AC 2010-793: ENGINEERING BEYOND THE CLASSROOM

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Engineering Beyond the Classroom: Afterschool Experiences for Technological Literacy

Abstract

Technology surrounds us, and technological literacy benefits all members of society – engineers and non-engineers alike. Our understanding of technology influences a wide range of decisions we encounter in our daily lives, from selecting healthcare options to making informed product purchases and dietary choices. At the same time, most people have very few direct, hands-on connections to technology, except as finished consumer goods. This lack of engagement is responsible, at least in part, for societal shortfalls in technological proficiency.

In 2008, through support from the State General Assembly and Department of Education, seven organizations and institutions were awarded funding to develop an afterschool program designed to spark student interest in science, technology, engineering and math (STEM). The afterschool setting was targeted with the goal of creating opportunities for middle and high school students to build STEM skills through fun, hands-on activities in a relaxed atmosphere. The partners, which include our University, represent the education continuum from K-12 through higher education, and collectively have developed and implemented standards-based, hands-on, afterschool STEM programs, professional development programs, and STEM-related monitoring and evaluation contracts.

For their part, our University faculty applied the principles of problem-based learning in the context of “demystifying magic” to develop a module in which students explore events that appear to have a magical quality. Unlike most illusions, the “tricks” learned through these activities aim not only to mystify, but to demystify as well, as students unravel the STEM behind the sorcery. Phenomena related to surface tension, pressure differentials, buoyancy and the behavior of light are among those explored, and information about engineering applications is included with each activity, as well as resources related to black and female inventors. As a capstone event, students are challenged to stage their own magic show, creating original “tricks” based on what they learned.
Introduction

Importance of Technological Literacy

Technology surrounds us, and technological literacy benefits all members of society – engineers and non-engineers alike. Our understanding of technology influences a wide range of decisions we encounter in our daily lives, from selecting healthcare options to making informed product purchases and dietary choices. In Technically Speaking: Why All Americans Need to Know More About Technology, technological literacy is described as a critical characteristic of informed citizenship. At the same time, the authors note that “most people have very few direct, hands-on connections to technology, except as finished consumer goods” and that this “lack of engagement” is responsible, at least in part, for societal shortfalls in technological proficiency.

Overwhelming evidence exists that students from all backgrounds have the capacity to become technologically literate, and that children of all ages can and do engage in complex reasoning about the world. However, according to recent statistics published by the National Academies, “Just more than one-third of fourth graders reached the proficient level in mathematics in 2005, and the rates were lower for mathematics at grades 8 and 12, and at all three grades for science. International comparisons of student mathematics and science performance indicate U.S. students perform below average in mathematics and science for industrialized countries. U.S. 15-year-olds ranked 27th out of the 39 countries participating in the 2003 Program for International Student Assessment (PISA) examination, designed to assess students’ abilities to apply scientific and mathematical concepts to real-world problems.

At the same time, the U.S. Bureau of Labor Statistics forecasts that total employment in fields that the National Science Foundation classifies as science and engineering will increase at nearly double the overall growth rate for all occupations by 2014, growing by 26% from 2004 to 2014, while employment in all occupations is projected to grow 13% over the same period. Yet in spite of such promising job prospects, the National Science Foundation recently reported that the United States is experiencing a chronic decline in homegrown science, technology, engineering and math (STEM) talent and is increasingly dependent upon foreign scholars to fill workforce and leadership voids. Results from a recent survey by the American Society for Quality (ASQ) revealed that more than 85% of students today are not considering technical careers and that more parents encourage their daughters to become actresses than engineers. This is one of the most serious issues our nation will face over the next decade, as the current science and technology workforce retires without a pipeline of workers to replace them.

Demographic Disparities in Math and Science Achievement

According to the National Science Board’s Science and Engineering Indicators 2008, there are significant racial and ethnic gaps in science and mathematics performance, as evidenced by studies that follow the same groups of students as they progress through school. These studies “reveal performance disparities among demographic subgroups starting when they enter kindergarten… Although all subgroups made gains in mathematics and science during elementary school, the rates of growth varied and some of the achievement gaps widened.” Similar gaps were observed in rates of immediate college enrollment, with black and Hispanic students, as well as those from low-income and poorly educated families, trailing their white
counterparts or those from high-income and well-educated families. Currently, the state of Connecticut has the largest achievement gap between urban and suburban school districts in the country, with the greatest concentration of population in the cities and ring-towns. In light of the increasing diversity of the American population, such gaps are unacceptable.

The outlook is also bleak in higher education. For example, nationwide statistics show that in 2003, 68.3% of engineering degrees were awarded to Caucasians, 14% to Asian Americans, 5.1% to African Americans, 5.4% to Hispanic students and 7.2% to others. It is important to note that since 1999 there has been a declining trend in the number of Hispanic and African American students among all engineering graduates. At the same time, the percentage of bachelor’s engineering degrees awarded to women is only 20%.

Benefits of After School Programs

Well-implemented after school programs can have a positive impact on a range of academic and other outcomes, particularly for disadvantaged children and youth. Academic outcomes associated with participation in after school programs include:

- Better attitudes toward school and higher educational aspirations
- Higher school attendance rates and less tardiness
- Less disciplinary action (e.g., suspension)
- Lower dropout rates
- Better performance in school, as measured by achievement test scores and grades
- Greater on-time promotion
- Engagement in learning

After school programs can also promote social outcomes which contribute to in-school success. Many of the studies in which academic gains were accomplished through after school programs have also found gains in other developmental domains, which suggests that academic success is integrally related to a student’s social, emotional, behavioral, and physical well-being.

For instance, in a study of North Carolina middle-schoolers, it was noted that “in addition to [academic] achievement, psychosocial adjustment and in particular, students’ feelings of connectedness and perceptions of positive aspects following a transition into middle school were also moderately related to participation in extracurricular activities.” Similarly, Gardner, Roth, and Brooks-Gunn researched the connections between participation in high school extracurricular activities and success two and eight years after graduation. Among their findings was that “more intensive participation was also associated with greater educational, civic, and occupational success in young adulthood.” Research based on a longitudinal study of adolescents in Maryland had similar results as did the two-year longitudinal Study of Promising After-School Programs, which examined the effects of participation in quality after school programs among 3,000 elementary and middle school students in 14 cities and eight states. Results indicated that regular participation in after school programs was associated with improvements in work habits and task persistence, along with significant gains in standardized math test scores, compared to their peers who were regularly unsupervised after school.
Demographic Disparities in After School Program Participation

Significant demographic differences exist in activity participation across a range of both school-based and community-based after school programs. Recent research from the Harvard Family Research Project\textsuperscript{12} reveals that children and youth whose families have higher incomes and more education:

\begin{itemize}
\item Are more likely to participate in after school activities
\item Do so with greater frequency during the week
\item Participate in a greater number of different activities within a week or a month
\item Are more likely to participate in enrichment programs, while their disadvantaged peers are more likely to participate in tutoring programs, thus not reaping the benefits associated with enrichment experiences
\end{itemize}

These findings are especially alarming in light of multiple studies which conclude that youth experience greater gains across a wide variety of outcomes if they participate in after school programs with higher frequency over a greater number of years.\textsuperscript{16-22}

The Connecticut After School Grant Program

The After School Grant Program was established by the Connecticut General Assembly for the purpose of creating high-quality after school programs outside of regular school hours. After school programs are defined by the state as programs that take place when school is not in session and provide educational enrichment and recreational activities for students in grades K-12. These programs, located in elementary, secondary or other facilities, provide a range of services to support student learning and development while assisting working parents by providing a safe environment for their children.

Project Description

Overview and Objectives

In 2008, seven organizations and institutions were awarded funding by the Connecticut State Department of Education (CSDE) to develop an after school program designed to spark student interest in STEM. The after school setting was targeted with the goal of creating opportunities for middle and high school students to build STEM skills through fun, hands-on activities in a relaxed atmosphere. The project partners are listed below:

\begin{itemize}
\item School of Engineering and Technology at Central Connecticut State University
\item Connecticut Academy for Education in Mathematics, Science & Technology, Inc.
\item Connecticut Academy of Scientists and Engineers
\item Connecticut Career Choices and The Center for 21\textsuperscript{st} Century Skills @ Education Connection
\item Connecticut Center for Advanced Technology
\item Connecticut Women’s Education & Legal Fund
\item Connecticut Pre-Engineering Program
\end{itemize}
The partners, which include our University, represent the education continuum from K-12 through higher education, and collectively have developed and implemented standards-based, hands-on, after school STEM programs, professional development programs, and STEM-related monitoring and evaluation contracts. Several of the partners have conducted public campaigns to increase the engagement of historically underrepresented students in STEM fields.

In total, six standards-based curricular modules were developed by the project partners with the overarching theme of exploring 21st century problem solving. Each module included an Instructor’s Guide as well as a Demonstration Kit, which included all supplies necessary to conduct the activities. A brief description of each module is provided below.

1) **Aerospace Engineering, Middle School:** Students will explore the world of aviation and aerospace to discover what has motivated us to fly higher, faster, and farther. Through hands-on activities and experiments in flight dynamics, micro-gravity, and engineering principles, students will investigate the science, discovery and innovation that have driven the fields of aviation and aerospace. As the generation that will call space home, students will capture the entrepreneurial spirit of earlier pioneers in flight, and use their knowledge of aerospace engineering to design the first “space resort.”

2) **Scratch Game Development, Middle School:** Through the creation of Scratch games, students will learn important mathematical and computational skills, while also gaining a deeper understanding of the process of computer programming and game design. This project includes computer programming, computer animation, multimedia technologies and technical writing. Students will use Scratch to create interactive stories, animations and games that focus on STEM content and concepts and will share those creations on the Internet.

3) **Bio-acoustics, Middle School:** Students will explore how sound is produced, collected, analyzed and used in their surroundings as well as how sound is transmitted. They will use sound meters to study sound, and they will analyze sound using Audacity and Raven Lite free software downloads. They will explore questions like why we have two ears, what it is like to communicate without sound and how animals communicate. They will also consider noise reduction techniques.

4) **Using Evidence to Beat Criminals, Middle School:** Students will develop forensics skills and knowledge that will allow them to collect and interpret evidence to solve crime scene scenarios. Some of the evidence they will analyze may include prints and impressions, hairs and fibers, blood spatter, glass fragments and written notes. They will learn how to document evidence and arrive at evidence-based conclusions.

5) **Demystifying Magic, Middle/High School:** Students will explore the mystery in events that appear to have a magical quality. Events include occurrences that demonstrate phenomena such as surface tension, polarization of light, refractive index of light, chromatography, air pressure differentials, buoyancy, and numerical coding. Students will analyze what they see and describe how an event appears to be contrary to what they expect to happen. They will explore these magical phenomena and apply fundamental principles of science to arrive at an understanding of them.
6) **Cleaning Water – The Natural Way, High School:** Students will explore the need for remediation of water resources. They will look at the effect of plants and bacteria on water resources. They will explore linking the remediation of water with sustainable energy solutions and focus on the use of wind with a wind turbine and a wind powered electric water pump. Students will use the skills of science, math, engineering and technology to design and build model systems to clean water resources for human use.

Our university was responsible for development of Module 5: Demystifying Magic, which will be described in greater detail in a later section of this paper. Along with the modules, materials related to recruiting and retaining underrepresented students, bilingual public relations materials, and recommendations for monitoring and tracking were also provided.

**Development Process**

The partners agreed on the following principles to guide all development work:

- Increase the number of students, especially girls and underrepresented minority students, engaged in STEM after school activities
- Convey relevance to underrepresented student populations
- Motivate students to advance in STEM school-related programs and seek additional learning opportunities
- Broaden children’s view of STEM-related career opportunities and seek additional learning
- Engage children, parents/caregivers, educators and the community in STEM activities
- Connect after school program with the entire PreK-workforce talent pipeline
- Provide opportunities for industry and higher education mentoring and role models
- Include flexibility, variety, scalability and connectivity among various grade levels
- Deliver an inquiry-based, technology-rich program with a capstone project

Additionally, the partners agreed on the following:

- Modules must intrigue youngsters by engaging them in inquiry
- Modules must guarantee student success by building in both reinforcement for students weak in skills and further explorations for students wanting to go on
- Plan for modules to run 6 to 8 weeks, and expect 2 to 3 meetings per week of approximately 45 minutes each (16-20 hours of total contact time)
- Build modules for 20 students often working in groups of from 2 to 4 students, depending on the complexity of the activity
- Plan to keep materials and equipment costs around $500

**Review Process**

All project materials underwent two rounds of external peer review by committees of 3-4 reviewers per module or other program component (e.g., bilingual materials). The reviews were intended to provide developers with useful information to bring modules to completion and to produce a degree of consistency in the appearance and organization of all modules.
Reviewers were solicited by invitation letters sent to key stakeholders, including the school districts selected by the CSDE to pilot test the modules, as well as representatives from other school districts, industry, informal science, state government and universities. Each reviewer completed an extensive online survey with questions designed to thoroughly evaluate each module, and the results were reported to the module developers. A summary of the specific items assessed through these surveys is provided in Table 1. Combined, the development and review processes took six months to complete.

Table 1. Module characteristics evaluated through external peer review.

<table>
<thead>
<tr>
<th>THE MODULE</th>
<th>STANDARDS/GOALS</th>
<th>KNOWLEDGE AND SKILLS</th>
<th>COMMON MISCONCEPTIONS</th>
<th>STRATEGIES TO ADDRESS DIFFERENTIATED NEEDS AND TO ENGAGE UNDERREPRESENTED</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Is coherent or unified</td>
<td>- The table of contents identifies all the sections contained in the module</td>
<td>- The enduring understandings:</td>
<td>- Are clearly and concisely stated</td>
<td>- Are clearly and concisely stated</td>
</tr>
<tr>
<td>- Addresses all STEM areas: mathematical/computational skills, lab/investigative skills, technological skills, engineering skills and the development of concepts in those areas</td>
<td>- The summary coherently describes:</td>
<td>- Are clear, concise and comprehensive</td>
<td>- Are addressed in module activities</td>
<td></td>
</tr>
<tr>
<td>- Demonstrates an appropriate sequence in the development of concepts and skills</td>
<td>- The goals</td>
<td>- Have lasting value</td>
<td>- Are likely to be challenged by module activities</td>
<td></td>
</tr>
<tr>
<td>- Will appeal to the STEM target audience</td>
<td>- The organization</td>
<td>- Are at the heart of STEM</td>
<td>- Are clearly and concisely stated</td>
<td></td>
</tr>
<tr>
<td>- Has opportunities for collaborative work</td>
<td>- The activities</td>
<td>- Require exploration of abstract and often misunderstood ideas</td>
<td>- Are utilized in module activities</td>
<td></td>
</tr>
<tr>
<td>- Reinforces students’ development of verbal and written skills</td>
<td>- A module that sounds intriguing</td>
<td>- Are appropriate to the module</td>
<td>- Are clearly and concisely stated</td>
<td></td>
</tr>
<tr>
<td>- Has elements that need further development (specify)</td>
<td>- The summary describes a module that students:</td>
<td>- Are appropriate for the students</td>
<td>- Are utilized in module activities</td>
<td></td>
</tr>
<tr>
<td>- The module title will attract the STEM target audience</td>
<td>- Will want to participate in</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Can relate to</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### CAPSTONE ACTIVITY
- Will engage students in critical thinking skills such as synthesis, analysis, evaluation and/or problem solving
- Utilizes skills and knowledge developed in the module’s activities
- Provides an authentic performance task where students can demonstrate their understandings and skills
- Includes clear, concise and comprehensive performance criteria to judge students’ development of skills and understandings
- Brings all of the STEM areas together

### ACTIVITIES
- Are interesting and engaging
- Are inquiry-based
- Help students develop STEM skills
- Help students develop STEM understandings
- Are technology rich
- Are grade level appropriate
- Are effective for various learning styles
- Should increase confidence and insure success
- Titles catch attention and interest
- Guiding questions are clearly and concisely stated
- Guiding questions are intriguing
- Guiding questions focus on valuable learning outcomes
- Overviews describe activities clearly and concisely
- Overviews develop an element of intrigue for students and staff
- Materials are identified specifically
- Materials have quantities clearly stated
- Student instructions are clear, concise and complete
- Student instructions are easy to follow
- Student instructions provide tables, charts and handouts as required
- Student instructions engage students in critical thinking and problem solving
- Student instructions address safety issues
- Instructor notes are clear, concise and complete
- Instructor notes identify and explain safety issues
- Instructor notes are adequate to allow an instructor with limited STEM background to be successful in supporting students in their investigations
- Instructor notes inform the instructor about expected results
- Instructor notes provide adequate content and concept development to allow an instructor with limited STEM background to be successful in supporting students in the interpretation of their findings
- Instructor notes suggest ways to broaden or modify activities
- Instructor notes suggest support for students in need of additional skill development

### LITERATURE AND OTHER RESOURCES
- Are specifically identified
- Include such areas as print, Internet and video materials

### MATERIALS
- Are identified specifically
- Have quantities clearly stated
- Have suppliers clearly identified
- Have approximate costs included

### STAFF DEVELOPMENT MATERIALS
- Are clear, concise and complete
- Identify and explain safety issues
- Are adequate to allow an instructor with limited STEM background to be successful in supporting students in their investigations
- Inform the instructor about expected results
- Provide adequate content and concept development to allow an instructor with limited STEM background to be successful in supporting students in the interpretation of their findings
- Suggest ways to broaden or modify activities
- Suggest support for students in need of additional skill development
“Demystifying Magic” – Module Overview

It was recently reported that “Comparisons of science standards and curricula in the U.S. with that of countries that perform well on international science tests reveal overly broad and superficial coverage of science topics in U.S. classrooms … an overemphasis on recipes for data collection procedures may strengthen the misconception that scientific discoveries emerge unproblematically if one just faithfully follows the steps outlined in the science text.”  

With this and the project partners’ guiding principles in mind, our University faculty applied the principles of problem-based learning in the context of “demystifying magic” to develop a module in which students explore events that appear to have a magical quality. Unlike most illusions, the “tricks” learned through these activities aim not only to mystify, but to demystify as well, as students unravel the STEM behind the sorcery. Phenomena related to surface tension, pressure differentials, buoyancy and the behavior of light are among those explored, and information about engineering applications is included with each activity, as well as resources related to black and female inventors. As a capstone event, students are challenged to stage their own magic show, creating original “tricks” based on what they learned.

Module Organization

This module is a plan for 21 after school activities organized into six sub-units (labeled ‘I’ in Figure 1), plus discussion sessions (II) and a capstone activity (III). Most activities are designed to be experienced in one 45- to 60-minute period. Additional periods are allotted for students to develop personalized illusions and to plan and rehearse the capstone performance.

Each sub-unit is focused on a single scientific principle, and designed for about three after school periods (see Figure 2). The teacher begins with the

Figure 1. Module organization.
demonstration of an illusion, and then provides opportunities for students to use inquiry skills to demystify the illusion. Students are then challenged to develop their own illusions, employing the same principle, for use in the capstone performance.

Table 2. Sub-unit content and themes.

<table>
<thead>
<tr>
<th>theme</th>
<th># illusions</th>
<th># activities</th>
<th># extension activities</th>
<th>scientific / mathematical principles</th>
<th>engineering connections</th>
</tr>
</thead>
<tbody>
<tr>
<td>Properties of Water (sub-unit 1)</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>• surface tension</td>
<td>• bioengineering</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• capillary action</td>
<td>• hydrology</td>
</tr>
<tr>
<td>Light and Energy (sub-units 2,3)</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>• index of refraction</td>
<td>• photonics</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• polarization</td>
<td>• fiber optics</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• axis of light transmission</td>
<td></td>
</tr>
<tr>
<td>Materials in Motion (sub-units 4, 5)</td>
<td>4</td>
<td>6</td>
<td>2</td>
<td>• pressure differentials and distribution</td>
<td>• aeronautics</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• buoyancy and density</td>
<td>• transportation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>engineering</td>
</tr>
<tr>
<td>Logic and Probability (sub-unit 6)</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>• correspondence</td>
<td>• cryptology</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• binary number system</td>
<td>• computer science</td>
</tr>
</tbody>
</table>

Ongoing Guided Discussions

This module contains two discussion topics, “Inventiveness, Invention, and Inventors” and “Magic, Science, Technology, and People,” with six questions designed to encourage deeper student thought about the personal, societal, and even academic issues related to the STEM
content in the unit. The discussion topics in “Magic, Science, Technology, and People,” while not inappropriate for younger students, are most suited for high-school students. The three “Inventiveness, Invention, and Inventors” questions are intended for younger students, but any of the six, with some instructor guidance, should be useful for students in middle or high school.

**Capstone**

The capstone event for this module is a “magic show” designed, directed, and performed by students. Although practical and educational limitations will be placed on this project by the instructors and the logistics of an after school project, this is a very open-ended challenge. Outlines for four “Capstone Planning Sessions” are included in the Instructor’s Guide. These sessions, most of which can take as little as ten minutes each, are intended to be conducted throughout the term as time is available. The purpose of these sessions is for the class to arrive at consensus on a series of questions designed to help shape the final capstone presentation. The main questions which will need to be answered over the course of the term relate to the goals of the event, its format, the assignment of roles and responsibilities to students, and scheduling the event.

**Professional Development**

During the program’s pilot year, 2008-2009, faculty from our University met with the high school teacher selected by the CSDE to pilot our module (see Implementation and Assessment section of this paper) for a series of training sessions. Faculty were also available on an ongoing basis for consultation or questions. In addition, an interactive, multimedia tutorial was developed as a supplemental training resource (see Figure 3).

**Major Stem-Related Goals**

In terms of mathematics content as described in the 2005 Connecticut Mathematics Curriculum Framework, most of the mathematic concepts and skills emphasized in this module relate to Domain 4, Working with Data. These are correlated to the Framework’s Expected Performances for Grade 8 and for the Grade 9-12 Core. The module’s technology focus is aligned with the Expected Performances for Grades 9-12 of Content Standard 4, the Creation and Use of

The authors of the 2004 Connecticut Core Science Curriculum Framework identify two distinct bodies of standards: those which relate to scientific literacy and those which relate to “conceptual themes” in physical, life, and earth sciences. The primary conceptual themes emphasized in this module are related to Physical Science (Themes II, III, and IV). But perhaps most importantly, this module also has a cross-disciplinary focus on innovation. The relevant state science standard is Conceptual Theme I: Inquiry; the relevant technology standard is Standard 3: Research, Design & Engineering. Note that themes from Ongoing Guided Discussions are not included in Table 3 because their implementation will vary widely depending on the age of the students.

Table 3. Major STEM-related goals.

<table>
<thead>
<tr>
<th>theme</th>
<th>content-related goals</th>
<th>process-related goals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Properties of Water</td>
<td>● Properties of Matter (SCI II)</td>
<td>● Working with Data (MATH 4)</td>
</tr>
<tr>
<td></td>
<td>● Forces and Motion (SCI IV)</td>
<td>● Inquiry (SCI I)</td>
</tr>
<tr>
<td></td>
<td>● Creation and Use of Technology (TECH 4)</td>
<td>● Research, Design and Engineering (TECH 3)</td>
</tr>
<tr>
<td>Materials in Motion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light and Energy</td>
<td>● Energy Transfer and Transformation (SCI III)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>● Nature and Evolution of Technology (TECH I)</td>
<td></td>
</tr>
<tr>
<td>Logic and Probability</td>
<td>● Working with Data (MATH 4)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>● Nature and Evolution of Technology (TECH I)</td>
<td></td>
</tr>
</tbody>
</table>

Strategies for Recruiting and Retaining Underrepresented Students

Overview

The development of the recommendations and resources for recruiting and retaining underrepresented students was led by the Connecticut Women’s Education and Legal Fund. The following were included in the definition of “underrepresented students”:

- Female students
- Students who are categorized as a racial/ethnic minority
- Students who live in high-poverty communities
- Students who may not have previously shown interest or self-selected into STEM activities or programs
- Students who have disabilities
- Students who will be the first generation in their families to attend college

The overall strategies for the recruitment and retention of underrepresented groups have much in common with best practices for after school programs developed out of a youth development model. However, these known strategies for success may need to be applied differently depending upon culturally and historically specific characteristics of a community (urban, rural, and suburban) or of sub-populations (race, class, or gender specific). For example, what may work with girls in high-performing schools in well-resourced high schools may not work with Latino boys in the same setting or a setting that is more rural, or with fewer resources. Race, social class and gender may differently impact students depending upon the environments in
which students learn. Some recommended strategies for reaching all students with STEM after school activities are listed below:

Content-based Strategies

- Use and teach with the latest technologies and provide students with tools from many and various media
- Contextualize activities by connecting with real-life situations and societal issues
- Provide opportunities for individual student expression and connection to their cultures and experiences
- Provide students with as much choice as possible in some aspect(s) of the activity
- Provide activities that link content areas (for example, dance and geometry, writing and astronomy)
- Provide a varied slate of activities

Pedagogy-based Strategies

- Make personal connections with students and facilitate student connections with program staff and others
- Emphasize and give students time for reflection on group process
- Consider students’ learning styles
- Structure opportunities for students to take leadership roles
- Provide safety for students to take learning risks
- Provide for group/team building activities from day one
- Allow for flexible grouping, but also be vigilant for students falling into gender-stereotypical roles

The strategies for recruitment and retention should be dynamic as research and practice knowledge is both culturally and community specific and times and conditions change. Therefore, these approaches cannot be static, but must be consistently revisited and revised. Materials developed for outreach and professional development should be available in multiple formats depending upon the needs of the audience.

Bilingual Public Relations Materials

An outside creative agency was contracted to develop bilingual public relations materials for the program. Their rationale was based on key focus group findings, which revealed student perceptions of technology-based after school programs as “too long and boring” and “for nerds.” Some participants confessed concerns that they might not be “smart enough to participate” and described the ideal after school program as including “assistance with homework, creative activities and sports.”

In light of this, the agency decided to pursue the approach of a “Lifestyle Campaign,” which reflected the current lifestyles of Latino youth by means of cultural cues, such as dancing, colors and an urban setting. Materials included eye-catching posters (see Figure 4) with messages such as “The Laws of Physics. You can’t break them, but you can break to them,” and “Understanding gravity will help you defy it!”
To appeal to Spanish-speaking parents, a bilingual flyer was developed for dissemination in areas trusted and frequented by both students and parents, such as schools, community centers and churches. In a recent installment in the Harvard Family Research Project’s series of evaluation briefs, “Issues and Opportunities in Out-of-School Time,” Lauver et al. list effective outreach to families among the key strategies for getting students into programs and sustaining their participation, underscoring the importance of parent involvement.

Implement and Assessment

One middle school, one high school and one school district (representing three districts in total) were selected by the CSDE through a competitive grant application process to pilot the STEM after school program materials during the 2008-2009 academic year.

In the pilot and subsequent years, it was recommended by the program partners that the CSDE should monitor programs to insure module integrity, document any changes made to content or format, and offer technical assistance and/or resources. Additionally, the CSDE was advised to collect baseline and year-end data relative to outcome and process goals with respect to programming, students participating in programs, and instructors implementing the STEM modules. These data are necessary to document program strengths and challenges, disseminate best practices, and make connections between STEM after school program participation and further STEM course-taking and achievement. It was also recommended that data collection efforts be aligned with the current evaluation design for state-funded after school programs so that the data collected can be analyzed for any commonalities and distinctions among and between STEM and regular after school programs.

Initial Conclusions and Future Directions

In fall 2009, representatives from the seven organizations and institutions responsible for module development met with key personnel from the CSDE and pilot districts for an informal
discussion of outcomes. Although feedback from the pilot districts was positive overall, it will be
difficult to draw any conclusions regarding the impact of the program until formal student
monitoring and tracking measures are put into place. To this end, the CSDE has released a
subsequent request for proposals from institutions seeking funding for the expansion or
implementation of high-quality after school programs, including the STEM program described in
this paper. Among other requirements, a funded applicant must commit to the following
activities related to program assessment:

1) Providing an *End of Year Report (EYR)* that describes project activities, accomplishments
and outcomes to include school attendance, student achievement and in-school behavior
of student participants.
2) Participating in evaluation studies and data collection conducted by CSDE and their
subcontractors.
3) Setting aside five percent of the annual grant budget for the statewide data collection and
evaluation project.
4) Providing program and student data for the statewide evaluation project in a timely
manner. The data to be collected must include:
   - Site information
   - Details of activities offered (e.g., start and end dates, type of activity)
   - Teacher surveys
   - Staff demographics
   - State Assigned Student Identification (SASID) numbers
   - Student demographics
   - Program attendance
   - School attendance

With the addition of this quantitative and qualitative data, it will be possible to more rigorously
evaluate the effectiveness of our program and the extent to which we achieved the goals that
were established at the onset of the development process. We are optimistic that the hands-on
and problem-based nature of our modules will prove to be an excellent way of piquing student
interest and excitement about STEM and improving their technological literacy.

**Bibliography:**


9. (2009) Mommas don’t let their babies grow up to be engineers. ITworld.


