# AC 2009-1247: A MIDDLE-SCHOOL PROJECT FOR SCIENCE AND MATH ENHANCEMENT THROUGH ENGINEERING


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# A Middle School Project for Science and Math Enhancement through Engineering


## Abstract

This study is focused on the impact of curricular and extra curricular engineering-based instructional activities on middle students' perceptions of their ability to become engineers. Middle school students are at an age where high interest activities are essential for motivation and relevant learning. This is also the age where students' interest can be piqued to consider careers in STEM fields. This study also looks at math content knowledge, attitudes toward math and science, and perceptions of technology, engineering, and what defines engineering.

In 2007, the Stillwater Middle School received a $15,000 grant from the Stillwater Public Education Foundation to start an engineering program for sixth- and seventh-grade students. The grant allowed the middle school to partner with Oklahoma State University to develop a multi-faceted engineering program. Through this partnership between the middle school and local university, three primary instructors have developed, coordinated, and conducted the majority of the components of the program. The ideas and initiative behind the program were proposed and enacted by a chemical engineering professor at Oklahoma State University, who is also highly involved in the pre-service teacher program at the university as well as several engineering education initiatives at her university. She has partnered with two middle school science instructors to develop, fund, conduct, and expand the engineering program at the middle school.

*The Enriching Science and Math through Engineering* project consists of the following three components for students with an embedded teacher professional development program for middle school teachers. **A Curriculum Integration project** has sixth and seventh grade core team teachers (math, science, social studies, and language arts) using existing and new integrated engineering modules during school. The new modules were developed by the teachers working with engineering and education professors. **A Summer Camp** is an engineering project based program for $6^{th}$ and 7th grade students delivered by two science teachers with support from an engineering professor. **An After School Mentoring Program** that meets once a week for 45 sixth and seventh grade girls. The College of Engineering provided mentors to support the students in understanding engineering and to encourage them to consider engineering careers. Middle school students participate in engineering projects that were age appropriate and encouraged problem solving, creativity and collaborative learning, as well as meet professional engineering women. Seventh grade girls served as cross-age mentors for sixth grade girls in addition to the college level mentors. In 2007, the engineering professor was the lead for the project. In 2008, the two middle school science teachers are providing project leadership.

A variety of instruments were administered to determine mathematics and science content knowledge changes, knowledge about engineering and technology and the impact the instructional activities had on overall student perceptions. Results have shown positive impact of the interventions.

## Background

Teachers and researchers alike initiated this research with concern for the special learning needs of middle level students and an enthusiasm for learning how a focus on engineering lessons and activities might increase students' motivation and interest in science and mathematics and engender new career interests in engineering.

Middle school students are students in transition.[1] In this developmental phase of continued brain development and grand physiological changes, middle schoolers also begin dramatic changes in their school structure, responsibilities, and social relationships. By the time they reach middle school, students have already begun to develop dispositions toward mathematics, science, and engineering.[2-4] By ninth grade, these dispositions are solidified and it becomes more difficult to change the students' feelings toward STEM careers.[2] In this period of early adolescence, students either begin to develop strong academic habits or they begin to struggle academically.[3] "Middle grade[s] students are drawn toward mathematics if they find both challenge and support in their mathematics classrooms."[1] Therefore, it seems essential for middle schoolers to engage in interesting, relevant learning.

Some students, at or near middle school age, develop anxiety or an aversion to mathematics believing that only certain students can be good at math and that no amount of effort can make a difference for those who are not good at math [5-6] Referencing the many people who do not use "math" and "simple" in the same sentence, Dewdney[7] and Withnall[8] suggested, ". . . even people who are quite competent in other areas of life are not ashamed to admit they can't do math. Innumeracy is more socially acceptable and tolerated than illiteracy."

Students' developing beliefs, that their own difficulties with mathematics are due to a lack of ability, undermine their motivation and can lead to math anxiety.[3] Teacher support can be an important factor in managing for math anxiety and motivating middle school students to learn mathematics and science. Teachers' encouragement and support can lead to students' increased interest and enjoyment in school work, enhanced academic self-image, and greater expectancies for school success (in science and mathematics) in the classroom.[3]

The National Research Council[9], the National Council of Teachers of Mathematics[1] and the National Science Standards[10] recommended inquiry learning experiences to anchor science and mathematics content understanding. Without inquiry, students may have a difficult time learning new material.[11] Petrosino, Lehrer, and Shauble[12] refer to important inquiry science tools that allow students to extend their everyday experiences and organize data in ways that provide new insights. Imagination is one of the least emphasized science processes.[13] Indeed, research on students' perceptions of science indicates that they see scientific work as dull and rarely rewarding, and scientists as bearded, balding, and working alone in the laboratory.[14]

Middle school students need to be able to conceptualize science and mathematics in ways that allow them to understand and transfer learning to new situations.[1,15] Students need to learn in a balanced way. They need both procedural and conceptual knowledge.[16] Conceptual understanding involves the concepts, operations and relations in mathematics; this web of connections between discrete pieces of information is essential to learning mathematics. When students can make real-world connections while they are learning science and mathematics, they become more fluent and able to transfer their knowledge to new situations.

Science and mathematics are closely related systems of thought and are naturally correlated in the physical world. Science can provide students with concrete examples of abstract mathematical ideas that can improve learning of mathematics concepts.[17] Children learn best when they discover through their own concrete experiences.[18-20] Math can enable students to achieve a deeper understanding of science concepts by providing ways to quantify and explain science relationships. Science activities illustrating mathematics concepts can provide relevancy and motivation for learning mathematics.[17,21]

In order for the United States to become a nation of thinkers and problem-solvers, teachers must move toward *why* rather than *how to* as the goal in mathematics -- and education in general.[22, 23] This teaching for understanding means, as McKinney[24] posited, "students don't just memorize information but actively seek it. It means that teachers are facilitators, not just preachers of facts. It means moving away from simply absorbing facts, to constructing knowledge." With regard to increased motivation, Berlin[21] found that students greatly enjoy integrated lessons but that teachers, administrators, and parents worry whether students are really learning or simply playing. Barab[25] found high school students showed higher interest in integrated classroom activities and their cooperative-group, problem solving skills increased. Jacobs[26] reported integrated curriculum associations with higher attendance and better attitudes toward school.

Problem based learning (PBL) situates students' learning in the real world, focuses on relevant learning and problem solving skills essential to daily life.[27, 28] PBL experiences enable students to make connections between what they are learning and how it can be used. These real-world connections make learning more useful and more transferable.[27,29] Roth[30] suggested that PBL helps students recognize their misconceptions, build upon those misconceptions, and create new knowledge. When they are working within a problem solving milieu, students are not simply memorizing science or mathematics content without connecting it to their own real-world conception.[27]

Engineering education bridges classroom lessons to real world experiences through concrete applications.[31] Engineering provides a vehicle for integrating science and mathematics – and a context for the relevance and application of science and mathematics.[32] Given that women and minority populations are under-represented in engineering professions, and that engineering degree enrollments are flat, there is grave concern for the general public's limited awareness of engineers and their roles in creating new technologies and in improving our quality of life.[32] As Mooney et al[2] suggested, "In order to encourage students to pursue careers in engineering, educators have to improve attitudes and perceptions towards math, science and engineering, develop students' content knowledge in mathematics and science, and must provide positive engineering experiences." Certainly, engineering education in middle school can serve to introduce engineering as a viable career option. As Berryman suggests,[2] it may be essential to reach students in the middle grade years, as students begin to identify their career plans by ninth grade. So too, "Emphasizing the usefulness that science and engineering has for improving peoples' lives can persuade a wider range of young students to study these fields."[33]

Research and intervention projects since American Association of University Women (AAUW) Educational Foundation's report *How Schools Shortchange Girls* have indicated patterns of progress in improved instruction and innovative learning opportunities for girls.[34] Still, many bright students, particularly women and minorities, choose not to pursue engineering careers.[2] Though women make up nearly half of the U.S. workforce, they make up only 26% of the STEM (science, technology, engineering, and mathematics) workforce.[36]

**Research Methods**

The following research questions have guided the study for the middle school engineering program:

- In what ways do engineering projects and exposure influence middle level students' ideas and attitudes towards science, mathematics, and engineering?
- Is there a pre/post difference between male and female students' attitudes towards math, science, and engineering?
- Is there a pre/post difference between those students in after-school mentoring, summer camp, and curriculum interventions (as compared to no intervention students') regarding attitudes towards science, mathematics and engineering?

<u>Participants</u>

Participants included current 6-9$^{th}$ graders (N=1,287) and 12 teachers (all content areas) from Stillwater Middle School. Two science teachers from this group (one 6$^{th}$ and one 7$^{th}$ grade) led the after-school mentoring program and the engineering summer camps along with university faculty in Science Education and Engineering. This middle school serves approximately 757 sixth and seventh grade students (78% Caucasian, 9% African American, 3% Asian, 3% Hispanic, and 6% Native American). Approximately 32% of the student body are eligible for free and reduced lunches. These 12 project teachers utilize Standards-based curriculum and regularly participate in district-wide professional development days (5 per year). The 2 science teachers (1 early career and 1 experienced teacher) also attend annual state and national science conferences and have helped lead engineering summer camps for middle level students. During the 2006-2007 school year, 81% of the 6$^{th}$ grade students and 90% of the 7$^{th}$ grade students scored at satisfactory or above on the state assessments in mathematics (science exams are not yet required). In 2007, nearly 40% of seventh graders tested scores at the advanced level in mathematics as compared 22% at the state level.

**Interventions**

<u>Summer Camp</u> The introductory camp was designed in 2007 to focus on the process of engineering, and included students who had not previously participated in the middle school engineering program. Students self selected to participate in the program. During the camp, students completed projects allowing them to discover the differences between science and engineering, as well as product versus process design. The students worked in cooperative groups to design candy airplanes, engineer the best popcorn, design products that use slime, and formulate the best film canister rocket propellant. The advanced summer camp (developed in 2008 and administered along with the intro camp in 2008) focused on environmental

engineering, and included students who had previous experience with the engineering program. During the camp, students were given the challenge to uncover the cause of a mysterious illness that affected an imaginary town. The students then used the information to determine the best solution for the environmental problem. The aforementioned middle school instructors and chemical engineering professor compiled the curriculum and co-taught both camps.

*After School Mentoring Program* The middle school instructors and university professor also collaboratively plan and oversee the after school mentoring program that was started in fall 2007. Approximately ten female engineering students each serve as mentors to groups of four to five female middle school students (for a total of 45 girls). The female students in $6^{th}$ and $7^{th}$ grade self select into the program. The mentors are selected from an application and interview process. The middle school students complete engineering projects, talk with guest speakers about opportunities within engineering professions, and take field trips to watch engineers in the field. Examples of engineering projects the groups have completed include designing a water purification system; designing and building trebuchets; designing homes to protect penguins from the effects of global warming; and working with robotic cars. A major project that was undertaken is the *Amazon Mission* module developed at the Boston Museum of Science as part of their Building Math.[37] The focus of this project is to strengthen student's algebraic skills through engineering activities. "The students build a carrier to insulate medicine, filter water, and devise a plan to stop the spread of influenza." Transportation is provided to the students to insure that all socioeconomic levels of students can participate.

*Curriculum Integration Project* Two core teams (one sixth and one seventh grade) taught an integrated thematic unit entitled *Get A Grip* (originally developed at Northwestern University and funded by the National Science Foundation). This dynamic, interdisciplinary unit is aligned with both the National Science Education Standards [10] and the *Benchmarks for Science Literacy*.[13] The unit was taught in May of each year (in sixth grade the first year and seventh grade the second year) by four teaching team members (science, mathematics, social studies, and language arts). The timing was necessitated by the need to avoid conflict with state testing. Some adaptations were introduced in seventh grade as some of the students had participated in *Get a Grip* during their sixth grade year. This *Get a Grip* unit exemplifies the notion that "the best way to become familiar with the nature of engineering and design is to do some."[13]Authors Olds, Harrell and Valente,[38] intended the *Get a Grip* Curriculum would: (1) familiarize middle school students with engineering as a career, (2) help students to understand the design process, and (3) encourage students to make connections between science concepts and a real-world engineering task. "A critical component of the unit is its ability to demonstrate to middle school students that strong, interdisciplinary knowledge is required to solve engineering problems."[38] Students are challenged to design a prosthetic arm (from common materials) to help 12-year-old Afghani girl eat and carry water from a nearby river to her home. (For more information on the structure of the unit, visit www.middleschoolengineers.com).

**Project Assessments**

A mixed methods procedure with both quantitative and qualitative data collected simultaneously was used. See Table 1 below.

**Table 1 – Project Assessment Methods Used**

| | Mentoring | Summer Camp | Integrated Unit | Reference |
|---|---|---|---|---|
| **Quantitative** | | | | |
| Middle School Math and Science Attitude Survey (MSMAS, MSSAS) | X | X | X | 39,40 |
| Boston Museum of Science Engineering and Technology survey to assess students understanding of engineering and technology | X | X | | 41 |
| Survey developed at New Jersey Institute of Technology to assess student perceptions of science, math and engineering. | X | X | | 42 |
| "Adventure Engineering" survey to assess engineering attitudes | X | | X | 2 |
| A math content test | X | | | |
| Cooperative Learning Key to assess how well students can work in teams, essential for engineering | | X | X | 43 |
| Problem Solving Process Key to assess how the students are able to solve problems, which is an invaluable skill for engineers | | X | X | 43 |
| Author generated engineering content survey | | X | | |
| **Qualitative** | | | | |
| Draw an Engineer Test | X | | | 44 |
| Field notes by engineering and education faculty | X | X | X | |
| Teacher interviews | X | X | X | 39 |
| Teacher and mentor reflections as well as middle school students | X | | | |

## Research Results

The research results will be organized by assessment method to compare across and among intervention types.

*Middle School Math and Science Attitude Surveys (MSMAS, MSSAS)*

The authors developed the Middle School Math and Science Attitude Survey to evaluate students' science, math and engineering attitudes in 2007.[39] Major details of the development, reliability, validity and rigorous statistical analysis of the MSMAS and MSSAS development and results have been left to the reader to further examine.[39] The survey was derived from the Modified Fennema Sherman[40] the Adventure Engineering Survey [2] as well as researcher generated questions (4-point Likert). The survey has been administered to all current $6^{th}$ to $9^{th}$ graders in the district (the only assessment that has been given to all of these students). Details of the Mann Whitney U-test (needed because the data was skewed) are provided in Redmond et al.[39] Table 2 lists the major research findings of the MSMAS and MSSAS assessments for the Get a Grip intervention with gender comparisons.

**Table 2. Major Research Findings from MSMAS and MSSAS – Get a Grip Intervention with Gender Comparison**

| **Get a Grip Intervention** | **6th** grade participants compared to **6th** grade non participants | **7th** grade participants compared to **7th** grade non participants | **6th** grade **girl** participants compared to **6th** grade **boy** participants | **7th** grade **girl** participants compared to **7th** grade **boy** participants |
|---|---|---|---|---|
| Mathematics confidence | Higher | Higher | | Higher |
| The value of mathematics | Higher | Higher | | |
| Advantage of effort put forth in mathematics class | Higher | Higher | | Higher |
| Girls just as good as boys at math | | | Higher | Higher |
| Girls are smart enough to do math | Higher | | Higher | Higher |
| Science confidence | | Higher | | |
| The value of science | Higher | Higher | | |
| Advantage of effort put forth in science class | Higher | Higher | | Higher |
| Girls just as good as boys at science | | | Higher | Higher |
| Girls are smart enough to do science | | Higher | Higher | Higher |
| Know what an engineer is | Higher | Higher | *Lower* | *Lower* |
| Interest in engineering as a career | Higher | Higher | *Lower* | *Lower* |
| I could be a good engineer | | | *Lower* | *Lower* |
| Girls can be an engineer | | | Higher | Higher |

Higher – higher agreement - statistical significance difference between groups ($p<0.05$)
*Lower* – lower agreement - statistical significance difference between groups ($p<0.05$)

This data shows that the *Get a Grip* engineering program seemed to have a significant impact on middle school students' (1) math confidence, (2) science confidence, (3) effort toward mathematics and science, (4) awareness of engineering, and (5) interest in engineering as a potential career. Not presented in the table but noted here is that for those students who participated in the *Get a Grip* program over two years, there appeared to be no additional benefits except in mathematics confidence. Students that had *Get a Grip* in both 6th and 7th grades demonstrated significantly higher mathematics confidence when compared to the students that only had one experience with *Get a Grip* in 7th grade.

Additionally, there were some very interesting gender differences in the data. The differences were between boys' and girls' ideas about 1) whether girls were just as good as boys in science and math and 2) whether girls were smart enough to do science and mathematics. The girls' belief in their own skills and potential was significantly more positive than the boys' belief in the girls. This seems to point to the fact that *Get a Grip!* improved the girls confidence while the boys held to more stereotypical beliefs. However, the girls felt lower than the boys on knowing what an engineering is, interested in a career in engineering, and whether they could be a good engineer. They did believe in general that girls can be engineers, just not themselves.

The impact of the mentoring program on girls, the camp program on girls, and the combination of mentoring and camp and Get a Grip (all three) on girls is shown in Table 3.

**Table 3. Major research findings from MSMAS and MSSAS – Females in Various Interventions**

| | 6th grade female participants compared to 6th grade female non participants | 7th grade female participants compared to 7th grade female non participants | 7th grade female participants compared to 7th grade female non participants | 7th grade female participants compared to 7th grade females that did not participate in all three interventions |
|---|---|---|---|---|
| | **Mentoring** | **Mentoring** | **Camp** | **Mentoring/ Camp/GAG** |
| Advantage of effort put forth in mathematics class | | | Higher | Higher |
| Science confidence | Higher | | | |
| The value of science | | Higher | | |
| Know what an engineer is | | | Higher | Higher |
| Interest in engineering as a career | Higher | | Higher | |
| Girls can be an engineer | | Higher | | |

Higher – higher agreement - statistical significance difference between groups ($p<0.05$)

Certainly the data on the after-school mentoring program for girls pointed to 6th graders' significantly greater science confidence and interest pursuing an engineering career and 7th graders' indicated significantly greater value of science as compared to those 6th and 7th grade girls who did not participate in the mentoring program. The girls that participated in the summer camp showed significantly increased knowledge of what an engineer does and interest in pursuing an engineering career. The girls that participated in all three had higher attitudes towards advantage of effort put forth in math class and knowing what an engineer is.

*Boston Museum of Science What Do Engineers Do/What is Technology*

The researchers also wanted to get at the students perceptions of what engineers do and what is technology. An instrument developed at the Boston Museum of Science[41] was used for this purpose. The instrument has 16 items for each of what engineers do and what is technology that the students circle. These assessments were administered to the two 2008 camps (pre and post intervention) as well as to the girls starting the mentoring program (pre) in the fall of 2008. See Figures 1 and 2 for the results. The data shows results for students in the introduction camp (N=18) and the advanced camp (N=11) as well as the 2008 mentoring program (N=45).

Figure 1 shows the results for the "what do engineers do" survey. As expected students knew that engineers did not arrange flowers, sell food, clean teeth or make pizza. The was less agreement for careers that are considered technical in nature, such as driving machines, repairing cars, constructing buildings etc. Their then was more agreement on the setting up factories, designing ways to clean water, working as a team, designing things, and improving machines that are truly engineering functions. In all of the "engineering tasks," the students in the advanced camp were more likely to have correct selections. Interestingly, only about 45% of the students knew that engineers read about inventions. This is particularly intriguing to the engineering co-author that is married to an engineer that is also a patent attorney!

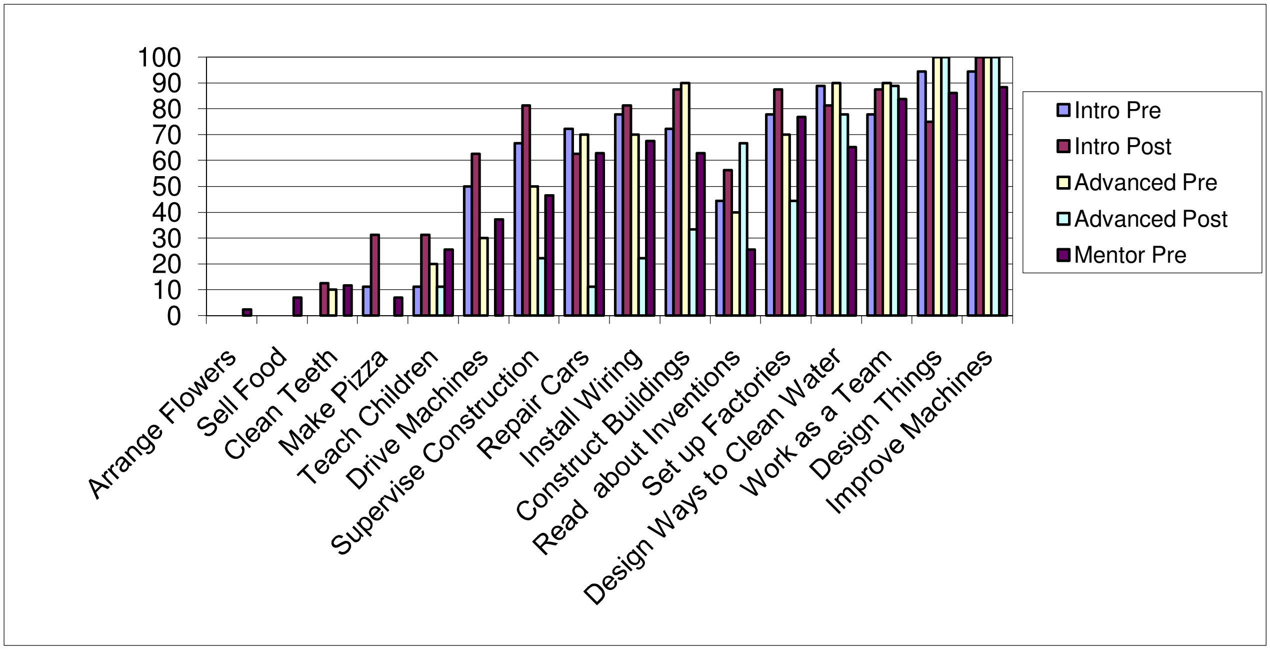


**Figure 1: What Do Engineers Do – 2008 Summer Camps and Fall Mentoring – Percentage of Students Selecting Given Response**

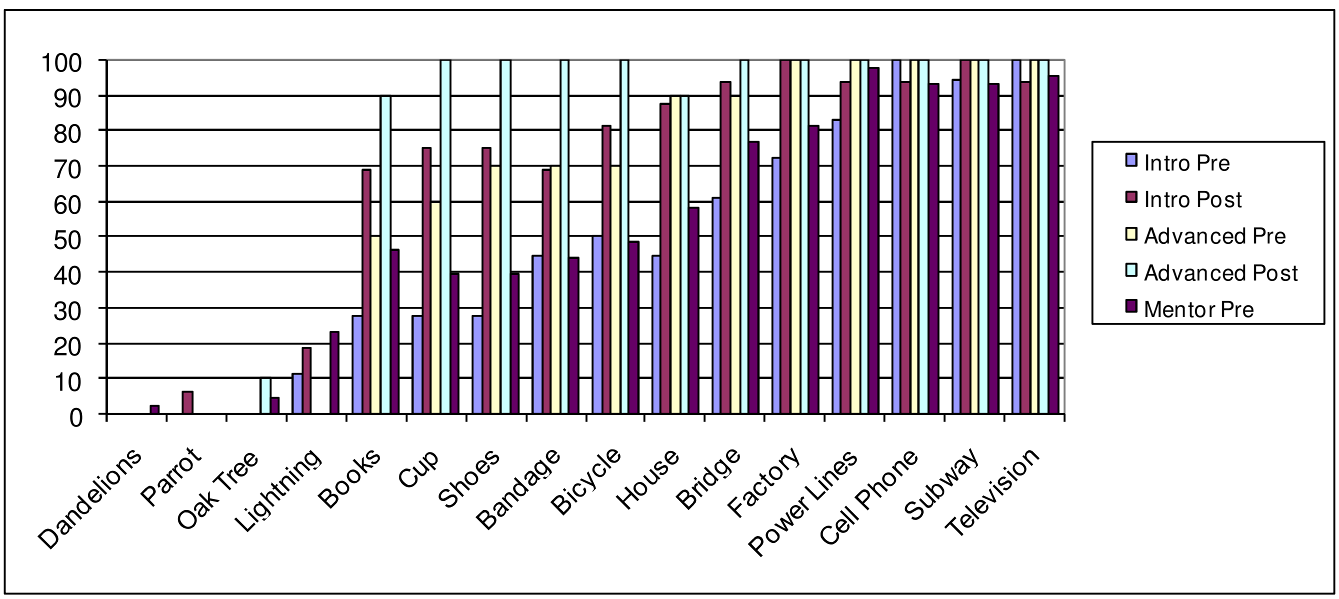


**Figure 2: What Is Technology – 2008 Summer Camps and Fall Mentoring – Percentage of Students Selecting Given Response**

For the "What is Technology" assessment data in Figure 2, students easily were able to identify that dandelions, parrots, oak trees and lighting were not technology. Students were not in agreement on the items that don't have a lot of sophistication (cup, shoes, etc). The students in the advanced camp were more accurately able to understand that these items are also technology. The items at the right side of the figure tend to run on electricity and are much more intricate and more students were able to identify these as technology.

*Hirsch Survey*

The authors chose to administer a survey developed by Linda Hirsch and coworkers[42] to understand some of the impact that the various interventions had on perceptions of engineering. The instrument is a 36 Likert Scale (Agreement towards various statements) survey. The results of the pre/post assessment for the 2008 summer camps (advanced and introduction) are shown in Table 4. The students in the 2008/2009 after school mentoring program have also been given the pre assessment, but is not presented here due to lack of post data.

As is noted, the data that is presented is for those 11 questions that had large changes (20 percent or greater) in pre/post for one of the two cohorts. The data presented shows the percentage of the cohort that agreed with the given statement.

**Table 4 – Hirsch Attitudes to Mathematics, Science and Engineering – For Large Pre/Post Differences**

| | | Intro Camp Pre N=18 | Intro Camp Post N=18 | Advanced Camp Pre N=11 | Advanced Camp Post N=11 |
|---|---|---|---|---|---|
| 1 | I would like a job where I could help invent things | 66.67 | 75.00 | ***70.00*** | ***90.00*** |
| 2 | I would like a job in which I could design clothes to be worn in outer space | ***0.00*** | ***25.00*** | 20.00 | 30.00 |
| 3. | To be good at math or science you have to be very smart. | 27.78 | 31.25 | ***50.00*** | ***30.00*** |
| 15. | I would like a job that lets me figure out how things work. | 66.67 | 81.25 | ***60.00*** | ***80.00*** |
| 18. | I would like a job that lets me spend a lot of time working on computers. | ***27.78*** | ***62.50*** | 50.00 | 60.00 |
| 19. | I would like a job that helps me make new medicines. | 16.67 | 18.75 | ***50.00*** | ***20.00*** |
| 20. | I would like to study science or math because I could make more money when I grow up. | 50.00 | 68.75 | ***55.56*** | ***80.00*** |
| 25. | I think I know what engineers do. | ***61.11*** | ***93.75*** | 100.00 | 100.00 |
| 26. | When I grow up I would like to build computers. | ***16.67*** | ***43.75*** | 22.22 | 30.00 |
| 27. | I would like a job in which I could help protect the environment. | ***33.33*** | ***60.00*** | 88.89 | 80.00 |
| 31. | I like thinking of new and better ways of doing things. | ***77.78*** | ***100.00*** | 77.78 | 80.00 |

% that agree with the following statements

***Bold, italicized percentages are for large pre/post differences***

The students in the advanced camp showed the largest changes in agreement for the wanting a job where they could help invent things, to be good at math or science you have to be very smart (note the DECREASE in agreement showing the recognition that you can be good at math and science if you work hard). These advanced students would also like a job that helps them figure out how things work. The advanced camp cohort also had some interesting responses for jobs that make new medicines and having a career in math or science to make more money. This last item may come from discussions about the kinds of salaries that engineers make during the summer camp.

For the introduction camp, the students thought it would be neat to have a job to design clothes to be worn in outer space. They also really changed their perceptions of having a job that lets me spend a lot of time working on computers as well as building computers. The introduction cohort had a large change in agreement with understanding what engineers do, wanting a job that would protect the environment and they liked thinking of new and better ways of doing things. These assessment results show the impact that can be made after a one week, 20 hour introduction to engineering camp or a specialized program for those kids already exposed to engineering.

*Adventure Engineering Survey*

The 7th grade science teacher co-author had found the Adventure Engineering Survey [2] and felt that this was a good assessment to use for the integrated unit. The students in her team (N=109) completed this 57 item Likert (5 point scale) as a pre and post assessment. The results are shown in Table 5. To get a comparison, the assessment (post) was also given to the after school mentor students from the 2007/2008 academic year (N=27). Differences between the pre and post for the GAG unit and between the GAG cohort and the mentoring cohort were calculated. Largest differences are shown in the table.

**Table 5 Adventure Engineering Results 2008**

| | | GAG Pre N=109 | GAG Post N=107 | Diff GAG Post to GAG Pre | Mentor Post 2007/8 N=27 | Diff 2007/8 Mentor Post to GAG Post |
|---|---|---|---|---|---|---|
| 14 | Science is not helpful in understanding today's world. | 1.59 | 2.14 | **0.55** | 1.37 | -0.77 |
| 27 | I do not do very well in science. | 2.66 | 2.50 | -0.17 | 1.52 | **-0.98** |
| 32 | I know what an engineer does. | 2.97 | 3.52 | **0.55** | 4.00 | 0.48 |
| 48 | I believe that I could be a successful engineer. | 3.27 | 3.07 | -0.19 | 4.04 | **0.96** |
| 49 | I like doing science. | 3.64 | 3.31 | -0.33 | 4.00 | 0.69 |
| 50 | Engineering would be a good career for a woman. | 3.52 | 3.48 | -0.05 | 4.48 | **1.00** |
| 52 | Engineering seems fun. | 3.60 | 3.06 | **-0.55** | 4.19 | **1.13** |
| 53 | Learning science can lead to a successful career | 4.19 | 3.50 | **-0.68** | 4.41 | **0.90** |
| 57 | Engineers are creative. | 4.06 | 3.49 | **-0.57** | 4.30 | 0.81 |

5=Strongly Agree, 1=Strongly Disagree
Data presented is mean for the group

The largest differences are bolded in the table. In analyzing the results it is important to realize that the GAG students were taking these assessments in May, after state testing and during that time where filling out bubble tests can be the last thing on a middle schoolers' mind. For the pre/post for the GAG unit, the only large positive change was for understanding what an engineer does. Negative changes were seen for science not being helpful, engineering seems fun, learning science can lead to a successful career and engineers are creative. Somewhat dismal results, but when looked at with the MSSAS and MSMAS where the positive impact of the GAG unit, can be seen as results that are skewed due to the poor attitude of the students at that time of year.

The negative attitude can also be shown in comparing the GAG and after school mentoring cohorts. The girls felt they did well in science, could be a successful engineering, engineering is a good career for a women, engineering seems fun, and learning science can lead to a successful career. This shows a much better attitude than the GAG students.

*Math Content Test*

To assess gains in mathematics learning during the Amazon Mission portion of the after school mentoring program that covered the *Building Math: Amazon Mission* module. To build this assessment, six items were used from released items from the Texas Assessment of Knowledge and Skills (TAKS™) test. These items covered primarily functions and algebraic reasoning.

The pre/post results for the students are shown in Table 6. The overall percentage increased from 63% to 71%, showing that the students gained somewhat in their mathematics content knowledge during that period. It can also be noted that during the pretest 2 of the 33 students got all of the questions right whereas 7 of the students got them all right in the post test.

**Table 6 - Student Performance on Math Content Test**

| | Problem 1 | Problem 2 | Problem 3 | Problem 4 | Problem 5 | Problem 6 | Overall | Number of students that got all correct | % |
|---|---|---|---|---|---|---|---|---|---|
| Pre Test % (N=33) | 81.82 | 69.70 | 30.30 | 87.88 | 39.39 | 69.70 | 63.13 | 2 | 6.06 |
| Post Test % (N=33) | 93.75 | 75.00 | 43.75 | 71.88 | 81.25 | 62.50 | 71.35 | 7 | 21.88 |

*Cooperative Learning Key/Problem Solving*

To begin to understand the students' perception of how well they cooperated and engaged in problem solving during engineering activities, a post self assessment was given to students at the conclusion of their engineering projects. This assessment was adapted from Dischon et al.[43] The 2008 summer camp cohorts and the GAG integrated unit cohort were given a 10 item survey for cooperative learning (see Table 7) and problem solving (see Table 8)

While the scores didn't vary that much and were in the "good to very good" range, high values were seen in the accepting others ideas for all three cohorts. Sharing of ideas was also high as was having their part done on time. The GAG group generally had lower numbers than the other two cohorts on both assessments.

**Table 7 – Cooperative Learning Key**

| | Intro | Advanced | GAG |
|---|---|---|---|
| **Helped others in the group** | 3.00 | 3.10 | 3.01 |
| **Worked well in the group** | 3.25 | 3.30 | 3.00 |
| **Shared ideas** | **3.75** | **3.30** | **3.18** |
| **Helped keep the group on task** | 2.31 | 2.90 | 2.24 |
| **Disagreed in a nice way** | 2.56 | 3.10 | 2.62 |
| **Accepted others ideas** | **3.44** | **3.20** | **3.41** |
| **Performed a variety of jobs** | 2.94 | 3.00 | 2.74 |
| **Had an equal voice** | 3.19 | 3.30 | 2.60 |
| **Had their parts done on time** | **3.00** | **3.40** | **3.29** |
| **Stayed focused in group** | 3.06 | 3.10 | 2.96 |

**Didn't do = 0, Limited = 1, Good =2, Very Good=3, Great =4.**

**Table 8 – Problem Solving**

| | Intro | Advanced | GAG |
|---|---|---|---|
| **Collecting info** | 3.13 | 3.10 | 2.40 |
| **Generating ideas** | 3.25 | 3.10 | 3.03 |
| **Organizing ideas** | 3.06 | 2.70 | 2.73 |
| **Narrowing ideas** | 2.88 | 3.00 | 2.65 |
| **Evaluating ideas** | 3.13 | 2.70 | 2.84 |
| **Making decisions** | 3.38 | 3.30 | 3.01 |
| **Implementing ideas** | 3.19 | 3.20 | 2.91 |
| **Evaluating implementation** | 3.06 | 2.90 | 2.87 |
| **Revise as necessary** | 3.00 | 3.20 | 2.87 |
| **Stayed focused** | 3.06 | 3.00 | 3.04 |

**Didn't do = 0, Limited = 1, Good =2, Very Good=3, Great =4.**

*Engineering Content Test*

The engineering coauthor developed an assessment to gauge pre/post engineering content knowledge for the summer camps in 2007 and in 2008. Data are presented in Table 9 and 10 for the Introduction Camp. Questions 3 to 10 specifically addressed the content of the summer camp which focused on chemical engineering.

For all questions, the trend was for more students to have correct or partly correct answers on the post test than they did on the pretest. These results also show the ability to impact engineering content knowledge during a one week introduction to engineering camp.

**Table 9 – Engineering Content Knowledge - 2007**

| **Pretest 2007** | **Q3** | **Q4** | **Q5** | **Q6** | **Q7** | **Q8** | **Q9** | **Q10** |
|---|---|---|---|---|---|---|---|---|
| Correct | 0 | 9 | 0 | 55 | 18 | 45 | 0 | 55 |
| Partly correct | 64 | 0 | 64 | 0 | 36 | 45 | 0 | 0 |
| Didn't know | 36 | 91 | 18 | 9 | 45 | 9 | 91 | 27 |
| Not Correct | 0 | 0 | 18 | 36 | 0 | 0 | 9 | 18 |
| **Post Test 2007** | **Q3** | **Q4** | **Q5** | **Q6** | **Q7** | **Q8** | **Q9** | **Q10** |
| Correct | 31 | 92 | 54 | 62 | 46 | 38 | 54 | 31 |
| Partly correct | 62 | 0 | 31 | 8 | 38 | 54 | 38 | 8 |
| Didn't know | 8 | 8 | 8 | 0 | 15 | 8 | 8 | 8 |
| Not Correct | 0 | 0 | 8 | 31 | 0 | 0 | 0 | 54 |

Data presented is percentage of cohort

**Table 10– Engineering Content Knowledge – 2008**

| **Pretest 2008** | **Q3** | **Q4** | **Q5** | **Q6** | **Q7** | **Q8** | **Q9** | **Q10** |
|---|---|---|---|---|---|---|---|---|
| Correct | 0 | 17 | 0 | 39 | 39 | 39 | 0 | 44 |
| Partly correct | 78 | 0 | 67 | 0 | 50 | 56 | 39 | 6 |
| Didn't know | 22 | 78 | 22 | 0 | 11 | 6 | 61 | 22 |
| Not Correct | 0 | 6 | 11 | 61 | 0 | 0 | 0 | 28 |
| **Post Test 2008** | **Q3** | **Q4** | **Q5** | **Q6** | **Q7** | **Q8** | **Q9** | **Q10** |
| Correct | 0 | 94 | 50 | 69 | 81 | 75 | 31 | 31 |
| Partly correct | 94 | 0 | 31 | 0 | 19 | 19 | 31 | 25 |
| Didn't know | 0 | 6 | 6 | 0 | 0 | 6 | 38 | 13 |
| Not Correct | 6 | 0 | 13 | 31 | 0 | 0 | 0 | 31 |

Data presented is percentage of cohort

The final assessment for the summer camps was an 5 question Likert survey developed by the engineering co-author that examined changes in perception for a variety of experiences given in the camp. The results are show in Table 11 below.

**Table 11 – Perception Questions for Introduction Camp 2007 and 2008.**

| | Pre2007 | Post 2007 | Pre2008 | Post 2008 |
|---|---|---|---|---|
| I understand the difference between product and process design | 2.00 | 3.46 | 2.17 | 3.44 |
| I am comfortable working in groups/on teams. | 3.73 | 3.38 | 3.61 | 3.44 |
| I am confident in my brainstorming abilities to solve design problems. | 2.95 | 3.19 | 3.22 | 3.56 |
| I am confident giving presentations. | 2.77 | 3.04 | 3.11 | 3.25 |
| I understand the similarities and differences between engineering and science. | 2.50 | 3.31 | 2.83 | 3.75 |

5-strongly agree, 1-strongly disagree.
Data shown is average for the cohorts.

The students had almost a one and a half point change in their understanding of product and process design in both years. This was a major content area of the camp. The other notable change was in the understanding of similarities and differences between engineering and science.

## Discussion

The variety of assessment instruments used showed effectiveness of the three interventions (summer camp, after school mentoring program, and integrated unit). Content knowledge gains were seen in introduction summer camp as well as for the Building Math: Amazon Mission portion of the after school mentoring program. Perception and attitude changes were also seen in the variety of instruments used.

However, it is recognized that some of the data comes from small samples and can be skewed by self selection (summer camp and after school mentoring program). Despite this challenge, the piloting of the three interventions have been deemed a success.

Future directions include consistent use of assessment instruments to obtain larger sample sizes, purposeful observation and interviewing of students and mentors in the after school program, and engagement of more middle level teachers in the programs and future engineering professional development.

Additional lessons learned include appropriate timing of interventions and assessments. This was particularly important for the integrated unit, Get a Grip. Future work for this study includes a detailed data analysis to determine significant differences among and within cohorts.

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