Spring 2016

Engaging Adolescent to Young Adult Females in Science, Technology, Engineering, and Mathematics Fields

Grace Hutcherson
The University Of Akron, geh19@zips.uakron.edu

Engaging Adolescent to Young Adult Females in Science, Technology, Engineering, and Mathematics Fields

Grace Hutcherson

Department of Education

Honors Research Project

Submitted to

The Honors College

Approved:	Accepted:
_____ Date _____ Honors Project Sponsor (signed)	_____ Date _____ Department Head (signed)
___Dr. Linda Saliga_____ Honors Project Sponsor (printed)	___Dr. Peggy McCann_____ Department Head (printed)
_____ Date _____ Reader (signed)	_____ Date _____ Honors Faculty Advisor (signed)
_____Heidi Cressman_____ Reader (printed)	___Dr. Nidaa Makki_____ Honors Faculty Advisor (printed)
_____ Date _____ Reader (signed)	_____ Date _____ Dean, Honors College
_____Dr. Lynn Pachnowski_____ Reader (printed)	

Abstract

Over the years women have made significant advances in the workforce and in science, technology, engineering, and mathematics (STEM) fields, but there are still disparities that exist and are yet to be overcome. Women are still underrepresented in many STEM fields and progress still needs to be made. There is significant research backing this up and trying to explain why these issues still exist. In June 2015, The University of Akron put on a See UA! Women in Engineering Camp that allowed high school females interested in engineering the opportunity to learn more about engineering, the different possible fields within engineering, available careers, and worked to advance the skills and interest necessary for this field. Through helping with this camp I saw first-hand some activities, topics, and methods that were effective at engaging as well as being thought-provoking for high school females in these fields. In addition, much of the research and observations from the camp show what could be done in the high school classroom in order to engage all students, in particular females, in science, technology, engineering, and mathematics fields.

Section 1: Women in STEM Fields

Undeniably women have made amazing strides in American history. Legislation has been enacted with the goal of equality for both sexes including The Civil Rights Act of 1964 which required equal employment opportunities for both genders and Title IX of the 1976 Education Amendments protecting people from discrimination based on gender in education related programs. According to the National Science Foundation, women earned 57.4 percent of the Bachelor's Degrees awarded in 2012. Unfortunately, there are many areas where women are still underrepresented. Among them are physics where women earn only 19.1 percent of the total Bachelor's degrees earned, engineering graduating only 19.2 percent women with Bachelor's degrees, and mathematical and computer sciences where women earn only 25.5 percent of Bachelor's degrees (National Science Foundation, 2015).

This underrepresentation leads to an important question, "why are more women not entering and graduating with degrees in science, technology, engineering, and math (STEM) fields?" A survey done in 2009 asked engineers what factors might act as barriers to women in engineering and found three main areas. The first included factors related to the nature of the field. These might consist of the lack of role models, the types of projects on which engineers often work, a lack of flexibility, male command in the field, and the struggle to balance work and other life issues. The second related to factors caused by society, including the perception of STEM fields being for "males." The third set of factors were education related, including stereotyping students to subjects, male oriented methods of teaching, and a deficiency of knowledge about some of these fields (Talascend, 2009).

Some of these cultural barriers are rooted in a form of societal sexism found in even simple aspects of life such as children's toys. While many boys play with Legos and toy tool

boxes, girls are often given dolls and toy kitchen sets. Though most would argue, this is not an intentional form of sexism, the result is boys who like to build and fix materials and girls who are prepared to nurture children and care for the home. While I have no issue with women choosing these roles in life, I struggle believe, and research supports, that the skills taught from a young age have no impact on career choices later on in life. An article from the Annual Review of Neuroscience reports a study on the effect of gender development on the human brain. Gender development included typical gender play, toys and treatment. Although it is difficult to directly relate these aspects to brain function and behavior, the study found a strong correlation between this gender development and gender trends in brain function. For example, males tended to achieve higher in mathematical ability and performance. For the Mathematics SAT, the ratio of those scoring in the upper extreme was 2.8 boys to 1 female in 2007 (Hines, 2011). One possible explanation is that the toys and games more often given to young boys require a higher level of critical thinking and logic skills than those more frequently given to girls.

The societal perception of males and females certainly does not stop after children are done playing with toys. The outlook of fields as “male” or “female” and the deficiency of female role models in STEM fields continue on into adulthood. At the high school from which I graduated, only one of the eight mathematics teachers was a female. Though I looked to these males as my role models, this may have been a deterrent, though subtle for some females. Throughout college I could commonly be the sole female found in my mathematics and physics courses. The physics department at my university, containing seven professors, consisted of only one female professor.

In a speech by Heidi Cressman, director of the Women in Engineering program at The University of Akron, she tells the story of traveling to a local middle school for a career day. She

went representing engineering, and was told by a friend at the school that no girls had signed up for her session voluntarily, but a few were persuaded to attend instead of the Hair Stylist/Nail technician presentation they had previously chosen. She came to the unfortunate realization that these girls were more concerned about their appearance, their hair and nails, than the possibility of a future where they could afford to support their families, purchase a home, and be comfortable financially. Leaving for the day, she heard the three female hair stylists discussing their financial difficulties, though it was doubtful that they had shared these concerns with the eighth graders interested in that career (Cressman). This is just one example of the lack of education about various careers and the often limited opportunities to learn more.

In a study found in the British Journal of Educational Psychology, a comparison was made between female performance and self-concept of ability in coeducational and single sex classrooms for the typically masculine subject of physics. Eighth grade students were randomly assigned to a coeducational or single sex physics classroom and then took a questionnaire to measure the physics-related self-concept of ability at the end of the year. While the male self-concept did not vary based on the type of classroom, the females did. Females in a single sex classroom had a better physics-related self-concept than those in a coeducational classroom (Kessels and Hannover, 2008). While all single sex classrooms may not be the overarching answer to the problem at hand, the study has interesting implications. The societal view of fields as male dominated has an effect on female performance and perception in the classroom.

Section 2: See UA! Camp

The Summer Experience in Engineering at The University of Akron is a camp for high school age females interested in the field of engineering. Another similar camp was offered the following week for middle school age females. The 2015 camp took place from June 14 to June 19. The camp was organized to allow the campers to learn more about the major types of engineering, what engineers do, what jobs are available in engineering, and to spark these young women's interest in these fields. Most days were structured so the campers could hear a lecture about a specific type of engineering, then work on a lab in that field, and then go out to a company where that type of engineer might work. The campers also worked on a design project in group of four with a graduate student helping each group for the duration of the camp and presented their results on the last day of camp.

On Monday, June 15 the area of focus was biomedical engineering. A professor from the department at UA spoke about a variety of topics. First he discussed some of the stereotypes about engineers, acknowledging that it is a very challenging, but also a very rewarding field. Next, he stated that in general engineers evaluate and design. The professor then posed the question, "What is Biomedical Engineering?" While some of the campers had ideas, many were unable to give much information about this field specifically.

The professor went on to explain that biomedical engineering is applying engineering to medical problems and working to improve healthcare. In addition, he explained what you can do with a biomedical engineering degree including jobs in industry, graduate school for research and design or management, medical, pharmacy, veterinary, or dental school, physical therapy, optometry, physician's assistant, or law school and patents. The described various areas of research in biomedical engineering. Some of these include medical implants, instrumentation,

imaging devices and detectors, cardiovascular, prosthetics, gait analysis, biophotonics imaging, spectroscopy, integrated imaging (such as in fluorescence goggles), materials for tissue engineering, and targeted drug delivery. Next, the professor explained the process of research in engineering, what he called the engineering design loop. The steps were:

1. Identify the need
2. Research the problem
3. Develop a possible solution
4. Select the most promising solution
5. Construct a prototype
6. Test and evaluate the prototype
7. Communicate the design
8. Redesign

After the biomedical engineering lecture, students broke into two groups to complete two different engineering labs led by other professors in the biomedical engineering department. The first, called "Clearing the Path," was a blocked artery lab in which campers had to design a solution to remove plaque from an artery. The lab used plastic tubing as a model for an artery and Vaseline to simulate the plaque. Students were given materials including pipe cleaners, wire, balloons, paper clips, rubber bands, tape, aluminum foil, and wood. They were then asked to consider constraints, brainstorm solutions, and then design and test the most promising solution. After students tested their prototypes, the professor leading the lab brought the class back together to discuss what went well, what needed improved, and possibilities for future prototypes and ideas.

In the second lab, students were asked to design and test a method of extracting an object from an ear. The professor leading the lab talked to the campers about the importance of customers' needs when designing a product for a company or the general market. In groups, students were then given a model ear with one of three "foreign objects" in it and were asked to extract the object without breaking the ear drum. The groups had a limited amount of time and number of resources to complete the task. After the time limit was up, the professor discussed the importance of teamwork in engineering design. He also talked about challenges that might be faced with customers. One example was that if this tool was going to be marketed, considering both left handed and right handed customers.

On Tuesday, June 16, campers went to the Chemical Engineering Department to learn about this branch of engineering. Two female professors from The University of Akron and two female chemical engineers from local companies were there to talk to the group. The professors introduced the activity which was making lip gloss. They talked about the process of creating the product, adjusting the product, conducting consumer research, analyzing the data collected, and adjusting for the final product. The campers were then asked to brainstorm what factors are important to them in a lip gloss and what materials might affect the lip gloss in what way. Two different methods for mixing ingredients were discussed including emulsion and dissolving. As a group they created criteria to evaluate the lip glosses on.

The students were then asked to break off into groups of three and create a lip gloss based on changes they make to the suggested recipes. After each group created a lip gloss, the students were asked to do "consumer testing" by testing each of the lip glosses and evaluating them based on the criteria they said earlier was important to them in lip glosses. As a whole group, the campers decided which lip glosses were the "best" based on the testing they did.

On Wednesday, June 17, campers went to the Electrical and Computer Engineering department to hear a lecture and do a lab with Dr. Carletta. Dr. Carletta first discussed the difference between science and engineering. By her definition, science is studying and researching to understand natural phenomena, while engineering is creating practical projects and products. She went on to discuss devices that computer and electrical engineers make such as wind turbines, medical devices (MRI machines, wheelchairs, glucose testers, etc.), FitBits, cell phones, GPS, cameras, airplanes and their flying devices, Pill Cam (replaces colonoscopy), RFID tags (for stores, dog tracking chips, potential as keys, etc.), tire pressure monitors, car batteries, car "night vision", and more. According to Dr. Carletta, computer and electrical engineers power the world, make the world a safer place, and make the world a greener place.

Students then split into groups to complete and LED Cube lab. In this lab, students learned the basics of programming and circuits. Students used a computer program shell and edited it to make a cube of 27 LED lights, blink in different patterns and at different speeds. The kit allowed students to do the programming on the computer and then download it onto a chip in the LED Cube so that the cube repeated the pattern even when not plugged into the computer. Students were asked to be creative in their designs and then display them to the class to see who came up with the most creative and unique patterns.

Also on Wednesday, students went to the Mechanical Engineering Department to listen to a lecture and do a lab with Dr. Garafolo. He discussed what an engineer does, that is helps people, creates designs, solves problems, improves society, and optimizes. He then explained what a mechanical engineer does, which was builds and optimizes technology, uses machines, incorporates physics, and solves mechanical problems. Dr. Garafolo also discussed the applications for mechanical engineering and some of the companies that these apply to. Some of

these were designing and making bearings (Timken), designing and maintaining machines for production (Smuckers plant), designing tread on tires (Bridgestone), jet engines, transmissions on cars (GM), patent attorney with a law degree, and robots and movement and replication of life. He explained that some of the topics mechanical engineers study are the motion of fluids and heat and vibrations and when they cause structural failure. Students then did a cell phone vibration lab. In this lab, students used Labview and Vernier tools to graph data from the vibrations of their cell phones. Through the data collected in this lab, students were able to determine the frequency at which their cell phones vibrate, and compare that to various other cell phones.

On Thursday, June 18, Dr. Roke spoke to the campers about civil engineering. He discussed what civil engineers, including overall improving the quality of life. Specifically he stated that civil engineers solve problems such as daily challenges in crumbling infrastructure, natural disasters, pollution, and traffic congestion. Civil engineers also study structure, geotechnics, transportation, waste treatment, water management, and construction management. Management projects consist of overseeing engineering projects to ensure quality and timely work. Dr. Roke emphasized that civil engineers generally interact with people regularly. There are five areas of emphasis within the Department of Civil Engineering at The University of Akron, listed below:

1. Structural: design of various facilities to withstand loads
2. Geotechnical: design and evaluate facilities and systems related to soils and subsurface
3. Transportation: design, evaluate, and operate transportation system facilities

4. Water Resources: design of hydraulic, waterway, irrigation, port, coastal, and ocean engineering systems
5. Environmental: focus on water resource management, bioremediation, and the effect of technological advances on the environment

Section 3: Analysis of See UA! Camp

There were many wonderful aspects of the See UA! Camp. Among them was the sheer number of young females interested in a field where they are underrepresented and passionate about a career that will challenge them mentally. These bright young women were given the opportunity to learn more about a field where they would have the opportunity to develop their critical thinking skills, make a living from which they can support themselves and their families, and create innovative products to help people and the world. The camp surrounded these young females with other females who were either already successful in the field of engineering, such as professors and people they met at the various companies we visited, who were in the process of becoming engineers, such as the camp counselors most of whom were engineering majors, and peers that were just as excited about this field as they were.

One limitation of this camp was that it focused only on engineering and not on other STEM fields. This could be attributed more to the lack of other camps like this rather than this camp itself though, since these girls were all interested in engineering specifically and the camp was a week packed full of information, activities, and learning. In the future I would love to see The University of Akron and other universities develop a series of camps like this to cover all areas of STEM for females. Another expansion I feel would have made this type of programming more effective is working to interest more adolescent females in this field rather than just giving information to those who are already confident they will choose a type of engineering as their major in college. This type of programming and outreach may need to be done in a different form and is happening at career days by Heidi Cressman and other faculty, but the engaging activities done at this camp could be enough to spark many more students' interest in the field.

While the lectures provided by professors in various departments at the See UA! Camp were very beneficial, the hands on activities were what really stood out as the highlight for the week. In the biomedical engineering labs, campers had to think critically about how they would remove a blockage from an artery or an object from an ear. This process of being assigned a real world problem and having to analyze materials, restrictions, and goals in order to find the best solution is an excellent example of student led learning. These campers struggling with the idea and then coming to a conclusion allowed them to use their own evaluative skills and grow in thinking rather than handing them answers.

The electrical and computer engineering lab gave campers the opportunity to follow directions and express their creativity. Students were able to learn simple programming in order to light various bulbs and then had to come up with a creative design for the lights to flash and determine what needed to be modified in the program in order for that to happen. Student had to consider various scenarios, for example figuring out how to write code for the cube so two bulbs would flash "simultaneously." Technically this cannot occur, but because our eyes can only perceive a certain gap of time in the flashing of a light, if the time in between flashes is small enough they appear to flash at the same time. These types of questions and challenges pushed students to persevere in solving problems and develop creative solutions.

While the mechanical engineering lab did not require the level of critical thinking that some of the others did, making the lesson apply to real life still made it an engaging activity. Most of these campers use their cell phones on a regular basis and this lab allowed them to use technology to evaluate the functionality of their cell phones compared to others when vibrating. This was an overall interesting experiment for the campers.

The chemical engineering lab was not one the high level labs that many of the others were. This lab required little critical thinking, but instead resulted in most campers mixing random ingredients to make a "lip gloss." The evaluating discussion felt more like opinion than like a scientific analysis of the products as well. In addition, the overall idea felt a bit stereotypical, assigning a group of young girls the task of making lip gloss. Many of the camp leaders felt the same way, but the activity still seemed to interest many of the campers. On a positive note, the activity did give campers an idea of how a business might evaluate a product in its preliminary stages.

Section 4: Application in the AYA Classroom

Through research and observations at the See UA! Camp, I have developed some insight into what can be effective for the middle school and high school age classroom. In particular, the labs during the camp demonstrated that giving students a task rather than step-by-step directions allow for a much higher level of engagement and critical thinking. In How Students Learn: Science in the Classroom, research showed that having students complete inquiry activities where they are able to investigate real life phenomena was the most effective method of scientific learning (Donovan and Bransford, 2005). This method absolutely applies for both male and female students, but implementing these types of activities in the classroom could engage more students overall, including females, and allow for a wider interest in the related fields.

Another important note is that the awareness and knowledge about some STEM fields needs to increase. More high schools should make an effort to make their science and math classrooms have a focus on these as careers, as well as implementing extracurricular activities that allow for experience in STEM areas. Many are moving in the right direction, with engineering classes, robotics clubs, and other involvement becoming more popular at the high school level. Job fairs or opportunities to hear more about various careers from a young age would also be an excellent way to interest more young people in these fields.

Societally we need to make improvements as well. Careers need to stop being labeled and reinforced to young people and adults as “masculine” or feminine.” Children’s toys should not be stereotyped by gender, or at least should be adjusted so that there are a wider variety of toys targeted for both genders. For example, a company called GoldieBlox now creates a wide array of toys and games marketed to young girls in order to develop engineering and problem solving skills. This is a step in the right direction in my opinion, considering eliminating the stereotypes

altogether will take time and effort from many people. Raising awareness and continuing to make strides in the right direction is critical.

Finally, one of the largest actions I can implement as an individual teacher in my own physics or math classes might be providing support for all students, in particular females. One of the overarching themes I have seen in research and at the camp is that when females have positive female role models in STEM fields, they are more likely to be interested and successful in these fields. I hope that I can be that for many of my students, showing that as a math and physics teacher I have succeeded in a field where women are often the minority. I hope to be teaching the next generation of scientists, mathematicians, and engineers, particularly females, that can look back and say their high school math or physics classroom and teacher had an impact on their career.

References

Cressman, Heidi. Perception is reality. Personal Collection of Heidi Cressman, The University of Akron, Akron, Ohio.

Donovan, M. S. and Bransford, J. D. (2005). How students learn: science in the classroom. National Research Council. The National Academic Press.

Hines, M. (2011). Gender development and the human brain. Annual Review Of Neuroscience, 3469-88.

Kessels, Ursula. and Hannover, Bettina. (2008). When being a girl matters less: Accessibility of gender-related self-knowledge in single-sex and coeducational classes and its impact on students' physics-related self-concept of ability. *British Journal of Educational Psychology, 78*: 273–289.

National Science Foundation, National Center for Science and Engineering Statistics. (2015). Science and Engineering Degrees, by Race/Ethnicity of Recipients: 2002–12.

Talascend. (2009). Women in Engineering Survey.