics encourages teenagers to facilitate activities with younger youth. Older teens interact with younger learners and work together to explore the big ideas identified in each module. Allowing teens to teach younger youth has been shown to provide benefits for both the teens and younger participants (Lee & Murdock, 2001).

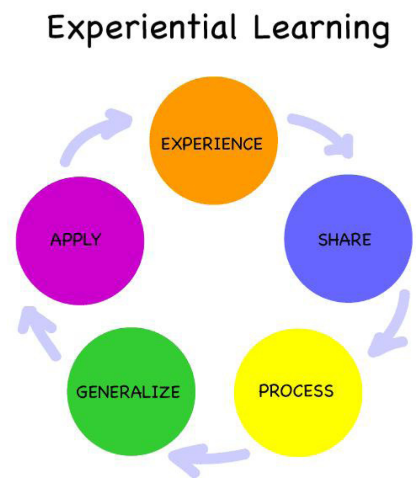
Frame activities in the experiential learning cycle and promote inquiry

The experiential learning cycle is a natural pedagogy to help youth nurture their natural curiosity (Carlson & Maxa, 1998; Kolb, 1984). The model contains five steps: 1) experiencing, 2) sharing, 3) processing, 4) generalizing, and 5) applying. Each activity begins with an experience. After experiencing is complete, presenters help youth reflect on the activity by encouraging sharing and processing with open-ended questions. To complete the learning cycle, each activity contains a generalizing and applying section to help youth connect concepts to both broader robotic concepts and to the real world. In addition, each module (consisting of several activities) also follows the learning cycle, starting with exploration of basic science concepts and processes and moving towards application in design and building activities.

Small group learning

Youth participants learn from each other by working in pairs or small groups. The opportunity for youth to collaborate, share, and work with each other promotes learning while also enhancing life skills in teamwork, communication, and group decision making. When youth work in small groups, they tend to learn more than when working individually (Lou, Abrami, & d'Apollonia, 2001; Robinson, 2005).

FIGURE 2
Five-Step Experiential Learning Cycle (Kolb, 1984).



Junk Drawer Robotics modules are designed around three phases – to learn (science), to do (engineering), and to make (technology).

- To Learn (Science): Exploration – Typically one to three activities within each module. These activities form the foundation upon which youth build conceptual understanding. Youth learn through exploring scientific processes and knowledge with minimal guidance or expectations of accomplishments. This learning phase promotes deeper inquiry, allowing youth to experience, share and process with peers, and start constructing knowledge.
- To Do (Engineering): Concept Development – Typically one design activity per module. This activity builds upon the knowledge gained in the exploration phase related to the concepts in the module. Youth are presented with a design problem and relative constraints. In small groups, youth work together to design and plan a solution. This learning phase promotes problem identification, framing, and solving as youth work within the given constraints to engineer a solution to the challenge.
- To Make (Technology): Concept Application – Typically one construction activity per module. In building and testing their design from the previous activity, youth solidify and consolidate the concepts and reasoning patterns. In testing their finished

products, youth observe their solutions, find potential sources of failure, and redesign. The iterative process of engineering and technology allows for deeper exploration into concepts.

Each *Junk Drawer Robotics* level contains four to six modules around a central theme packaged in a facilitator's guide. Within a level, each module contains five or more activities. Each level also contains a companion youth robotics notebook used by youth participants to graph, chart, draw, and record data they generate in each activity. The central themes in each level are:

- Level 1: Give Robots a Hand – In this level, youth learn about robot arms and hands. Arms are flexible with joints – shoulders, elbows, and wrists – that allow placement into many positions. The hand with its fingers and thumb can grab, hold, and pick up items. Robot arms allow robots to grab, lift, move, or position items into a machine, to control a spot welder, or to assemble parts for an item. The underlying science concepts include form and function, scientific habits of mind, and leverage. Engineering and technology concepts include the form as a function of task and the role of engineering design.
- Level 2: Robots on the Move – In this level, youth learn about robot movement. Mobile robots are responsible for an array of applications allowing robots to complete tasks in locations and situations impossible for humans. Mobile robots travel to dangerous situations by land, air and water, traverse remote areas or planets, and carry instruments and sensors. The underlying science concepts include friction, basic electrical power and motors, gears systems, and buoyancy. The role of constraints and engineering iteration are emphasized.
- Level 3: Mechatronics – In this level, youth learn about the synergy when mechanical, electronic, and feedback systems are merged. Robots use a variety of sensors to explore the natural world with computer controlled systems interpreting signals. Advanced robots use digital systems and are computer programmed to respond to environmental stimuli. The underlying science concepts include electronic circuits, sensing, and mathematical number systems. The level includes basic concepts in computer technology including programming, number systems, and flowcharts.

EVALUATION METHODS

The predecessors to *Junk Drawer Robotics* (i.e.*, S.E.T. Robotics, Adventures in Robotics,* and *Ventures in Robotics*) underwent multiple reviews and revisions. In addition, the 4-H SERIES model was a NSF funded and evaluated project that provided the initial base for adaptation. During the course of years in development these earlier works received feedback from industrial technology educators, youth development professionals, afterschool providers, volunteers, teens, and activity pilot testing in multiple settings. This helped provide a solid base upon which to build the new curriculum modules, activities and notebook. During *Junk Drawer Robotics* development, the curriculum was evaluated using three primary methods: expert review, formative data collection, and an external evaluation field test.

Expert Review

During the development process, *Junk Drawer Robotics* modules were reviewed by a combination of experts, including University engineering professors and students; professional youth development staff in three states; evaluation experts, and blind review conducted by the 4-H National Headquarters. Reviewers provided feedback on areas of strength and suggestions for improvement. In general, review comments were positive about the curriculum's methods and content.

Formative Data

The formative evaluation protocol was designed by an external evaluation team at the University of Nebraska and implemented by academics at the University of California. The evaluation consisted of two evaluation instruments, one for 4-H youth participants and another for 4-H adult or teen presenters. The one-page youth instrument contained Likert-scale questions asking youth to self-report their science, engineering, technology and mathematics learning and narrative prompts asking youth about what they liked best and thought could be improved. The presenter instrument asked for perceptions of youth engagement and learning. Both instruments contained six Likert scale questions which were converted to interval data based upon the responses of: *1-Strongly Disagree; 2-Disagree; 3-Neutral; 4-Agree; 5-Strongly Agree.*

From fall 2009 through spring 2010, three California counties were involved in pilot testing and provided formative data: Kern, Merced, and Santa Cruz. In each of these three counties, youth were selected based on their participation in either a 4-H Club or afterschool program. In general, the sample consisted of youth from mixed socioeconomic statuses and included youth from Hispanic, Asian, and African American racial groups. A total of approximately 250 youth participated.

In Merced County, eight UC Merced engineering undergraduate students and 4-H staff facilitated weekly activities at 11 local 5th - 8th grade afterschool sites with approximately 20 youth at each site (total of approximately 220 youth). In Santa Cruz County, four 4-H volunteers and teens facilitated activities in two 4-H Club projects twice a month consisting of approximately 10 youth each (total of 20 youth). In Kern County, two teens and a 4-H staff led a countywide 4-H project using the curriculum with approximately 10 youth. None of the sites implemented the entire curriculum, but rather, delivered curriculum modules which were identified as needing additional formative data for their development.

After the activities from a module were delivered, the presenters asked youth participants to complete the evaluation instrument and then complete the form themselves. While most adults and youth completed the survey, a few at each site elected not to complete the instrument. In a few cases, due to programmatic constraints, adults and youth did not complete an entire module, but were still asked to complete the survey evaluating the activities they completed within the module.

RESULTS

The aggregate youth and presenter responses for each module across all sites are provided in Tables 1, 2 and 3. On average, youth participants and adult presenters responded between ‘neutral’ and ‘agree’ that youth learned science, engineering, technology, and mathematics concepts. In Level 1, module 2, focusing on robotic arms, youth participants felt they learned the most about engineering concepts. Youth rated engineering, on average, higher than science and technology concepts.

TABLE 1
Evaluation Results for Junk Drawer Robotics Level 1, “Give Robots a Hand”

Module 2 Arms Responses for youth participants (n=40)	
Survey questions for youth	*Mean Values**
The lesson/activity helped me to learn about science or science concepts.	3.25
The lesson/activity helped me to learn about technology or technology concepts.	3.56
The lesson/activity helped me to learn about engineering or engineering concepts.	3.69
The lesson/activity helped me to learn about mathematics or math concepts.	3.62
I found the lesson or activity to be interesting.	3.55
I would tell my friends that the activity was a good one.	3.36

**Means are from Likert response values: 1-Strongly Disagree; 2-Disagree; 3-Neutral; 4-Agree; 5-Strongly Agree*
(*Note:* Data from Level 1, Modules 1 and 3 are not presented in the table. These modules underwent substantial modification after being delivered, in part from the results of the formative data, hence the collected formative data for these modules is only applicable to the earlier versions. All other modules underwent minor revisions.)

In Level 2, robotic movement, modules 1 through 4, youth participants tended to respond with higher levels of engineering learning, on average. However, in Module 2, magnets and motors, youth participants also felt they learned about science concepts. Adult facilitators generally rated their perception of youth learning higher than the youth themselves, yet followed the same trend of rating engineering education higher than the other three subjects.

TABLE 2
Evaluation results for Junk Drawer Robotics Level 2, "Robots on the Move"

Level 2, "Robots on the Move"	*Module 1 Friction*	*Module 2 Magnets & Motors*	*Module 3 Gears*	*Module 4 Underwater ROV*
	Responses for youth participants			
	n=53	n=72	n=31	n=72
Survey questions for youth	*Mean Values**			
The lesson/activity helped me to learn about science or science concepts.	3.00	4.01	3.61	3.81
The lesson/activity helped me to learn about technology or technology concepts.	3.32	3.93	3.77	3.48
The lesson/activity helped me to learn about engineering or engineering concepts.	3.34	3.86	3.94	3.97
The lesson/activity helped me to learn about mathematics or math concepts.	2.81	3.37	3.55	2.99
I found the lesson or activity to be interesting.	3.37	4.26	3.97	4.08
I would tell my friends that the activity was a good one.	3.00	4.28	3.61	3.93
	Responses for adult presenters			
		n=12	n=12	n=7
Survey questions for adults	*Mean Values**			
The lesson/activity helped youth to learn about science or science concepts.		4.00	3.50	4.29
The lesson/activity helped youth to learn about technology or technology concepts.		4.17	4.08	3.86
The lesson/activity helped youth to learn about engineering or engineering concepts.		4.25	4.33	4.29
The lesson/activity helped youth to learn about mathematics or math concepts.		2.91	3.75	3.14
I found the lesson or activity to be interesting to youth.		4.33	3.91	4.00
The lesson/activity was engaging to youth.		4.42	3.92	4.00

**Means are from Likert response values: 1-Strongly Disagree; 2-Disagree; 3-Neutral; 4-Agree; 5-Strongly Agree*
(*Note:* Data from presenters for Level 2, Module 1 is not included in the table due to program factors at those particular sites when activities in this module were being implemented.)

Module 2 received higher responses from both youth and adults rating the activity as "interesting" and "a good one." This echoes anecdotal evidence from observations of youth participating, as the To Do and To Make activities, titled "Can-Can Robot" allowed for creativity, artistry, and were visually appealing.

In Level 3, merging of electronics and mechanics, youth participants tended to rate technology education higher than science or engineering. This fits as the third level incorporates elements of circuits, sensors, and computer programming into the curriculum. However, responses to the curriculum being "interesting" and "good" are lower than those from the other Levels. This may be due to the more abstract nature of the concepts presented, including basic computer programming and mathematical numbering systems (e.g., binary). To help youth learn about these complex concepts, many of the activities are group scenarios which attempt to provide analogies and do not contain direct hands-on building activities found in Levels 1 and 2.

In almost all cases, both youth and adult facilitators

TABLE 3
Evaluation results for Junk Drawer Robotics Level 3, "Mechatronics"

Level 3, "Mechatronics"	*Module 1 Circuits*	*Module 2 Sensors*	*Module 3 Logical Operators*
	Responses for youth participants		
	n=163	n=10	n=21
Survey questions for youth	*Mean Values**		
The lesson/activity helped me to learn about science or science concepts.	3.31	2.67	2.62
The lesson/activity helped me to learn about technology or technology concepts.	3.33	2.80	2.80
The lesson/activity helped me to learn about engineering or engineering concepts.	3.13	2.50	2.57
The lesson/activity helped me to learn about mathematics or math concepts.	2.83	2.40	2.75
I found the lesson or activity to be interesting.	3.35	2.70	2.52
I would tell my friends that the activity was a good one.	2.95	2.40	2.24
	Responses for adult presenters		
	n=14	n=2	n=3
Survey questions for adults	*Mean Values**		
The lesson/activity helped youth to learn about science or science concepts.	3.93	4.00	3.00
The lesson/activity helped youth to learn about technology or technology concepts.	4.14	4.50	3.33
The lesson/activity helped youth to learn about engineering or engineering concepts.	3.86	4.50	2.67
The lesson/activity helped youth to learn about mathematics or math concepts.	2.79	2.50	3.33
I found the lesson or activity to be interesting to youth.	3.71	4.00	3.00
The lesson/activity was engaging to youth.	4.00	3.00	3.00

**Means are from Likert response values: 1-Strongly Disagree; 2-Disagree; 3-Neutral; 4-Agree; 5-Strongly Agree*

rated mathematics learning lower than science or engineering. This is to be expected as the curriculum does not emphasize mathematics education. For engaging youth interest, adult presenters tended to rate their perception of youth interest higher than the youth participants themselves. However, both tended to rate their interest in the activities moderately, with notable exceptions in Level 3, modules 2 and 3. Both of these modules tend to rely on group activities rather than building and constructing.

Overall, the formative data seem to indicate the curriculum was well received by adult facilitators in establishing a productive learning environment for science, engineering, and technology. These Likert responses, along with the open-ended comments (not included here) pertain to the draft modules during the development process. As part of the curriculum development, the open-ended responses on the formative evaluation instruments were used to improve and strengthen activities.

External Evaluation Field Test

In addition to the formative evaluation results presented above, an evaluation field test was conducted in July 2010 at a four-day summer camp program by evaluators in Nebraska (Grandgenett, 2010). Adult presenters who were not previously involved with curriculum development delivered *Junk Drawer Robotics* to 15 youth members. The research methodology contained two strategies: 1) a pre-test, implementation, and post-test design, using two evaluation instruments: a 33-question Likert scale attitude survey and an open-ended content instrument; and 2) a feedback form similar to the instrument used in the formative data collection.

The attitude assessment did not find a statistically significant improvement in youth attitudes around science, mathematics, and learning. Though, this may have been due to the youth participants self-reporting relatively high on both the pre-test and post-test.

The content instrument examined "big ideas" within science and engineering with broad questions, allowing a variety of responses. The external evaluation team analyzed and scored responses based on whether the youth illustrated a deeper understanding from pretest to posttest. Findings showed a deeper understanding around STEM, especially pertaining to the definition of robots. For example, youth showed a deeper understanding on three items emphasized in the curriculum: "what is a robot" (46.6% of participants improved their knowledge), "how are robots used in real life" (33.3% of participants), and "what is a computer program" (33.3% of participants). There was not much improved understanding in "what is mathematics" (6.6%); however, while mathematics is included in some activities, it is not a focus in *Junk Drawer Robotics*.

The feedback form was completed by youth participants after each module was completed. The instrument contained six Likert scale questions which were aggregated based upon the responses of: *1-Strongly Disagree; 2-Disagree; 3-Neutral; 4-Agree; 5-Strongly Agree*. In both the youth and presenter feedback forms, the means for all questions tended towards the positive "agree" side. Presenters rated a little higher than the youth reported values (a range of 3.41 to 4.18 for youth and a range of 3.33 to 4.53 for presenters). The lowest means pertained to mathematics. Youth interest and engagement were rated highest by both groups on the 5 point scale (4.04 and 4.18 for youth and 4.44 and 4.53 for presenters). Overall, the results were positive for learning around science, engineering, and technology and excitement for the activities.

DISCUSSION

While not as prominent as science and math, and sometimes called the missing T and E in STEM, engineering and technology can be successfully added to out of school time nonformal science curriculum. The *Junk Drawer Robotics* curriculum shows promise in engaging youth in engineering and technology within a science framework. As illustrated earlier in this chapter, science, engineering, and technology overlap in mutually beneficial ways. The use of robots as the focal point provides a natural relationship for learning in these three domains.

Over the past 12 years, 4-H educators from various organizations have utilized earlier versions of what has become *Junk Drawer Robotics*. Anecdotal comments from these educators were overwhelmingly positive, and voiced desire for the revised and published curriculum.

Evaluation data collected for the *Junk Drawer Robotics* curriculum demonstrate gains in content knowledge around engineering and robots. These findings confirm other research on using robots in engineering and technology education and suggest hands-on robotics activities engage youth and increase science knowledge. These positive outcomes confirm the benefits of the *Junk Drawer Robotics* curricular structure, focus on process skills, activity framing in the experiential learning model, emphasis on small group learning, and the use of teenagers as presenters.

Junk Drawer Robotics curriculum may benefit from additional outcome evaluation with a larger sample (the Nebraska outcome evaluation only had 15 youth participants). Other evaluation avenues to explore may be looking at the influence of utilizing teenagers as teachers versus adult facilitators; application of concepts to the real world; and the effectiveness of curricular structure into three separate types of science (to learn), engineering (to do), and technology (to make). In addition, the evaluation efforts conducted thus far have not included the recent addition of a youth notebook. During the development process, adult educators identified the need for a place for youth to record their observations, complete their design drawings, and combine handouts into one place. The youth notebook may improve both SET understanding and language literacy. Future evaluation work could follow youth as they progress in the curriculum to determine if engineering skills of drafting, drawing, and designing improve.

CONCLUSIONS

The United States relies on scientific research and technological innovation to sustain its way of life. There has not been consistent emphasis on engineering and technology education, even with a national focus on STEM in formal education. However, there is a growing trend to include more engineering and technology in STEM education, as evidenced by the report *Engineering in K-12 Education* and the 2010 addition of "Engineering" to the *International Technology and Engineering Educators Association's* name. The theme of robotics utilizes the engineering design process while also engaging youth in science and technology, improving problem solving abilities, and increasing visibility of engineering careers. The University of California 4-H Youth Development Program is one of the leaders in nonformal science, engineering, and technology education. Starting with the SERIES curriculum, a set of process-focused science literacy curricula, the later expansion with YES for younger children, now *Junk Drawer Robotics* extends into engineering and technology processes and concepts. *Junk Drawer Robotics* moves forward youth science, engineering, and technology educational efforts.

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