Enhancing STEM Awareness for Pre-Service Teachers: A Recruitment Initiative

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Abstract

The shortage of engineers in the United States has been the focus of numerous recent reports. Results from a recent Intel funded study showed a lack of familiarity with the engineering field as one of the key barriers. Recognition of this has resulted in a growing movement to create awareness and intensify outreach efforts by engineering/STEM educational programs across the country. One potential solution is to train middle and high school teachers in STEM areas so they can influence young students. This seems promising, considering the majority of K-12 teachers have limited to no training in engineering and the implementation of specialized programs or efforts is often prohibitive due to limited resources. This paper documents the activities and results of a Pre-Service Teacher Workshop at Texas A&M International University. This workshop addressed the limited knowledge of secondary teachers about engineering degrees and careers. Participants, for example, were made aware of the difference between the Scientific Inquiry Method and the engineering design process and other concepts taught in college engineering courses. Fourteen participants successfully completed the workshop. This paper provides details about the workshop, including the topics covered. Results of pre- and post- workshop surveys are also presented and discussed.

I. Introduction

The declining competitiveness of the United States (U.S.) and impending shortage of engineers has been the focus of numerous reports [1, 2]. The Texas Higher Education Coordinating Board attempted to respond to the looming crisis through the creation and implementation of the Closing the Gaps: The Texas Higher Education Plan [3]. Under the program's strategies, a goal to significantly increase the number of degrees awarded in critical Science, Technology, Engineering, and Mathematics (STEM) fields was established. In 2008, engineering degrees represented 30% of all bachelor's degrees in China while they accounted for only 5% in the United States [4]. Another concern is that minorities' representation in engineering is low. The proportion of bachelor's degrees in engineering in 2004 was 20.2% for women and 7.4% for Hispanics [5].

Various studies have been undertaken to determine the primary factors that influence an individual's educational and career choices [6-9]. Results from a recent Intel funded study, which involved more than 1,000 teenagers, showed a lack of familiarity with the engineering field as one of the key barriers [10]. This was consistent with findings in a 2005 study by Hirsch, Kimmel, Rockland, and Bloom [11]. The authors stated, "One of the many reasons more students are not choosing to study engineering in college and pursue careers in engineering is that they simply do not know what engineering is or what engineers do."

While a number of issues affect STEM recruitment, another area of great concern is student retention. Surprisingly, poor service and treatment, the feeling that college education is just not worth it, and the indifference students perceive from the college or university are among the major factors that affect retention and success. Studies show it is neither the students' capabilities nor their potential for performing as an engineer that determines persistence. The most effective way to improve persistence is to improve the quality of the engineering learning experience [12].

Different approaches for engaging U.S. engineering education exist, including [12]:

- Developing local communities of expertise in educational innovation via cross-unit appointments (e.g., joint/adjunct appointments between engineering and education, educational psychology, anthropology, ethnic studies, women's studies) and cross-disciplinary research collaborations with education and related learning science fields;
- Developing "educational incubators" where engineering faculty may experiment with new pedagogies with professional support and minimal risk;
- Including members of the K-12 community, education and learning science community, as well as industry on department and college curriculum committees; and
- Integrating the design experience vertically by including K-12, freshmen, sophomores, juniors, and graduate students in engineering design projects; among others.

However, one particular solution for engineering recruitment and retention is to train teachers in STEM areas so that they can intercede while students are still young. Many universities conduct summer programs for middle and high school students; however, little has been done to train K-12 teachers. This paper documents the efforts to increase STEM awareness of pre-service teachers through a one-week engineering workshop at Texas A&M International University (TAMIU).

II. Pre-Service STEM Teachers Workshop

The purpose of this workshop is to address the gap in secondary teacher knowledge on engineering degrees by engaging participants seeking secondary STEM teaching degrees. The objective is to join with industry to make these pre-service STEM teachers aware of career opportunities in engineering and to distinguish the currently taught Scientific Inquiry Method from the engineering design concept taught in college engineering courses and later applied on the job. This will allow for those going into STEM secondary teaching to be able to address student questions associated with what an engineer does, and be able to guide their students into these fields with greater confidence.

Pre-service teachers in 8-12 certification programs were solicited from the different programs at TAMIU. Some of students were identified by contacting the college of education, the mathematics faculty, and the office of the registrar. Once identified, invitations were emailed to students and others were personally invited. Fifteen students submitted applications and all of them were qualified. All but one attended the workshop. All participants were Hispanic and 43% were women.

Selection criteria were as follows:

- Full-time student enrolled in STEM teaching major
- Jr./Sr. status
- Graduating within 3 semesters
- Short essay on expectations of the workshop

III. Enrichment Activities

Several activities were organized to create a professional development engineering workshop. These activities were aligned with the workforce and academic skills and practices of engineers, with a common message and foundation established that maintains and honors the unique needs of local industries.

The goals of the one-week program included:

- Understanding the various disciplines of engineering
- Understanding the engineering design process
- Participating in an engineering industry tour
- Participating in an engineering discussion with engineering professionals.

The program was broken down into several specific areas. Figure 1 shows the schedule, which included discipline-specific experiences from engineering fundamentals, as well as industry engagement.

The engineering fundamentals were introduced at the beginning of the program, followed by presentations by engineering faculty in their area of expertise. These areas included engineering design process, chemical engineering, systems engineering and electrical engineering.

	9:00 A.M. – 12:00 P.M.	1:00 P.M. – 4:00 P.M.
Day 1	Welcome Engineering Foundations	Engineering Design Process
Day 2	Chemical Engineering Concepts	Hands-on Activity-Chem Engr
Day 3	Systems Engineering Concepts	Hands-on Activity-Sys Engr
Day 4	Electrical Engineering Concepts	Hands-on Activity-Elec Engr
Day 5	Industry Tour	Panel Discussion Workshop Evaluation Presentation of Certificates

Figure 1: Summer 2013 Workshop Schedule

a. Engineering Design Process

The engineering design process sessions consisted of several presentations. The first one was to clarify the purpose and objectives of the workshop. A presentation titled "Engineering as a Profession," in which engineering careers were highlighted was next. This was then followed by a presentation on what it takes to become a Professional Engineer (PE). Another presentation described the Engineering Design Process. This latter presentation involved a hands-on activity where participants worked on solving a problem posted by the presenter.

b. Chemical Engineering

The second day of the program involved an in depth explanation of Chemical Engineering concepts. Hands-on activities, consisting of the production of biodiesel from waste vegetable oil and soybean oil followed a presentation by the instructor. After the experiments, participants were asked to think as a chemical engineer and discuss which of the two oils was the best alternative for the production of biodiesel.

c. Systems Engineering

Workshop day three consisted of lectures on systems engineering. Topics focused on systems engineering, systems engineering contributions, role of systems engineering in product development, systems engineering as a discipline, and systems engineering processes. Afterwards, the students learned how to build a DVD rental system from scratch using MS Access. This hands-on activity included an introduction to MS Access, creating database tables and an introduction to relational databases and design.

d. Electrical Engineering

The presentation involved an in depth explanation of Electrical Engineering concepts. Topics included the concept of electricity from a physics point of view, electromagnetic fields, water flow analogy, analog versus digital electronics, how computers are made, and description of various electronic components. Students were given an electric circuits experiment kit suited for children from 8 years of age, the Snap Circuits PRO SC-500. The students built several of the experiments. They learned how this product, considered a toy, can introduce their future students to the basic concepts of electrical engineering at a very low cost with minimal knowledge from the teacher. Also, students built a simple circuit consisting of a light emitting diode and a resistor using the bread boards that university students use.

e. Industry Field Trip

For the industry engagement portion, students were treated to a tour of the City of Laredo's Jefferson Water Treatment Plant, as seen in Figure 2. After this tour, participants traveled to the Laredo International Air Control Tower. These activities offered participants interactions with real-life engineers, and gave them a clear idea of what is required to succeed in engineering.

Figure 2: Jefferson Water Treatment Plant

f. Panel Discussion

This session included a presentation that highlighted the challenges that influence student interest in STEM disciplines, followed by a welcome from the Dean of the College. The panel discussion involved a luncheon with several engineers from the Laredo area and a number of STEM faculty members. Participants had the opportunity to converse with different Professional Engineers, and listen to their personal industry experiences. The panel concluded with a question and answer session.

IV. Survey Results

a. Engineering Familiarity Pre- and Post- Survey

Initially, participants were asked to complete a pre-survey to get an understanding of the participant's familiarity of engineering and the engineering design process. At the end of the workshop, participants were asked to complete a post-survey containing the same questions to identify the participants' improvement in the familiarity of engineering and the engineering design process.

The results show a clear improvement in the familiarity with all of the topics covered during the workshop. However, the areas of greatest increase were the familiarity with the engineering design process, the understanding of the process of communicating technical information, and the familiarity with engineering careers and disciplines. Surprisingly, participants' perception of good math skills in engineering careers changed from an 86% "Strongly Agree" in the pre-survey to a 71% "Agree" in the post-survey. Appendix A contains the graphic results for the individual questions of these surveys.

b. Workshop Evaluation

A final workshop evaluation was performed to get feedback from the participants on the entire workshop. Participants rated the questions on a scale of 1 (disappointing) to 5 (wonderful). Figures 3 and 4 illustrate the results for the individual questions. The majority of the participants rated the questions with a 5. This feedback helps us improve future workshops.

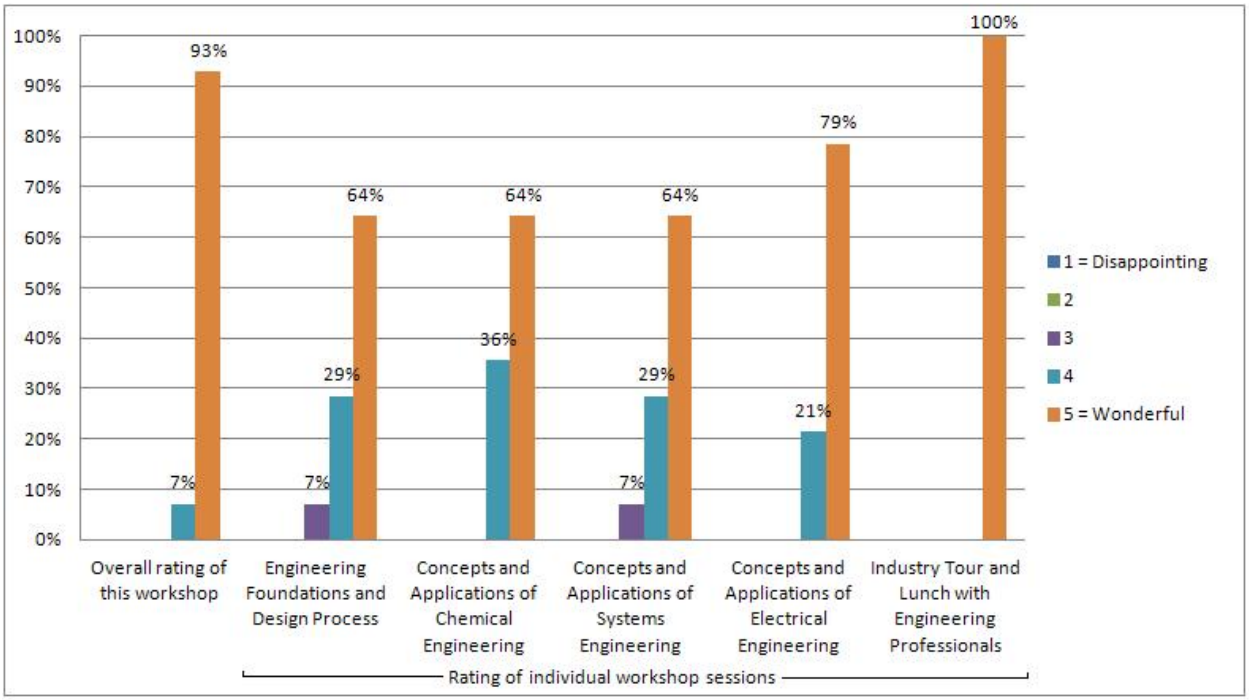

Figure 3: Feedback on Questions 1 and 2

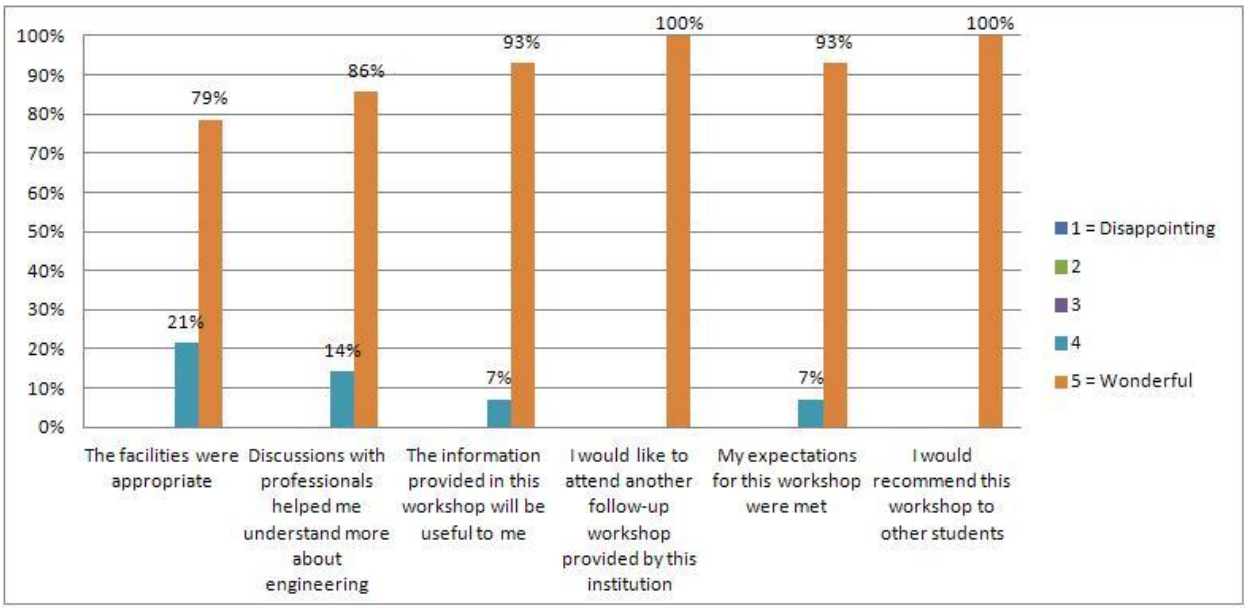

Figure 4: Feedback on Questions 3 to 8

Two open-ended questions were included at the end of the evaluation and the answers are summarized below:

How could the workshop experience be improved for future participants?

Better coordination with school calendar (commencement, maymester, etc.)
Slides given to participant were too small. Maybe an outline would be better.
Tour of Airport Controllers should be better organized.
Have a separate tour day from lunch with PE's.
Show videos in addition to PowerPoint's.
Some of the content was very dense and difficult to follow over a three-hour period. It was hard to remain focused throughout the entire morning session.
More real-world applications.
More hands-on activities.
Have two professional engineers each day, one in the morning and another one in the afternoon.
The workshop to last longer.
See engineers take part on some activities or present previous work.
Bring more diverse engineers to the presentation, not only civil engineers.
Break down sessions since there was a lot of information covered.

What additional information about this workshop would you like to obtain?

What schools/colleges in Texas offer engineering degrees and what type of engineering degrees do they offer?
Will there be more workshops?
Information on how to get an engineering degree at TAMIU.
More details about the engineering fields.

The engineering familiarity pre- and post- survey along with the workshop evaluation form can be found in Appendices B.1 and B.2.

V. Summary and Conclusions

All indications are that the 2013 Pre-Service Summer Engineering Workshop was a great success. Among the 14 students who participated, three of them graduated in May 2013 and were actively looking for employment in the local independent school districts. Results of the post-survey shows how these future STEM teachers could have an impact on the lives of those students seeking STEM careers.

VI. Acknowledgements

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VII. References

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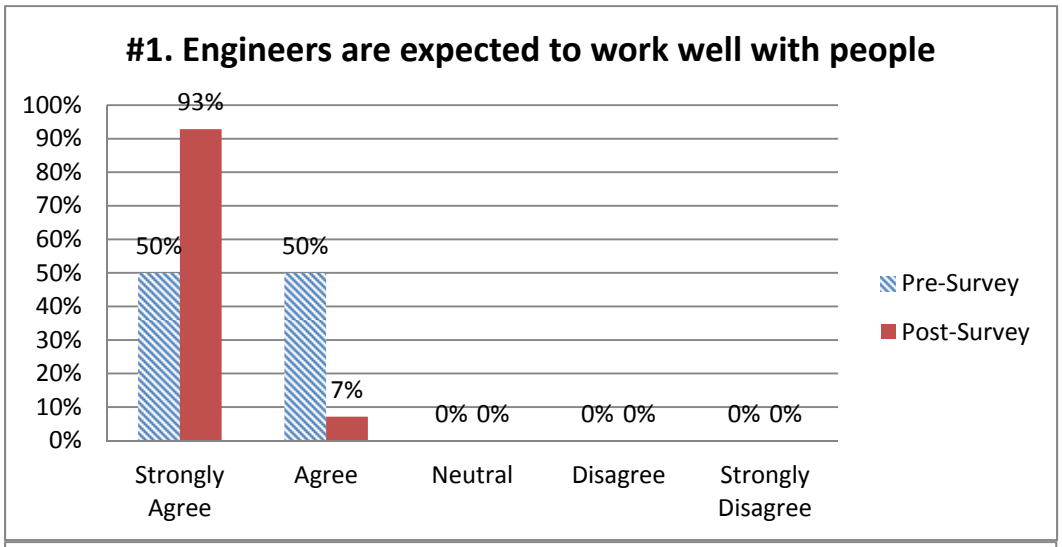
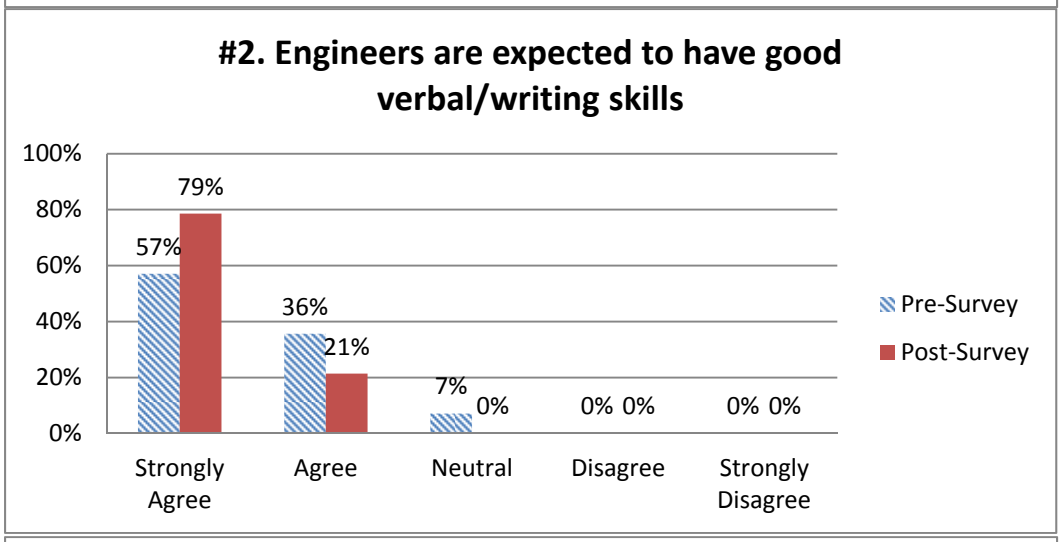
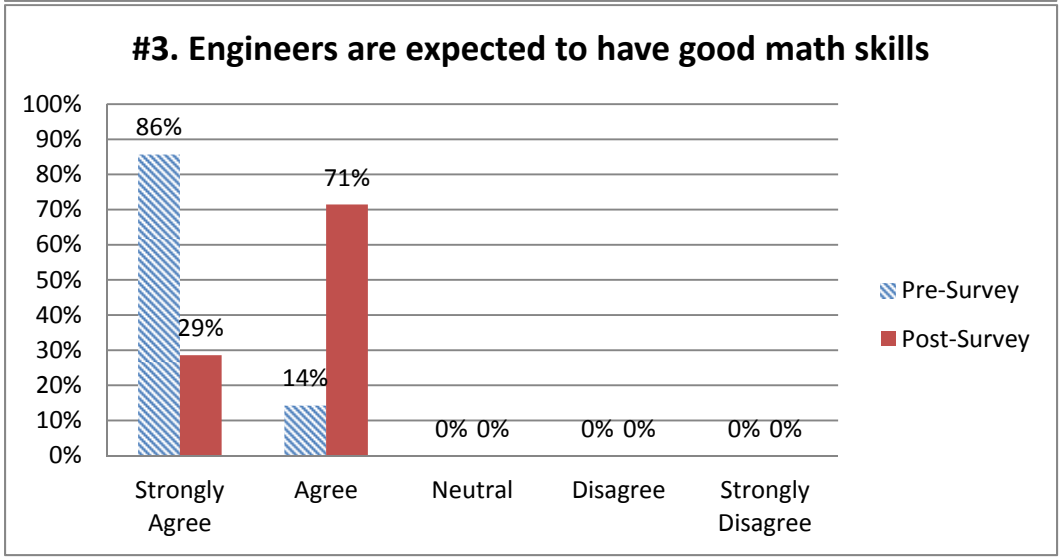
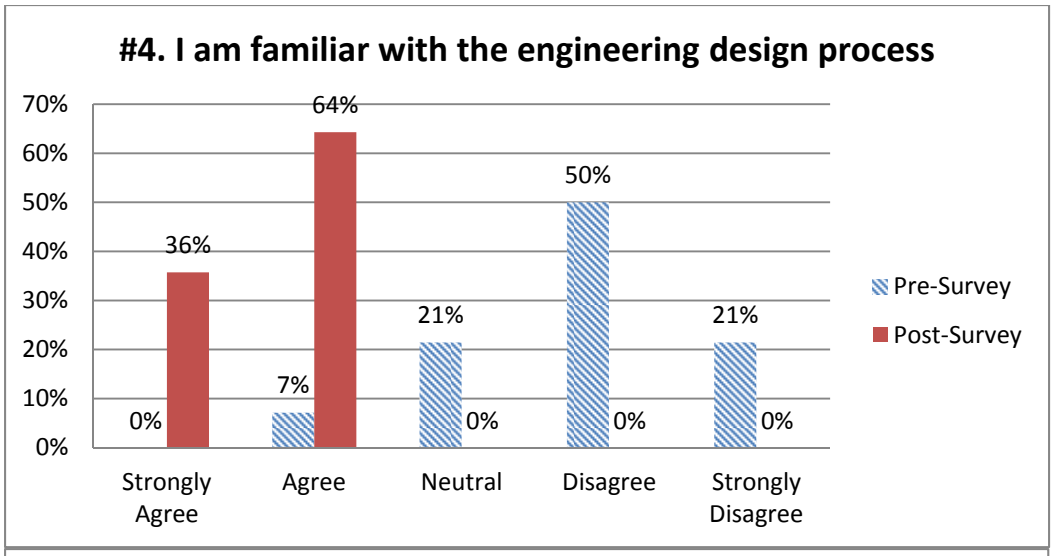
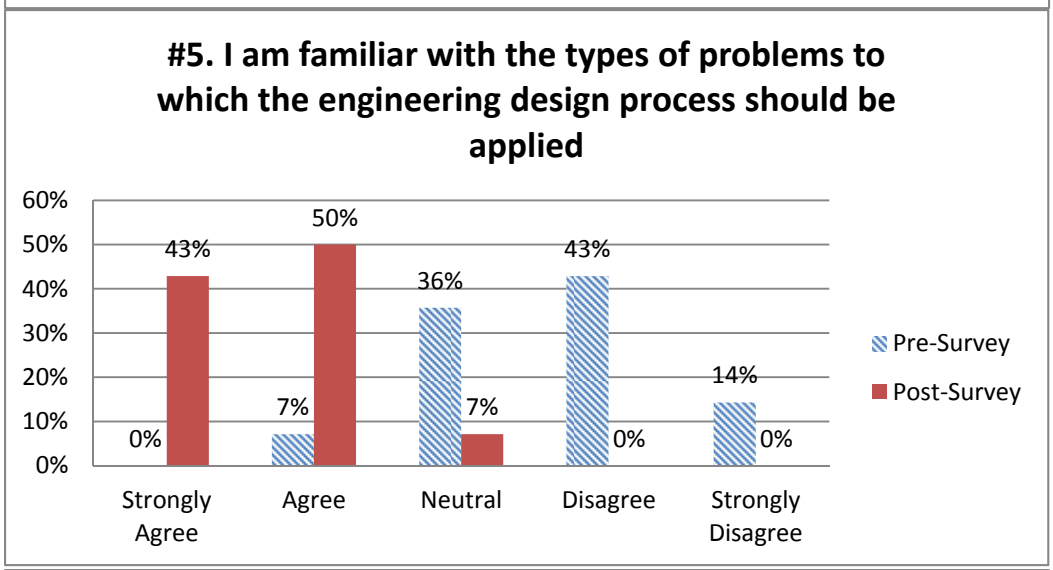
Appendix A: STEM Teachers Engineering Workshop -- Engineering Familiarity Pre- and Post- Survey Results (Summer 2013)

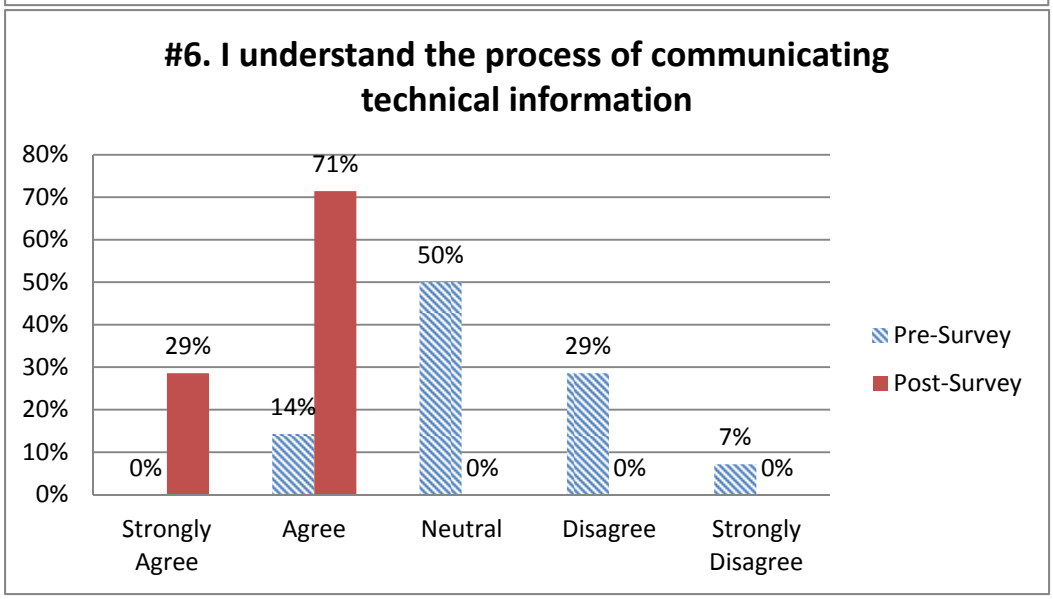


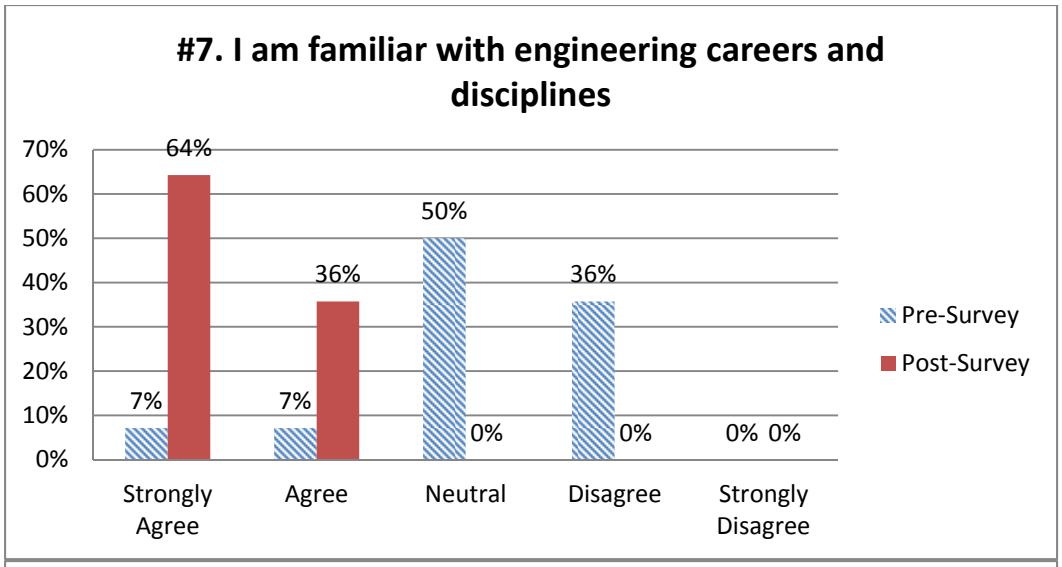


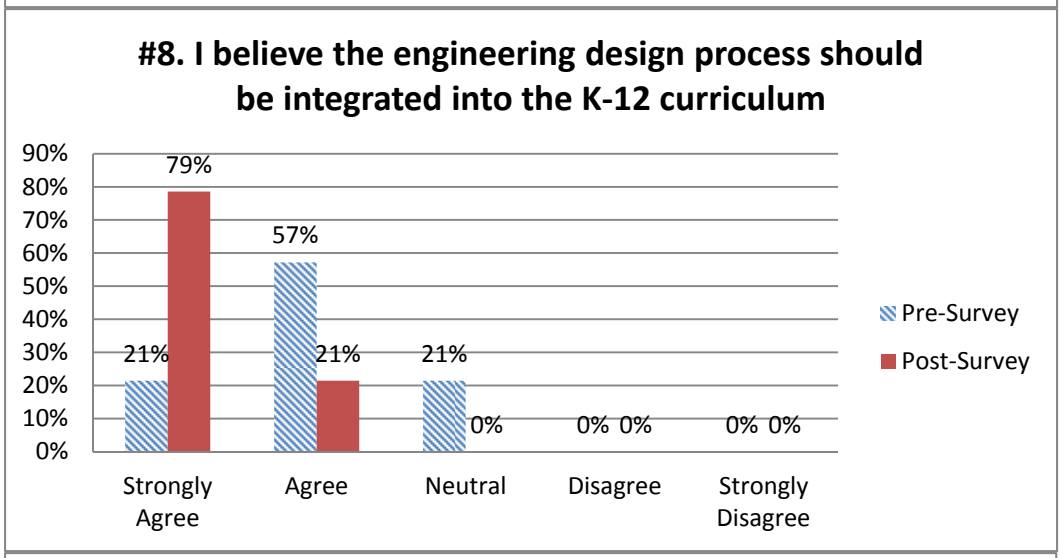


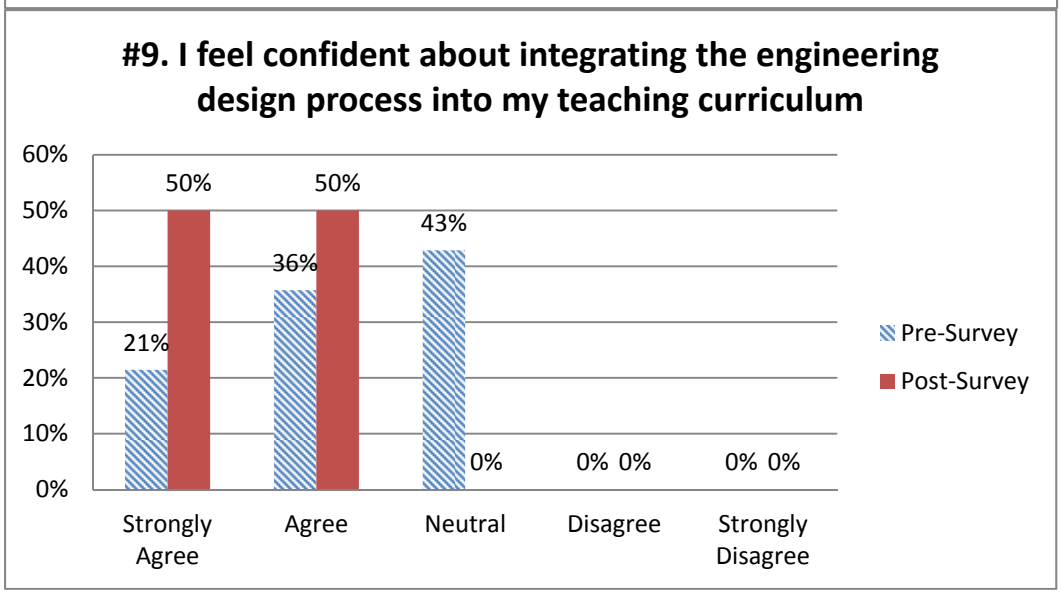

#4. I am familiar with the engineering design process
70%
60%
50%
40%
30%
20%
10%
0%
64%
36%
50%
21%
21%
7%
0%
0%
0%
0%
Strongly Agree
Agree
Neutral
Disagree
Strongly Disagree
Pre-Survey
Post-Survey

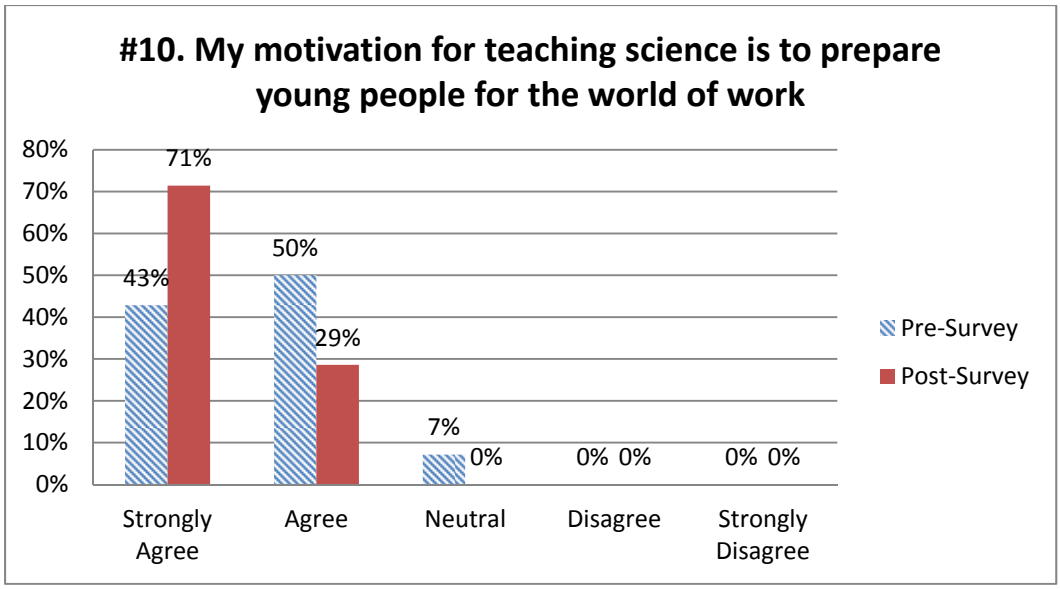

#5. I am familiar with the types of problems to which the engineering design process should be applied
60%
50%
40%
30%
20%
10%
0%
43%
50%
36%
43%
14%
7%
7%
0%
0%
0%
Strongly Agree
Agree
Neutral
Disagree
Strongly Disagree
Pre-Survey
Post-Survey


#6. I understand the process of communicating technical information
80%
70%
60%
50%
40%
30%
20%
10%
0%
71%
50%
29%
29%
14%
7%
0%
0%
0%
0%
Strongly Agree
Agree
Neutral
Disagree
Strongly Disagree
Pre-Survey
Post-Survey


#7. I am familiar with engineering careers and disciplines
70%
60%
50%
40%
30%
20%
10%
0%
64%
36%
50%
36%
7%
7%
0%
0%
0% 0%
Strongly Agree
Agree
Neutral
Disagree
Strongly Disagree
Pre-Survey
Post-Survey


#8. I believe the engineering design process should be integrated into the K-12 curriculum
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
79%
57%
21%
21%
21%
0%
0% 0%
0% 0%
Strongly Agree
Agree
Neutral
Disagree
Strongly Disagree
Pre-Survey
Post-Survey


#9. I feel confident about integrating the engineering design process into my teaching curriculum
60%
50%
40%
30%
20%
10%
0%
50%
50%
43%
36%
21%
0%
0% 0%
0% 0%
Strongly Agree
Agree
Neutral
Disagree
Strongly Disagree
Pre-Survey
Post-Survey


#10. My motivation for teaching science is to prepare young people for the world of work
80%
70%
60%
50%
40%
30%
20%
10%
0%
71%
43%
50%
29%
7%
0%
0% 0%
0% 0%
Strongly Agree
Agree
Neutral
Disagree
Strongly Disagree
Pre-Survey
Post-Survey

Appendix B.1: Pre-Service STEM Teachers Engineering Workshop

Engineering Familiarity Survey-- Summer 2013

Please completely shade or mark your response based on your understanding of the statements.

Statements	Level of Agreement/Disagreement				
	Strongly Agree	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**
1. Engineers are expected to work well with people.	❒	❒	❒	❒	❒
2. Engineers are expected to have good verbal/writing skills.	❒	❒	❒	❒	❒
3. Engineers should have good math skills.	❒	❒	❒	❒	❒
4. I am familiar with the engineering design process.	❒	❒	❒	❒	❒
5. I am familiar with the types of problems to which the engineering design process should be applied.	❒	❒	❒	❒	❒
6. I understand the process of communicating technical information.	❒	❒	❒	❒	❒
7. I am familiar with engineering careers and disciplines.	❒	❒	❒	❒	❒
8. I believe the engineering design process should be integrated into the K-12 curriculum.	❒	❒	❒	❒	❒
9. I feel confident about integrating the engineering design process into my teaching curriculum.	❒	❒	❒	❒	❒
10. My motivation for teaching science is to prepare young people for the world of work.	❒	❒	❒	❒	❒

Appendix B.2: Pre-Service STEM Teachers Engineering Workshop
Workshop Evaluation Form-- Summer 2013

On a scale of 1 to 5, rate the following statements (1 = disappointing; 5 = wonderful).

	1	2	3	4	5
1. My overall rating of this workshop.	❒	❒	❒	❒	❒
2. Rating of individual workshop sessions:					
a) Engineering Foundations and Design Process	❒	❒	❒	❒	❒
b) Concepts and Applications of Chemical Engineering	❒	❒	❒	❒	❒
c) Concepts and Applications of Systems Engineering	❒	❒	❒	❒	❒
d) Concepts and Applications of Electrical Engineering	❒	❒	❒	❒	❒
e) Industry Tour and Lunch with Engineering Professionals	❒	❒	❒	❒	❒
3. The facilities were appropriate	❒	❒	❒	❒	❒
4. The discussions with professional engineers **helped** me to understand more about engineering.	❒	❒	❒	❒	❒
5. The information provided in this workshop will be **useful** to me.	❒	❒	❒	❒	❒
6. I would like to **attend** another follow-up workshop provided by this institution.	❒	❒	❒	❒	❒
7. My **expectations** for this workshop were met.	❒	❒	❒	❒	❒
8. I would recommend this workshop to other students.	❒	❒	❒	❒	❒

9. How could the workshop experience be improved for future participants?

10. What additional information about this workshop would you like to obtain?