AC 2012-4830: CHALLENGES OF INTRODUCING ENGINEERING IN AFTER-SCHOOL SETTINGS

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Rodger Dalton (B.S.E.E., NCSU, 1992, and M.S.E.E., Duke University, 2006) is an electrical engineer with 20 years of industry experience and holder of nine U.S. and foreign patents, with more than a decade of experience designing fiber optic telecommunication products. With a passion for teaching, Dalton has fostered the aspirations of young engineers and scientists from elementary school students to mentoring new-grad engineers as they begin their careers. During his undergraduate studies at NC State, he operated a private tutoring business that served hundreds of students and developed curriculum for the electric circuits lab. While attending graduate school at Duke, he coordinated the Techtronics after-school program at Rogers Herr Middle School in Durham, N.C. The excitement of working with younger students led Dalton to create Techsplorers in 2009. Techsplorers is an engineering enrichment program that operates summer camps at three locations in Raleigh and Chapel Hill in addition to online learning via HD streaming videos and electronics project kits.

Challenges of Introducing Engineering in After-School Settings

Abstract

TechXcite is an informal, project-based engineering program for middle school students. The program is a partnership between the Pratt School of Engineering at Duke University, the Department of 4-H Youth Development and Family & Consumer Sciences at North Carolina State University, and the National 4-H Council. The TechXcite curriculum is centered on seven themes (Wireless Communication, Biomedical Technology, Digital Imaging, Solar Energy, Transportation, Heating and Cooling, and Photonics). Within each theme are modules containing four to six 45 minute activities designed to engage kids in the engineering design process in an informal setting. Each module is intended to introduce a modern and exciting technology that children encounter in their everyday lives while encouraging meaningful exploration and use of math and science as problem solving tools. 4-H Afterschool staff, most of whom do not have any formal engineering education, teach the program. Prior to teaching a module, 4-H Afterschool staff participate in a one-day workshop held at a 4-H Extension Center. This paper examines the challenges of training after-school instructors, who often do not have a science or engineering background, to teach engineering modules. Survey data from instructors trained in California are utilized. In addition, the paper examines the impacts of the program on the students through focus group data collected from the same state. Focus groups, conducted by Compass Consulting Group who is responsible for the external evaluation of the project, have provided means for getting more detailed information on the engineering concepts students learn from the curriculum. Instructor surveys indicate an increased level of comfort with the material and that the material is of high quality for use in their after-school programs. In addition, challenges to introducing engineering in an after-school setting indicated by focus group data are discussed. *TechXcite* is an Informal Science Education program funded by the National Science Foundation (Grant 0638970).

Introduction

TechXcite is a partnership between the Pratt School of Engineering at Duke University, the Department of 4-H Youth Development and Family & Consumer Sciences at North Carolina State University and the National 4-H Council. The *TechXcite* curriculum began with engineering modules developed for the *Techtronics* After-school program funded by the Burroughs Wellcome Fund. *Techtronics* is an after-school engineering program taught by students from the Pratt School of Engineering at Rogers-Herr Middle School in Durham, NC, using the model developed by the National Science Foundation's GK-12 Program[1]. The *TechXcite* partnership has provided an opportunity to widely increase the dissemination of the after-school engineering curriculum developed initially for *Techtronics* and also to expand the breadth of the curriculum through the development of new modules.

TechXcite has dramatically increased the reach of the engineering curriculum developed by the Pratt School of Engineering Curriculum team from a single after-school program to programs all over North Carolina, West Virginia, and California. *TechXcite: Discover Engineering* modules have been used in approximately 219 programs in three states over the last 4 years. In the next two years, the program will expand to more than 100 additional after-school programs in four additional states: Colorado, Michigan, Missouri, and Oklahoma. Funding for training 4-H county professionals and after-school providers to implement the curriculum and funding for kit materials is provided by a National Science Foundation Informal Science Education Grant (Grant 0638970).

This paper briefly outlines the curricular materials that are available for use in programs across the country on our website including new video training and materials lists. In addition, it provides results from evaluation of instructor training and student focus groups to highlight some of the most difficult challenges the program has faced and discusses ways in which those challenges are being overcome.

Curriculum

The *TechXcite: Discover Engineering* curriculum is a significant expansion of the *Techtronic*s curriculum designed to create engineering curricula to meet the needs of the 4-H SET (Science, Engineering, and Technology) initiative. The modules are intended to introduce exciting technologies that students encounter in their everyday lives while encouraging meaningful exploration and use of math and science as problem solving tools. Although there is a significant amount of science curriculum available in 4-H supported after-school programs nationally, little of it deals specifically with engineering. New curricular modules are first piloted by Pratt School of Engineering undergraduate and graduate students in local after-school programs. Then, they follow the module development process shown below including iteration and video creation. This process has provided the opportunity for feedback from many parties including students, an external editor, 4-H partners, and after-school providers.

Module Development Process Phases

1. Create draft module
2. Test with students in local program
3. Revise and complete
4. Utilize in 10-20 sites in one state
5. Revise based on feedback
6. External Editor provides final edits
7. Create video based on training and feedback
8. Solicit feedback on video and revise
9. Create illustrations for instructor guides and youth handouts

The modules currently in the *TechXcite: Discover Engineering* curriculum are listed in Table 1 organized by phase in the development process.

Table 1:TechXcite: Discover Engineering Modules

Modules with Video (Phase 8 above)	**Piloted Modules** (Phase 5 above)	**Modules in Development** (Phase 1 above)
Bionic Arm	Bioimaging	Thermostats
Your TV Remote	Wireless Burglar Alarm	What’s a pixel?
Racing with the Sun	Quest for Speed	Engineering World Health
Cooking with the Sun	Rainwater Harvesting	Developing World Technology

As an example of how the modules are structured, the Bionic Arm module introduces kids to technology designed to help people with disabilities. The kids explore the design criteria of developing a prosthetic arm to improve the quality of life for someone who has lost an arm. The module demonstrates interdisciplinary design by combining mechanical, electrical, and biomedical engineering concepts. Students explore properties of gases and liquids by applying hydraulic and pneumatic principles to make a mechanical arm move. Then, they create a rudimentary touch sensor to enhance sensation. At the end of this module, each pair of students has designed and built their own prosthetic arm.

Each curricular module contains the following which is available on the *TechXcite* website at www.techxcite.org. Materials are put on the website as they are completed, so some modules have all four while others just have the Instructor's Guide and Youth Handouts online.

- **Instructor's Guide**: This is a downloadable pdf file written to teach an instructor how to implement the module. The Youth Handouts are included at the end of this file because the Instructor's Guide refers directly to them. Printing the Instructor's Guide includes all of the Youth Handouts.
- **Youth Handouts**: If you are looking to print just the Youth handouts, download this pdf. These pages are exactly the same as the back of the Instructor's Guide.
- **Online Video Training**: The Online Video Trainings for instructors are embedded on the TechXcite module web pages. Each includes an introductory video and a video explaining each activity. The videos are designed to prepare instructors for the modules by highlighting difficult parts of the Instructor's Guide. You can watch the videos in full screen by clicking on the embedded video to get to it on YouTube. The videos are designed to provide professional development and are not designed for students.
- **Materials Lists**: Each TechXcite: Discover Engineering module utilizes its own set of tools and materials. Materials for each module are accessible through links on that module's page. TechXcite does not sell these materials directly, but instead provides information on ordering the materials for programs. These are provided through Google Documents spreadsheets and are also downloadable as excel files. Ordering and packing lists are both created from the same online Google spreadsheet so that when updates are made, such as changing a suggested vendor, the changes automatically propagate through to all sheets.

Professional Development

The biggest challenge of developing and implementing the *TechXcite* curriculum has been taking the initial activities that were facilitated by engineering students and adapting them so they may be facilitated by after-school staff with little or no formal training in science, math or engineering. After-school providers are not necessarily teachers, they may not have a STEM background, and there is a high rate of turnover in the position. This curriculum delivery personnel difference (undergraduate and graduate engineering students vs. after-school staff) is a major difference between the *Techtronics* and *TechXcite* programs. For these reasons, professional development for the after-school staff is a crucial aspect of the *TechXcite* program. While training the after-school provider is ideal, TechXcite has followed both a train the provider and a train the trainer model during the grant depending on which works best for the programs in the partner state. The video training is intended to help providers who are not able to attend the training gain an even greater level of comfort with the material by connecting them with the training staff.

Professional development is provided through training workshops once a semester on new curriculum. Training is currently provided by the Duke curriculum team in the following areas: 1) content knowledge to enable staff to understand and teach concepts, and 2) training in experiential and inquiry-based learning to enable staff to effectively utilize these approaches. In each state, 2 one-day workshops are provided per year. In addition to discussing steps and content for each Learning Module, trainees will complete the hands-on projects prior to teaching them. The Duke Curriculum team models ways to facilitate projects for middle school students including the projects' building phase. The *TechXcite* training team facilitates activities as if the trainees are middle school students in order to model appropriate methods for introducing inquiry-based engineering design activities. Training is ongoing, which has been shown by the National Partnership for AfterSchool Science (NPASS) to be an important part of working with after-school providers[2].

Results

Compass Consulting Group, LLC, provides program evaluation, which includes analyses of assessments embedded in the curriculum, surveys of after-school staff and student focus groups. Initial results from embedded assessments, survey data, and an initial round of focus groups have been previously reported.[3,4] This paper focuses on the ways in which engineering concepts are incorporated by after-school providers and students through examining training survey results and youth focus group results.

Table 2: Instructor Training Quality (n=60) – Statements were on a five point Likert scale from Not at All Agree to Completely Agree with those that had no responses omitted.

Survey Question	Response	SP2010		F2010		SP2011		Overall	
		%	#	%	#	%	#	%	#
1. The TechXcite training method I participated in was the most effective training I could have received.	Somewhat	0%	0	4%	1	0%	0	2%	1
	Very much	50%	8	42%	11	44%	8	45%	27
	Completely	50%	8	54%	14	56%	10	53%	32
2. The TechXcite training I received was of the highest quality possible.	Somewhat	0%	0	4%	1	0%	0	2%	1
	Very much	50%	8	42%	11	33%	6	42%	25
	Completely	44%	7	54%	14	67%	12	55%	33
3. The training I received was extremely useful in helping me to facilitate the TechXcite curriculum.	Somewhat	0%	0	4%	1	0%	0	2%	1
	Very much	50%	8	23%	6	22%	4	30%	18
	Completely	50%	8	73%	19	78%	14	68%	41
4. My understanding of the teaching techniques used in facilitating TechXcite modules greatly improved due to the training I received.	Somewhat	0%	0	4%	1	0%	0	2%	1
	Very much	56%	9	35%	9	22%	4	37%	22
	Completely	44%	7	62%	16	78%	14	62%	37
5. I am completely comfortable building the physical projects presented during the training.	Somewhat	0%	0	4%	1	6%	1	3%	2
	Very much	25%	4	38%	10	17%	3	28%	17
	Completely	69%	11	58%	15	72%	13	65%	39

Training Survey Results

Training surveys were administered at the end of the professional development trainings provided to after-school staff. Results are based on 60 respondents from three of the trainings provided in 2010-2011 in California. Based on these surveys, instructors felt very comfortable facilitating the engineering modules at the end of the trainings (see **Error! Reference source not found.**). Specifically looking at pedagogical teaching techniques 99% of respondents very much or completely agreed that their understanding of the teaching techniques used in facilitating TechXcite modules greatly improved due to training. With respect to using the physical kit materials, 93% of respondents very much or completely agreed that they were comfortable building the physical projects presented during the training.

Table 3: Curriculum Quality and Impact (n=60) – Statements were on a five point Likert scale from Not at All Agree to Completely Agree with those that had no responses omitted.

Survey Question	Response	SP2010		F2010		SP2011		Overall	
		%	#	%	#	%	#	%	#
The program curriculum is of very high quality.	Somewhat	0%	0	4%	1	0%	0	2%	1
	Very much	50%	8	31%	8	17%	3	32%	19
	Completely	50%	8	65%	17	83%	15	67%	40
As a result of participating in the training my knowledge of science and engineering concepts related to these modules improved greatly.	Not at all	0%	0	4%	1	0%	0	2%	1
	Very little	0%	0	4%	1	0%	0	2%	1
	Somewhat	6%	1	12%	3	6%	1	8%	5
	Very much	50%	8	35%	9	33%	6	38%	23
	Completely	44%	7	46%	12	61%	11	50%	30
As a result of participating in the training program my knowledge about engineering in general has greatly improved.	Not at all	0%	0	4%	1	0%	0	2%	1
	Very little	0%	0	4%	1	0%	0	2%	1
	Somewhat	19%	3	8%	2	11%	2	12%	7
	Very much	44%	7	46%	12	39%	7	43%	26
	Completely	38%	6	35%	9	50%	9	40%	24
I am able to define what engineering is more easily as a result of the training I received.	Not at all	0%	0	4%	1	0%	0	2%	1
	Very little	0%	0	0%	0	0%	0	0%	0
	Somewhat	6%	1	12%	3	17%	3	12%	7
	Very much	38%	6	38%	10	28%	5	35%	21
	Completely	56%	9	46%	12	50%	9	50%	30

In addition, instructors also felt the curriculum was generally of a high quality and that it accomplished its goals of improving understanding of science and engineering (see Table 3). 99% of respondents very much or completely agreed that the program quality was very high. 96% of respondents agreed at least somewhat that training greatly improved their knowledge of the science and engineering concepts related to the modules for which they received training; 88% very much or completely agreed and 8% agreed somewhat. Most importantly, trainees generally felt that the training improved their understanding of engineering.

- Question 8: 95% agreed at least somewhat that their knowledge about engineering in general had improved greatly after training; 83% very much or completely agreed and 12% agreed somewhat.

- Question 9: 98% agreed at least somewhat that they were more easily able to define what engineering is as a result of training; 85% agreed very much or completely and 12% agreed somewhat.

Focus Group Results

Student focus group data is provided below from two of the programs taught by the group of instructors trained and surveyed above. The focus groups were approximately a half hour in duration and were conducted in separate groups of male and female students. The following are a few of the questions from the focus groups.

1) Do students know what engineers do?
2) Have there been changes in student attitudes towards science, math, and engineering?
3) Are students more or less interested in pursuing a career in science, engineering, and technology?
4) Do students in rural and urban counties have different preferences in engineering activities?
5) Do girls/boys have different preferences in engineering activities?

Three focus groups were conducted with students in two suburban middle schools in California with the following demographics.

Middle School A – 6 students (1 group)

- 0 female, 6 male
- 6 grade 7
- 1 African American, 5 Caucasian

Middle School School B – 12 students (2 groups)

- 3 female, 9 male
- 3 grade 6, 3 grade 7, 6 grade 8
- 2 African American, 4 Asian American, 3 Caucasian, 3 Hispanic/Latino

Total Students:

- 18 students
- 3 female, 15 male
- 3 grade 6, 9 grade 7, 6 grade 8
- 3 African American, 4 Asian American, 8 Caucasian, 3 Hispanic/Latino

When asked how they would define engineering and what engineers do, students at Middle School B said that engineering is building “things like houses, machines, and engines,” “using basic items to make something more complex,” “welding and metal work,” and making things that work”. They also said that engineers “make stuff,” and “build future technology.” They cited examples such as “new ways to make electricity” and “new types of gasoline for cars.” Similarly, students at School A said that engineering is, “building things,” “fixing stuff,” “welding,” “creating blueprints for others to build things from,” and inventing.

When asked about their enjoyment of the program, there were drastic differences between the two groups. All of the students at Middle School B said that they enjoyed the TechXcite lessons and would like to do more of them, but students from Middle School A generally did not like the modules. When asked about the things that they enjoyed the most, one 8th grade girl noted that she “really liked connecting the wires and seeing when things worked and when they didn’t work.” All 12 students liked “seeing if the battery worked,” “making the radios because they gave all kinds of stations,” and “racing the cars, even though they didn’t work sometimes.” In addition, students said that they would like to do more projects that involve building things that move, such as robots, engines, motor-boats, remote control helicopters, and “a leg that moves”. There were no differences between the boys and girls at School B with respect to the modules that they preferred. The reasons that School B students provided for what they liked included:

- We learn about how things work. (3 female, 9 male)
- We got to experiment with stuff and try things out. (3 female, 9 male)
- It was fun. (3 female, 9 male)
- Learning new things. (3 female, 2 male)
- We made friends because we had to communicate with each other. (6 male)

Unlike School B, School A students stated that they were all “disappointed” and “would not want to repeat it” or do more. When asked whether there was anything at all about the sessions that they did enjoy, half said that they preferred the Solar Oven because they “got to eat the cookies that we baked.” Three others said that they enjoyed “designing the oven” and “watching the cookie dough change” through the baking process. One also said that he liked the Bionic Arm and one liked the Quest for Speed but they would not give any reasons as to why. None of the students liked the TV Remote because they said “it was too simple” and “not exciting at all.”

Discussion

The above results from the training surveys and focus groups highlight challenges of the program in two different areas.

1. The difficulty in teaching concepts surrounding the roles engineers play in society.
2. The difficulties in delivering STEM content in after-school programs that sometimes are designed more for the purpose of child care than for delivering enriching content.

Regarding the roles engineers play in society. It was very encouraging that instructors left the trainings more comfortable with engineering and science concepts. As mentioned before, instructors often come to the trainings without a STEM background. Therefore, the fact that 83% of respondents very much or completely agreed that their knowledge about engineering in general had improved greatly after training, is a compelling result. It was also compelling that 85% agreed very much or completely agreed that they were able to define engineering more easily after the training. The training clearly provides confidence in understanding engineering, which was one of its most important goals. In retrospect, it would also have been useful to have the instructors define engineering in their own words on the surveys for comparison with the focus groups, which may be added in the future.

Based on focus group data, the students did have some understanding of what engineers do including future technology, working in teams, and designing things, though the central concept of design was not highlighted as much as hoped. The fact that students mentioned building and making things when asked about engineering was good. It was great to see responses like making future technology including new ways of producing electricity and new types of cars. These are the types of ideas that we want instructors to convey when introducing the material. The concept of communicating with each other was mentioned by six of the students at School B and highlighted the concept that the modules involve teamwork. At School A, the one that had the less positive results, one of the students did say that “designing the oven” was something he enjoyed. It is clear that the concepts of making new technology, teamwork, and design are a part of the curriculum. It was hoped that students would associate design more strongly with engineering. Based on the above information, it appears that instructors felt comfortable with the concept of engineering, but they did not know how to emphasize the concept of design while implementing the design challenges. While the trainings did emphasize that engineers design things, and it does provide activities in which students are participating in aspects of the engineering design process, the structure of the process itself was not highlighted because we had a concern that it would create a rigid environment that would feel too much like school for an informal after-school setting. In future trainings, the engineering design process as a means of approaching problems and helping students to think like engineers will be taught more explicitly to the instructors. This will be done by introducing the engineering design process and then highlighting where design fits into each activity for the students.

It should be noted that previous focus groups in North Carolina for TechXcite also found that students associated engineering with inventing things to help people, which was particularly good as engineers making a difference in the lives of people was identified by the National Academy of Engineering study, *Changing the Conversation: Messages for Improving Public Understanding of Engineering*, as an aspect of engineering that kids of both genders are excited about, but that kids do not often associate with engineering[4,5].

While students at School B were very positive about the program, students at School A did not enjoy it. While the experiences of School B were more typical of the program based on previous focus groups[4], the issues at School A bring up a concern that is generally a problem for delivering curriculum, even hands-on activities, in after-school programs. There are some after-school settings that are designed to provide little more than child care. They do not typically provide academic enrichment. At School A, where students did not like the modules, the students did not seem to like the after-school program in general either, and there didn’t seem to be an environment that was conducive to learning. Even a strong teacher might have struggled in such an environment. The results suggest that even instructors with a solid understanding of the curriculum are not effective in environments where it does not have the support of the in-school teachers or the after-school program.

Conclusions

In conclusion, training survey data indicate that instructors consider the TechXcite program to provide high quality training with high quality curriculum. The after-school providers leave training with an increased understanding of engineering and comfort level in facilitating the hands-on engineering design challenges in the modules.

Focus group data indicate that the program is succeeding in teaching students that engineers build and make future technology and work in teams. Students are also learning that engineers make a difference in the world through the wide variety of areas in which they work. In most environments, the program is also succeeding in creating an exciting experience that students would like to continue.

The challenge of delivering curriculum in after-school settings that lack structure conducive to learning was also highlighted in the focus group. While this is not typical of programs we work with as shown by results from previous focus groups, it is a problem that we continue to face in some settings. Moving forward, we will continue to work with state partners to identify sites for TechXcite that will operate in an atmosphere conducive to learning, and instructors who are enthusiastic about teaching the curriculum.

Finally, the focus groups helped identify areas of focus for future curriculum improvement. Students have learned that engineers build a wide variety of technologies, but there was not significant mention of designing these things. While the program has been emphasizing design, an explicit alignment for instructors and students of the activities to the engineering design process will likely help students better describe what engineers do and apply it to problems in their lives.

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