Hands-on Summer Workshop to Attract Middle School Students to Engineering (Work in Progress)

Murad Musa Mahmoud, Utah State University

Murad is a PhD student in the Engineering Education department at Utah State University. My major advisor is Prof. Kurt Becker. I have a bachelor's and master's degree in Mechanical Engineering from the University of Jordan. I have about five years of experience in teaching, most of which is with computer-aided drafting (CAD). My research interests include; STEM recruitment, professional development and CAD.

Dr. Kurt Henry Becker, Utah State University

Kurt Becker is the current director for the Center for Engineering Education Research (CEER) which examines innovative and effective engineering education practices as well as classroom technologies that advance learning and teaching in engineering. He is also working on National Science Foundation (NSF) funded projects exploring engineering design thinking. His areas of research include engineering design thinking, adult learning cognition, engineering education professional development and technical training. He has extensive international experience working on technical training and engineering educaton projects funded by the Asian Development Bank, World Bank, and U.S. Department of Labor, USAID. Countries where he has worked include Armenia, Bangladesh, Bulgaria, China, Macedonia, Poland, Romania, and Thailand. In addition, he teaches undergraduate and graduate courses for the Department of Engineering Education at Utah State University.

Dr. Max L. Longhurst, Utah State University

Dr. Longhurst is an Assistant Professor of Science Education in the School of Teacher Education and Leadership at Utah State University. His research focuses on the appropriation of professional learning in science education. Heholds a Ph.D. in Curriculum and instruction from Utah State University (2015), a Masters Degree in Instruction and Curriculum from Arizona State University (1995), a Bachelor of Science in Elementary Education from Brigham Young University(1993). Dr. Longhurst has directed local and large scale professional development programs providing instructional learning experiences involving over 4,000 elementary teachers annually. Currently he coordinates the Elementary STEM Endorsement program at Utah State University.

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Introduction

STEM (Science Technology, Engineering and Mathematics) disciplines are essential to society and to competing in the global economy. Unfortunately, there is a lack of interest for students in the USA going into STEM fields, particularly engineering (Callahan and Callahan, 2004; Kazmierczak, 2005). According to the National Science Board (2012), only about 8.6% of high school students choose to go into STEM fields. Additionally, around 4% of nearly 4 million high school graduates in the USA graduate college with an engineering degree (Orsak, 2003).

In addition, STEM education is facing a diversity issue. Some ethnic groups and women are underrepresented, especially in engineering. Women make up half of the population and are not very interested in going into engineering for various reasons, including not feeling welcome in the engineering environment, not encouraged or expected to succeed in that field (Lambright, Johnson, & Coates, 2009), or the misconception that engineering is a 'nerdy' career (Borrego and Bernhard, 2011). According to Johnson, Ozogul, DiDonato & Reisslein (2013), females generally display much less interest going into STEM fields. Additionally, females represent only 20% of all engineering students, (The National Science Board, 2012). According to Yilmaz, Ren, Custer & Coleman, (2010), the number of STEM graduates has been steadily decreasing, while the number of STEM graduates from underrepresented groups; females, Hispanics and African Americans have been decreasing even faster.

Unfortunately, the number of engineering graduates is currently lagging behind other major competitors in the global economy such as China and India. The USA contributes around 4% of the total engineering graduates worldwide compared to 34% for China and 17% for Europe (National Science Board, 2012).

At the same time, the engineering job market has been increasing steadily and does not show signs of slowing down according to the US Department of Labor statistics. There is a clear gap between how many students should be in STEM fields and how many are actually there. Similar observations were made by the National Academy of Engineering (2005) in the "Educating the Engineer of 2020" report.

There is an increasing demand for competent engineers; hence, there is a need to recruit more engineering students (Becker, 2010; Prieto et al., 2009). While this is certainly a real problem, there are steps that could be taken to build up interest in STEM fields and have more STEM students and graduates. Laut, Bartolini & Porfiri (2015) believe that STEM recruitment is critical for the economy and society, and the results of their research show that students who participated in their outreach program have more interest in going into STEM fields.

Outreach programs to schools is one of the methods often used, and findings suggest that outreach programs are effective, especially on elementary school students (Johnson et al., 2013). Summer workshop outreach programs where students learn about engineering outside the school environment have been largely successful in increasing student interest in STEM fields (Abaid,

Kopman and Porfiri, 2013; Paulino, Babb, Saar, Friesen & Brandon, 2014; Yates, 2013; Yilmaz, Ren, Custer & Coleman, 2010). Findings show that outreach programs targeted at the high school level generally raise awareness and yield more interest in engineering.

Another factor to increase student interest in STEM is parents. According to a 2009 survey by the American Society for Quality, only 20% of parents encourage their kids to go into engineering. The same survey said that 44% of school students do not know a lot about engineering. This increases the importance of outreach programs for recruitment and for raising awareness of school students regarding engineering and STEM fields in general.

By the time students get to college, it is often too late to motivate them to go into engineering; even freshmen who are undecided are not very likely to go into engineering (Boesdorfer and Staude, 2016). Addressing recruitment at the middle and high school levels could raise awareness and get more students interested in engineering at an early age and before they get to college when it is often too late.

Because of the need for more students in STEM disciplines, the STARS! GEAR UP Partnership grant, funded by the Department of Education to increase student interest in STEM fields is underway. This 7-year project, housed at Utah State University (USU), is in its first year.

Summer Engineering Program

As part of the USU STARS! GEAR UP project, the implementation of a summer engineering program is underway to enable secondary students and teachers to perform real engineering research investigations in collaboration with engineering research faculty to study the interaction of urban and natural areas and their effect on water quality in a local watershed. The purpose of the program is to train teachers and their students in the area of watershed science and water quality using applied research activities. With the introduction of the Next Generation Science Standards (NGSS), and the framework for K-12 science education, teachers are experiencing difficulties in incorporating the recommendations in those standards in their curriculum (Boesdorfer and Staude, 2016). The summer program works in conjunction with teacher professional development to produce quality classroom lessons for teacher participating in the GEAR UP project.

The summer program targets 6 to 12 grade underrepresented students and science teachers to participate in the project. Because of the intense nature of the activities by participants and the mentorship required of program instructors (faculty, graduate students, and undergraduate student mentors), the participant pool is limited to 75 (60 students, 15 teachers), with a target student to teacher ratio of 4:1.

The summer program provides participants with direct, hands-on research experiences with topic areas of relevance to many minority populations, i.e., the environment, water quality, and urban water sustainability. These topic areas encompass several of the Grand Challenges identified by National Academy of Engineering. Students and teachers learn about water and nutrient cycles, and urban impacts to water quality, evaluate research questions relevant to the watershed in which they live, learn and apply measurement techniques used to monitor watershed health and

water quality status, and present their findings in a coherent and comprehensive manner. Teachers learn methods related to water quality monitoring and data presentation relevant to watershed and urban storm system measurement that can be used to address the Next Generation of Science Standards (NGSS). Students and teachers gain an understanding of water quality and urban development impacts, and are trained in field sampling and water quality monitoring techniques.

This past summer, the workshop took part over two weeks with half the students and half the teachers attending the first week, and half attending the second week. Inside the classroom, activities included presentations, design competitions and other activities. Outside the classroom, activities included hand-on field experiences. Table 1 includes the activities for the week-long resident workshop. Presented below is a description of some of the more popular activities.

Table 1: List of daily activities for the week-long workshop

Day/Activity	Morning Activity	Morning Activity	Afternoon Activity	Afternoon Activity	Evening Activity (Teachers only)
Day 1	Water Cycle experiment		Tragedy of the common experiment		Teacher Prof. Development
Day 2	River/watershed experiences in multiple locations upstream and downstream				Teacher Prof. Development
Day 3	Water runoff experiment	Storm water impact/multiple locations		Sand filters	Teacher Prof. Development
Day 4	Looking at bacteria under a microscope	Logan Lagoon site visit	Hyrum wastewater treatment plant visit		Teacher Prof. Development
Day 5	Poster Presentations & Team Photos		Power point slide presentations	Post workshop satisfaction survey	

Sand Filters Activity: Students were tasked to build a water filter using natural materials (sand and gravel). Teams of five competed to make potable water of the highest quality at the fastest rate. Quality of the filter was based on turbidity, pH, color, and odor. The element of competition added to the students' experience as they tried to figure out how to come up with the best design. In preparation for the activity, an overview of water use was presented to the participants and probing questions were asked, such as: *How much water do we use daily? For what? Does all the water need to be same quality? Who is responsible for drinking water? What is an engineers' role in drinking water?* In addition, a discussion took place on the use of simple iron chemistry (iron filings or iron nails) for arsenic removal from water in conjunction with water filters. Questions included: *What is arsenic? Why is it in water? How does it harm us? How can we remove it? Where is it a problem?* The activity was connected to work in developing countries with Engineers without Borders, decentralized treatment for cabins, isolated ranches, etc., in Southwest United States with high arsenic concentrations.

River/Watershed Activity*:* Students visited multiple locations along a river in Northern Utah and collected samples from upstream and then again from further downstream to compare water quality in those locations. The data collected included: turbidity, collection of macroinvertebrates samples (insects living in the water) – using a simple index, water temperature, dissolved oxygen and alkalinity nitrate, phosphate, collect E coli samples, among others. This part of the workshop was very interactive and students were eager to go to the river, collect samples and then report findings and compare with other locations on the river. From this activity participants started

asking questions as to why water quality drops further downstream. Other observations included: stream shape/form; riparian health and function; connectivity/shade; stream continuum concepts; importance of aspect, elevation, and native geology.

Water Run-Off Activity: Students visited multiple locations that treat storm-water. Among them was a large local business parking lot. It was explained to the students that storm-water can carry a lot of pollutants from the city such as leaking oil and other chemicals from cars and those should not be drained into the storm-water system and into rivers. Storm-water treatment uses plants to absorb pollutants out of the water before it is sent to the river. To show the students the impact of storm-water, food dye was dumped into the river and students observed as the river changed color. The students commented that they never realized how fast and how far pollutants can spread in a river and how they can affect the lives of people using water from rivers.

Microorganisms Activity: Students collected samples from a wastewater treatment plant. The samples were then placed under a microscope for students to observe the kinds of microorganisms that live in treatment plants to help break down the organic material in the water. This enabled the students to see how the microorganisms helped treat the water and return it to a useable form.

Data Collection

A satisfaction survey was administered at the end of the workshop to gauge the students' interest in the various activities during the week. This survey helped to determine the effectiveness of the program. The survey question was in the form of: "*I found the following morning/afternoon experiences valuable*". The responses were on a Likert scale from strongly agree to strongly disagree. The questions then list the activities listed in the table above. The teachers and students completed ten activities during the week-long engineering camp. Figure 1 shows each activity and the corresponding interest rating.

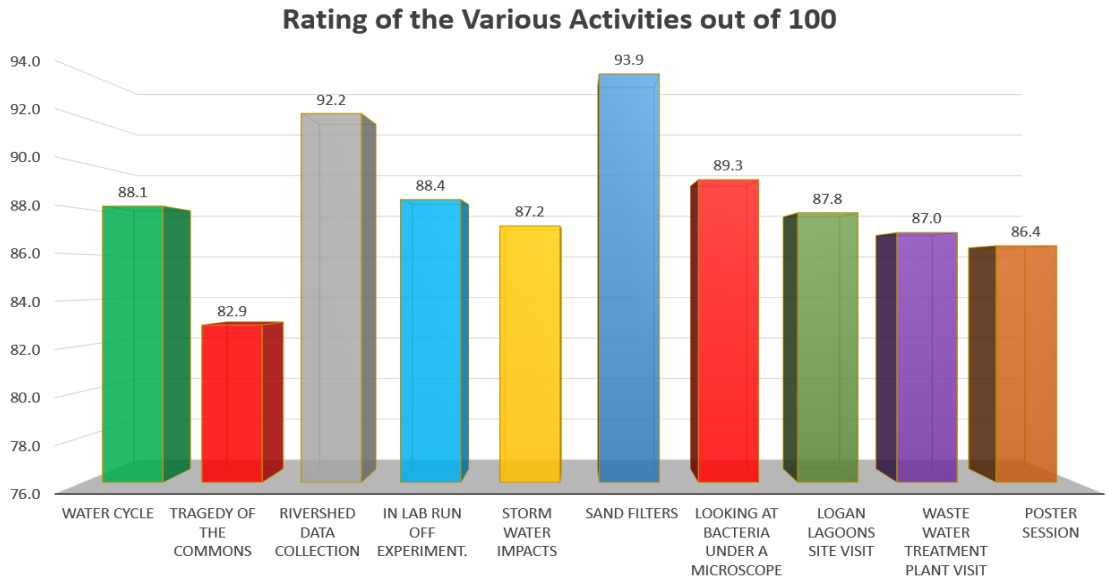

Figure 1: Rating of the various activities out of 100

Similarly, the teachers were given a survey at the end of the workshop to gauge their perceived level of knowledge gained from the professional development sessions and how they rated it. The survey question was in the form of: "*Please answer the following questions about the professional development*". The responses were on a Likert scale from strongly agree to strongly disagree. This is shown in Figure 2 below.

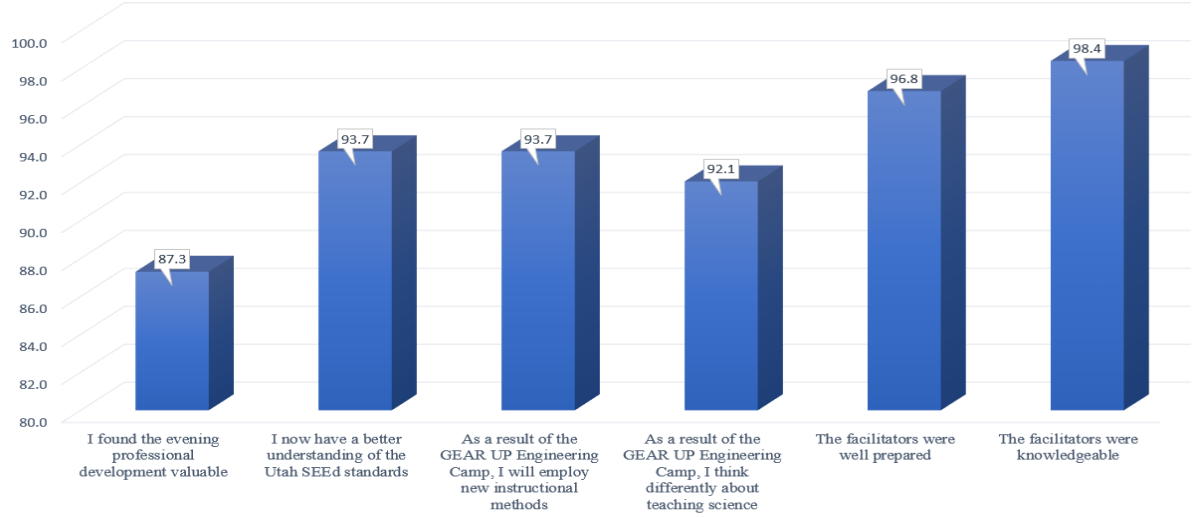

Figure 2: Professional Development Evaluation

Results

Results showed a very high overall satisfaction with the camp activities by the students. The survey results also show the success of the workshop and clearly points towards student appreciation of learning using hands-on experiences rather than being passive learners. This aligns with the constructivist theories on education where student-centered and active learning is proven to be more effective. The teachers were also satisfied with the professional development experience and with learning the new science standards to be used in the next school year.

Comments from students included: "*I loved being able to go out in the field instead of just sitting in a classroom and trying to understand what is being described rather than actually being able to see what is going on.*" A comment from a teacher: "*I feel that the camp was perfect for students. I like how structured it was, and how hard the student worked. I would not recommend slowing it down at all.*" Additionally, the researchers will collect data to determine students' interest and motivation in STEM during the coming summer workshop. Additional qualitative and quantitative data will be analyzed in a future publication as we collect more data from future workshops. This years' workshop was the first and a pilot for many similar summer workshops to take place over the seven years of the project.

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