AC 2010-755: IMPACTS OF ENGINEERING IN 4-H AFTER-SCHOOL PROGRAMS

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Impacts of Engineering in 4-H After-School Programs

Abstract

TechXcite is an informal, project-based engineering program for middle school students being implemented initially in after-school settings. 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: Discover Engineering* curriculum is centered on seven themes (Wireless Communication, Biomedical Technology, Digital Imaging, Alternative Energy, Transportation, Architecture, and GIS/GPS). Within each theme are modules containing 4-6 activities designed to engage kids in the engineering design and scientific thinking 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. After-school staff, most of whom do not have any formal engineering education, teach the program. Prior to teaching a module, after-school staff participate in a one-day workshop held at a 4-H Extension Center. This paper examines the impacts of the program on student learning through focus group data collected during the first two years of the project in North Carolina. Focus groups, conducted by Compass Consulting, who is responsible for the external evaluation of the project, have provided means of getting more detailed information than survey data has provided so far. Focus group data provide a more thorough investigation of student attitudes towards science, engineering, and technology than surveys because they provide a a method for determining the reasons for student responses. The goals of these focus groups are to answer the questions: 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 completed during the fall of 2009 based on the Bioimaging and Your TV Remote modules, and data from those groups is presented. *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[1-4]. 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 and expanding to other states. *TechXcite: Discover Engineering* modules have been used in 28 programs in 18 counties in North Carolina over the past two years. In the following three years, the program will expand to 132 additional after-school programs in six additional states: West Virginia, Colorado, Michigan, Missouri, California and Oklahoma. Funding for training 4-H county professionals and after-school providers to implement the curriculum and funding for kit materials is being provided by a National Science Foundation Informal Science Education Grant (Grant 0638970).

This paper briefly outlines the curriculum development efforts and discusses the results of focus groups conducted during the fall of 2009 after the two most recent modules were tested: Your TV Remote and Bioimaging. Goals of the program are to increase knowledge of what engineers do, to increase enthusiasm for engineering, to increase competence in science, engineering among middle school students, and to female students in engineering.

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. 4-H SET has the goal of "preparing 1 million new young people to excel in science, engineering, and technology by 2013"[5]. 4-H SET is working with curriculum developers to develop engineering curricula to be used in 4-H supported programs. After the grant is completed, National 4-H will make the *TechXcite* curriculum available to its programs across the nation provided the curriculum meets the criteria of the 4-H National Review Jury process. This process is currently being updated to include specific criteria for 4-H SET curriculum. The Design-It engineering curriculum for after-school has shown that creative design projects can motivate students in an informal setting[6].

The *TechXcite: Discover Engineering* curriculum currently contains six modules in three theme areas: Biomedical Engineering, Wireless Signal Transmission, and Solar Energy. An additional 8 modules are being developed in four additional theme areas which are tentatively Digital Imaging, GIS/GPS, Transportation, and Architecture. 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.

As an example, 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. Students 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.

Learning Module Curriculum Package:
1. **Student Handouts:** A Student Manual for each Learning Module: Introduction, Objectives, List of Materials (including cost), Team Activity requiring co-operative experimentation.
2. **Instructor's Guide:** An After-school Instructor's Guide listing required tools/materials, providing inquiry-based methods for guiding students through each Learning Module. This Manual will also include background core principles for each module.
3. **Module Materials:** A *TechXcite* tool kit with essential, reusable tools to be used by the entire curriculum as well as some materials that will need to be purchased on an annual basis. Expendable supplies will be provided for the first two years to each participating site.

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 even necessarily teachers, and there is a high rate of turnover in the position, which has made it difficult to deliver the level of content we had hoped. 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 this reason, the activities are being designed to be self-paced so the kids can work through them with as little help from adults as possible. For this reason, professional development for the after-school staff is a crucial aspect of the *TechXcite* program.

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[7].

Focus Group 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 and survey data to date have been previously reported.[8] This paper concentrates on the focus group data from fall, 2009. The focus groups were approximately a half hour in duration and were conducted separately between male and

female students. Questions included 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? In fall 2009, focus groups were conducted with middle and elementary school students in three North Carolina counties: Iredell, Wayne, and Chowan.

Iredell (suburban) – 10 students

- 10 male
- 5 grade 3, 5 grade 4
- 1 Caucasian, 9 African American

Wayne (rural) – 13 students

- 6 female, 7 male
- 8 grade 6, 2 grade 7, 3 grade 8
- 0 Caucasian, 13 African American

Chowan (rural) – 6 students

- 4 female, 2 male
- 2 grade 6,, 3 grade 7, 1 grade 8
- 4 Caucasian, 1 African American, 1 mixed

Totals:

- 29 students
- 10 female, 19 male
- 5 grade 3, 5 grade 4, 10 grade 6, 5 grade 7, 4 grade 8
- 5 Caucasian, 23 African American, 1 mixed

When asked how they would define engineering and what engineers do, students in all three groups said that engineering is building "houses, motors, and engines", putting things together to "make them work" and inventing electronic things like radios. The middle school groups also noted that engineers build "stuff to help communities." They cited examples such as ultrasound equipment for "seeing inside of people" so that they can "tell how babies are growing or if they have tumors."

In response to questions about what they had learned about science, engineering, and technology that they did not know before, all of the groups discussed learning about mass and density and "why some balls float even though they're bigger than some of the ones that sink." All of the groups also talked about light and sound waves and how sound "bounces off of any solid object and comes back to us. That's how come ultrasound machines can send sound waves into a person's body and when they hit a baby or a tumor and the sound bounces back, the waves can make a picture of it to see what is going on."

When asked to suggest some real world uses for the information they had learned and how it would help society, students mentioned using ultrasound and x-ray equipment "to keep people

healthy or to make them better if they are sick", fixing cars "so people can get where they need to be" and making cars "that don't pollute." They also talked about other things that were unrelated to the modules such as building hospitals, recycling, and exercising.

All 29 students said they enjoyed the *TechXcite* lessons and would like to continue them. There was nothing that the students disliked, and no one suggested anything to improve them. Without exception, students said that "there was nothing that needed to be better or different." When asked about their favorite part of the modules, all 29 said that they liked floating the balls to see which ones would sink or float, trying to figure out where items were in the boxes with the holes, and learning about "how sound waves bounce off of things and come back to us." Six students in one group said that one of their favorite parts was making animal footprint castings.

The responses that students provided included the following. Note that the study included 10 females and 19 males:

1. The hands-on experiments and activities because all we do in science class in school is fill out worksheets. We learn more and understand better when we get to see how things work. (10 female, 19 male)
2. Doing experiments to see if they turn out the way you thought they would. (10 female, 19 male)
3. It was fun. (10 female, 19 male)
4. Learning new things. (10 female, 18 male)
5. Testing out your brain and having to think a lot. (8 female, 18 male)
6. Learning about how and why things work. (8 female, 15 male)
7. Working in groups and helping each other. (9 female, 4 male)
8. Learning about the similarities and differences between red wolves and foxes. (3 female)
9. You get to use art stuff to do science (3 female)
10. Learning the story about how x-rays were invented. (2 female, 1 male)

Discussion

The results from the focus groups are generally positive. A knowledge of what engineers do is one anticipated impact, and from the focus groups, the kids associate engineers with building things and inventing new things to help people. It is particularly positive that the range of things kids know that engineers work on includes biomedical devices and electronics in addition to more traditional areas such as houses, motors, and engines. It is also very positive that the kids associated engineering with helping people. 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[9]. Based on that research, this is an important impact identified by the focus groups. We would like to see students associate designing these things rather than just building them with engineering, so this may be an area of improvement for the future.

Another positive result from the focus groups is that the students enjoyed the program and would like to continue it in the future. The areas they liked were the portions that provided the most opportunity for inquiry-based discovery through hands-on activities. Most male and female students noted projects that gave them freedom to explore, hands-on activities, experimenting, and learning how things work were things they liked.

Female students more than male students identified the last four points in the list as areas they particularly enjoyed in the study. Working in groups and helping each other, using art to learn about science, and learning about the story behind x-rays were all identified by females more than males as things they liked about the curriculum. These suggest that females respond better to collaborative learning environments and to problems with well-defined stories surrounding them.

Conclusions

The focus group data in this study is preliminary but suggests areas in which the *TechXcite* program is succeeding, and suggests areas in which the *TechXcite: Discover Engineering* curriculum may be improved moving forward. The program is succeeding in teaching students that engineers make a difference in the world through the wide variety of areas in which they work. It is also succeeding in creating an exciting experience that students would like to continue.

The focus groups also helped identify areas of focus for future curriculum development. Students have learned that engineers build a wide variety of technologies, but they did not specifically mention that engineers design these things. More of an explicit emphasis on engineers as designing technologies will be useful moving forward. The focus groups also suggest that creating activities that include a more well-defined story as a context for the activities and providing students the opportunity to work in groups in order to attract female students are areas for improvement.

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