2011

But What Does This Have to Do with Science?: Building the Case for Engineering in K-12

Micah Maranda Arafah
Cleveland State University

BUT WHAT DOES THIS HAVE TO DO WITH SCIENCE?

BUILDING THE CASE FOR ENGINEERING IN K-12

MICAH MARANDA ARAFAH

Bachelor of Arts in Sociology

University of Colorado Denver

May, 2008

submitted in partial fulfillment of requirements for the degree

MASTER OF EDUCATION

at the

CLEVELAND STATE UNIVERSITY

May, 2011

Acknowledgements

The past two years have been two of the most difficult I have faced. My journey as a student has nearly ended on numerous occasions, and if it were not for a few close people in my life I am not sure this paper could have been written.

First of all I need to give massive thanks to Brian Harper who stepped up after my admitted hiatus of the brain, helped me get back on track and agreed to be my Committee Chair within the first thirty minutes of meeting me. Plus? You are HILARIOUS. THANK YOU.

Secondly, I would like to give thanks to Stephen Duffy who has, on several occasions, paid for my lunches, software, and travel, and cracked me up in response to things I probably was *not* supposed to be laughing at. I am pretty sure that without you, my graduate school experience would have been completely different and sucked a whole helluva lot more.

And even though *you're not here* (insert squinty, menacing eyes here), I want to thank my academic advisor and resident statistical genius, Dr. Joshua Bagaka's. I really don't know if I could have made it through stats without you. What a teacher you are. You took me under your wing, sat through all my questions with patience and understanding, and taught me a great deal about a great deal. You made me feel smart, reminded me of my potential, and I hadn't felt that way in a very, very long time. Thank you.

Dearest Debbie Jackson, I have probably told you this a thousand times but I can't say it enough. You are the biggest reason I didn't quit. When I felt like I didn't belong in school you reminded me why I did, and when insecurities overwhelmed me, you helped me laugh them away. And most importantly, during those dark times I felt like I didn't have anyone, you wiped away the lines that drew us together as supervisor/employee and became my friend. Thank you for being my light when I couldn't see an inch in front of my face.

I need, need, need to give props to my dear husband, Khalid Arafah, for during this tedious process he has tolerated my moodiness, brought me food to keep me going, left me alone for entire weekends to give me a quiet house, not complained when I sat on the couch after a long day of writing just staring into space instead of holding a conversation, taken care of most household duties while I lived at my desk, reminded me that I was smart when I returned from the intellectual colonoscopy of writing all day, and did not divorce me even though I have been a less than ideal wife during this entire process.

Lastly I want to give a shout out to my Moms and Pops who have been down since Day 1. With their unconditional love and never-ending support I was able to fight through the people and systems that consistently tried to hold me in place to become the woman I am today. As I grew, I realized I was one of very few kids that would have memories of their parents that included grilled cheese sandwiches and playing catch until you couldn't see the ball. I was one of the luckiest kids in the world because my parents always encouraged me to be what I wanted, regardless of whether anybody else thought I should, or could, succeed.

I will forever be indebted to those who have given so much of themselves to help me through this chapter in my life. Thank you.

BUT WHAT DOES THIS HAVE TO DO WITH SCIENCE?

BUILDING THE CASE FOR ENGINEERING IN K-12

MICAH MARANDA ARAFAH

ABSTRACT

A national push for reform in STEM K-12 education and a raised focus on including engineering in the classroom have emphasized the necessity for specific professional development opportunities for teachers. These programs are available; however, they are typically very expensive and consequently inaccessible to most educators in the public school sector.

The Engineering Education Summer Conference (EESC) is a three day professional development conference for K-12 teachers interested in using engineering in their classrooms and is funded primarily by the University Transportation Center at Cleveland State University. Its goals are to debunk biases of engineers and engineering, provide resources and funding to teachers, and indirectly increase exposure K-12 students have to engineering. One day was devoted to hands-on activities during which teachers participated as learners, and the remaining days consisted of presentations by engineers, engineer organizations, staff at the Great Lakes Science Center, a grant writer, and teachers who have used engineering in their classrooms.

The EESC evaluation was conducted in the summer of 2010 and examined the effectiveness in achieving those goals using a combination of quantitative and qualitative research methods.

Findings show that the conference succeeded in increasing the belief that engineering is important and necessary in society. Results also suggested teachers left more familiar

with engineering, though this conflicted with qualitative responses that revealed they were still unsure how to incorporate engineering into the classroom and stated that time constraints, not enough concept knowledge, confusion about how engineering related to their standards, and a lack of money were significant barriers in doing so. Data shows that conference participants left with more stereotypical views of engineers; more specifically, there were significant increases in the beliefs that engineers do not work well with people and that minorities do not have the skills necessary to be an engineer.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I

INTRODUCTION

It has been well-documented that the general public knows little about engineering, and the K-12 teacher population is no exception. Educators in the K-12 education system are increasingly expected to integrate engineering into their teaching, as pressure to include or infuse engineering into standard curricula continues to rise (Katehi, 2009; ODE, 2010). In 2009, Chancellor Linda Katehi, of the University of California, presented the findings of a report entitled "Engineering in K-12 Education: Understanding the Status and Improving the Prospects" to the U.S. House of Representatives Subcommittee on Research and Science Education. This report was based on the premise that traditional STEM teaching had proven to be largely ineffective and needed to be reformed to produce better understanding of these subjects. In order for the United States to retain its competitiveness in the global economy, it needs technologically literate professionals able to tackle the challenges that the future presents in our increasingly technologically-dependent society.

The United States is in a STEM crisis. The last 40 years has seen a 51 percent decrease in federal funding of engineering research (Augustine, 2007) and as a result, in

2009 over 50 percent of all U.S. patents were given to non-U.S. companies (Donohue, 2010). In 2000, the amount of foreign students studying graduate-level science and engineering exceeded the number of American students (Task Force on the Future of American Innovation, 2006), and among developing nations, the U.S. ranks 27th in undergraduate degrees awarded in science or engineering (OECD, 2009). The growth in the science and engineering workforce grew from under 183,000 in 1950 to 5.5 million in 2007 (at a yearly rate of 6.2 percent, almost four times the 1.6 percent total workforce growth rate) and is due to not only rapid advancements in science and technology, but also the necessary immigration of foreign scientists and engineers that has helped the U.S. endure (National Science Foundation [NSF], 2010).

In response to these crises that affect our global competitiveness, our ability to compete for quality jobs, and our quality of life, The National Academies have offered four recommendations, two of which include "[M]ove the United States K-12 education system in science and mathematics to a leading position *by global standards*" and "[E]ncourage more United States citizens to pursue careers in mathematics, science, and engineering" (Augustine et al., 2010). The concern that the U.S. is falling behind in its production of highly skilled scientists and engineers has stimulated the creation of STEM schools (Cavanaugh, 2006; Means, Confrey, House, & Bhanot, 2008). Fortunately, as evidenced by the rising numbers of STEM schools and in federal initiatives like President Obama's "Math and Science Teachers Initiative" and his "Educate to Innovate" campaigns, the United States remains steady in its push for more STEM education.

Historically, STEM schools have only admitted the students at the top of the class were to their elite institutions, some of which are more selective than Harvard University

(Means, Confrey, House, & Bhanot, 2008). During the 1990s, the creation of STEM schools increased dramatically but remained discriminatory in admittance practices, enrolling mostly gifted students or those who had shown excellence through STEM-related competitions were enrolled. Percentages of African American and Hispanic students in these schools remained very low (Kaser, 2006). In examining the admission standards for 59 STEM schools, it was found that nearly 80 percent used standardized test scores as a requirement for enrollment (Subotnik et al., 2006). In recent years, however, the creation of “inclusive” STEM schools (schools that are geared toward underrepresented and minority students) has been on a rapid incline. In a study on STEM high schools, researchers found that STEM schools created before 1999 were more likely to be geared towards gifted and talented students, and most STEM schools opened after the year 2000 were specifically created to draw students of underrepresented and/or minority backgrounds (Means, Confrey, House, & Bhanot, 2008).

Unfortunately, the number of talented STEM teachers in public schools is dwindling, and public school students are suffering as a result (Business-Higher Education Forum, 2006). Sixty-nine percent of public school students in the United States in grades 5-8 are currently taught math by teachers with no degree or certification in mathematics, and ninety-three percent of the same students are in physical science classes with teachers with no degree or certification in science (National Center for Education Statistics, 2003). In The Trends in International Mathematics and Science Study (TIMSS) exams in 2007, the U.S. position declined in fourth grade (Gonzales, Williams, Jocelyn, Roey, Kastberg, & Brenwald, 2008). On another international test, the Program for International Student Assessment (PISA), 15-year-olds in the United States scored below most selected nations, and the U.S. standing among selected nations dropped below its 2000 rank in both mathematics and science. Given these numbers, and the fact that The World Economic Forum (2009) ranks the United States 48th in quality of mathematics and science education, it is clear that compared to their international peers, the U.S. student rankings in math and science are unremarkable (Gonzales et al., 2004).

In Katehi's report (2009), she noted two important trends. First, growing awareness of the importance of STEM teaching, and second, the need to increase the teaching of STEM skills and even change traditional methods, programs and ideology currently used by science teachers in K-12 settings. In the state of Ohio, the trend of promoting STEM education is also evident. In their second release of the revised P-12 education standards in March of 2010, The Ohio Department of Education (ODE) stated that teaching science through the use of real-world applications of technology is imperative for 21st century students in order to ensure that students are prepared for college and careers by making science relevant and increasing science literacy. The "Model Curriculum" they promote will utilize interdisciplinary integration which will add depth, provide relevancy in a student's life and help them develop real-world and global connections. This integration must include engineering and technology and problem-solving skills that ensure that students are gaining the knowledge they will require to succeed after high school (ODE, 2010). Regrettably, the educators that bear the most responsibility in implementing these changes do not have the resources or support necessary to implement a more in-depth STEM curriculum in their existing classes. In order to promote the types of curricula needed for exceptional STEM teaching, information on how to create the curricula and resources that will support it must reach the people who will lead the effort to take it into the classrooms.

Throughout all STEM subjects, there lie threads that bind them. Within science there are natural connections to mathematics, engineering, and technology. For example, in analyzing the world around them, scientists must use technological devices that were idealized by engineers who used mathematics and science concepts to design and construct them. Conversely, the engineers that created these technologies could not have succeeded without understanding the science behind them and using mathematics to effectively analyze the product. Because engineering problems naturally engage students in science and mathematics, many believe that engineering is a logical vehicle through which to teach math and science. Possibly one of the most common myths regarding the incorporation of engineering into the K-12 classroom is the idea that engineering would be an addition to the already overstuffed curricula. The truth is that by using engineering as a vehicle through which to teach science, technology and mathematics, the integration of all these subjects will require students to use multiple methods to solve problems by thinking critically and creatively. Unfortunately, though the natural link between STEM subjects is highlighted in a multitude of literature, suggestions and recommendations on how to integrate the subjects in the classroom are rarely mentioned.

By using engineering to connect disciplines, it is possible that scientific and technological literacy will increase, as has been shown in K-12 engineering programs such as "Project Lead the Way" (Bottoms & Anthony, 2005; Bottoms & Uhn, 2007), "Engineering Our Future New Jersey" (Hotaling et al., 2007) and online programs created by the Center for Innovation in Engineering and Science Education at Stevens

Institute of Technology (McKay & McGrath, 2007). These and many other studies focus on students that have chosen to participate in engineering education (e.g. attending engineering summer camps or enrolling in college preparatory engineering courses), which make generalizing to a more representative K-12 population nearly impossible. Despite the limitation, these findings remain positive that engineering has the ability to not only link all STEM subjects, but to increase achievement as well. It would also reason that an increase in math and science scores would open up a new realm of perceived career opportunities for students who otherwise would have dismissed STEM careers entirely.

Sadly, there is a tremendous lack of literature in professional journals published for educators wishing to learn about engineering. Because of this, many teachers are increasingly reliant on K-12 engineering professional development opportunities through which they can learn engineering concepts from engineers themselves. A phone conversation with the Ohio Department of Education revealed no knowledge of engineering professional development for teachers and advised people interested in such training to call local universities and ask the department of teacher education if they were aware of opportunities available. The committee behind the National Academy of Engineering and National Research Council report: Engineering in K-12 Education (2009) reports it was only able to find only three programs that offer pre-service training in the United States, and only twelve programs that provide professional development to existing teachers wanting to incorporate engineering into their classrooms.

In 2008, Cleveland State University's University Transportation Center (CSU-UTC) created the Engineering Education Summer Conference (EESC). The conference was created as a response to a national push for STEM reform and the studies that extol the benefits of using engineering as a catalyst for teaching math and science, a need for more engineering professionals in the U.S., and a lack of resources for K-12 educators. The EESC brings together K-12 educators, university faculty, and industry professionals for a critical conversation and practical strategies for implementing and improving engineering education in the K-12 curriculum.

In conjunction with the goals of the UTC, the EESC also originated out of the Garret A. Morgan Technology and Transportation Education Program (GAMTTEP) grant, which requires the recipient to publicly disseminate the successes of the programs provided for by the grant. Through this partnership the EESC was created. In 2010, its third year, the EESC offered all conference participants 2 continuing education credits, a teacher stipend of $250, and the opportunity to receive project stipends to directly enhance pre-engineering instruction in their classrooms.

1 Among the main objectives of the conference are:

- ∞ *Debunk misconceptions and stereotypes regarding engineering and engineers.* The conference brings together engineers and educators in order to learn from each other. Participants attend presentations by CSU engineering faculty, the Cleveland Engineering Society (CES), the Society of Women Engineers (SWE), and the high school outreach program for Cleveland State's Fenn College of Engineering, Fenn Academy.
- ∞ *Teach educators how to implement engineering into their existing curricula.* The EESC relies heavily on the participation of high school, middle school and elementary teachers who have experience bringing engineering

into their classrooms. The EESC depends on these teachers to share with their peers the activities they have successfully implemented and the results they have achieved. The focus is on hands-on, inexpensive activities that are relevant to state science and mathematics standards and can be easily replicated in the participants' classrooms.

∞ *Provide teachers with resources to help them use engineering in the classroom.* All EESC participants are provided with a binder and CD containing lesson plans, project outlines, educational resources, website directories, relevant engineering articles, and contact information for all those involved in the event. Additionally, teachers participate in several field trips, including the Biomedical labs at the Cleveland Clinic Lerner Institute, the Great Lakes Science Center (GLSC), the GE Lighting Institute, and the Fabrication Laboratory (Fab Lab) located at the MC^{2}STEM High School (a STEM platform high school) to learn more about the resources they can count on to improve their STEM teaching in Northeast Ohio.

∞ *Provide educators with funding for the implementation of their engineering education projects.* Since 2009, the EESC has given its participants the opportunity to apply for a project stipend. The goal of these project stipends is not only to encourage teachers to bring STEM projects to their students (by providing some initial funding), but also to provide an introduction to the formal grant writing process. The application requires conference participants to submit a short proposal detailing a STEM project they would like to introduce into their classroom, with an estimated budget for their proposed project and a schedule of execution for implementation.

- *Indirectly increase the exposure Ohio K-12 students have to engineers and engineering.* The more exposure anyone has to something, the more comfortable that person is talking about it, asking questions about it, and the more confidence that person has about the subject in general. By exposing teachers to engineers and the engineering profession, their comfort and confidence will increase and will indirectly affect their students.

The 3-day conference in 2010 began at a local public high school and consisted of "breakout sessions" that included two "hands-on STEM activities" for each grade level (elementary, middle, and secondary). These activities were led by teacher participants that presented a lesson they had used successfully in their classroom. For example, at the secondary level, teachers were shown and got to participate in a lesson on buoyancy by designing and building a boat out of straws and plastic wrap strong enough to hold 25 pennies for ten seconds before sinking; at the middle level, a presentation on wind energy was given before participants had to design, construct, and test a blade for their own wind turbine. The second day of the conference was held at Cleveland State University and started with a talk on project stipends given by the UTC and followed by presentations by previous project stipend award winners and how their projects are being used in the classroom. Participants spent time with university engineering faculty as they demonstrated how different CSU resources (e.g. a driving simulator or hydraulics lab) could be used in the classroom, and listened to presentations given by local engineering organizations. The day ended with a session on grant writing led by a national non-profit philanthropic organization. The last day of the conference was held at the Great Lakes Science Center (GLSC), an interactive science museum in Cleveland. Elementary and middle school educators saw presentations and participated in activities throughout the GLSC that could be adapted for classroom use. Plans for high school teachers to experience the Fab Lab, a small-scale workshop with the means to create almost anything, were cancelled as the Fab Lab had not yet been moved to the GLSC from its previous location.

CHAPTER II

LITERATURE REVIEW

Professional Development

Research suggests that for K-12 professional development to be effective, it must provide opportunities for participants to *build* their knowledge by participating as a learner, *translate* that knowledge into practice by helping to design their own lessons and addressing misconceptions about content, *practice* teaching by demonstrating the lessons, and *reflect* on that practice by discussing the experience with fellow teacher participants (Mundry, 2007). In addition, if the professional development is concentrated on curriculum modification, studies show that activities must be specific, and teacher participants need to be given explicit instruction on how to incorporate them into their classrooms by linking them to mandated standards (Borko & Putnam, 1995; Loucks-Horsley, Hewson, Love, & Stiles, 1998; Garet, Porter, Andrew & Desimone, 2001; Loucks-Horsley, Stiles, & Hewson, 1996; Asayesh, 1993; Maldonado, 2002).

Successful K-12 professional development focused on the relevance of engineering are typically coordinated around hands-on activities (Carlson & Sullivan, 1999) that show how the engineering design process can help learners develop a deep understanding of other STEM subject content knowledge (Johnsey, 1993; Johnsey, 1995; Roth, 1995, 1996; Fleer, 2000; Crismond, 2001; Fleer and Williams-Kennedy, 2002; Zubrowski, 2002; Kolodner et al., 2003; Linn, 2003; Kimmel et al., 2006; Lewis, 2005; Sadler, Barab, and Scott, 2007). These activities also needs reflective discussions; additionally these should be led by a knowledgeable facilitator that can explicitly explain the scientific and engineering concepts behind the activity (Cognition and Technology Group at Vanderbilt, 1997; Schwartz, Brophy et al., 1999; Schwartz, Lin et al., 1999; Adams, Turns, and Atman, 2003) and how those concepts fit within existing standards (Loucks-Horsley, Hewson, Love, & Stiles, 1998). A 2008 study on incorporating engineering into technology curriculum found that bringing together technology educators and engineers to lead professional development activities had more success than the activities led by only engineers or only teachers (Custer, R., Hailey, C., Cunningham, C., Erekson, T, & Householder, D., 2008). There is a need for more literature on engineering, rather than general, professional development in K-12. The literature on engineering professional development was frequently broad and did not normally focus on the characteristics of successful professional development programs.

Misconceptions and Stereotypes

There has been a great deal of published research on misconceptions and stereotypes of engineers and engineering held by not only the general public, but teachers as well (Carey, 1991; Chi, 2005; Crespo & Pozo, 2004; Diakidoy & Iordanou 2003; Reiner, Slotta, Chi, & Resnick, 2000; Smith, Maclin, Grosslight, & Davis, 1997; Yip, 1998). Part of the CSU-UTC's mission is to debunk misconceptions and stereotypes related to engineers and engineering through outreach programs where engineers visit schools and talk directly to students, or through conferences intended to reassure science, math and technology teachers that engineering provides a viable, accessible way of teaching their

STEM subjects. Studies have shown that the public, including teachers, have many misconceptions and stereotypes regarding what engineering is, what engineers do, and who is perceived as capable of pursuing a career in this field (Yasar, 2006; Arafah, Trombetta, Jackson, & Duffy, 2010). If misconceptions are not identified, specifically addressed, and challenged, people do not experience how to change them and they will persist (Schnittka, 2008). These views play a devastating role in narrowing the pipeline of future engineers in the United States.

Teachers of K-12 science in Arizona participated in a study on misconceptions of engineers (Yasar et al., 2006), and the results showed that the respondents held stereotypical views of engineering that were rooted in an overall lack of knowledge about what engineers do. A typical engineer was seen to have below average writing, verbal, and people skills. On the other hand, the participants recognized the need for an engineer to have good mathematics and science skills.

Teachers have always played a role in shaping the lives of their students, whether by encouraging them to pursue a certain goal, or by steering them in different directions. These narrow-minded views of engineering disregard a huge part of the profession, which is that engineers rely on team work and must give presentations and produce reports for a multitude of audiences to exhibit their work. Teachers with this limited view of engineering might sway able students into different careers due to the fact that they might not fit these stereotypes or may not appear to fill the skill requirements (Yasar et al., 2006) and could very well account for the underrepresentation of women and minorities in the work force.

Because many teachers hold biases that assume the majority of their students are not skilled or bright enough to be successful in engineering, teachers may be under the impression that including engineering in their curriculum would be extra work only benefitting a few students (Cummings and Taebel, 1980). It is important that educators and professionals see engineering as a catalyst for STEM education. The critical thinking that comes from problem solving and the connection that engineering problems have with real life can do wonders for increasing interest and providing relevancy in other subjects. If only the students that fit into the preconceptions of their teachers are exposed to the benefits of engineering education, then the potential benefits that it offers does not reach the masses, the misconceptions and stereotypes are strengthened, and the engineering pipeline narrows (Brophy et al., 2008).

CHAPTER III

AIMS AND LIMITATIONS

Aims

The goals of this paper are to discuss the impact the EESC had on participants' views on engineers and engineering, both inside and outside of the classroom, and how those results can improve future engineering in K-12 professional development.

Limitations

The sample size for this study was particularly small. A small sample size has a greater probability that the results could be due to chance; therefore it is harder to find and rely upon significant relationships from the data. There were also missing data on both the pre- and the post-survey. Some participants completed the pre- survey and not the post, and some the post-survey and not the pre. Only data that had complete pre- and post-test representation were used to determine significance. Also, the respondents were not only voluntary participants of the EESC, but for attending the entire conference, they were given stipends and were offered opportunities to apply for grants to assist them in purchasing equipment for their classroom. Because of this, generalizing these results to other populations may be difficult, especially in situations where the professional development is mandatory and attitudes toward the sessions may not be as positive.

CHAPTER IV

METHOD

Research Design

The purpose of this study was to examine the effectiveness of the EESC in reducing perceptions and understanding of engineers and engineering, as well as factors related to teaching engineering by using a pre- and post-survey. This data could be used to inform future coordinators of professional development opportunities and to help teachers infuse engineering into existing curricula. Registered participants in the EESC in 2010 were the respondents in the study on which I will report. A non-experimental within-groups design was used as I had access to only one group to whom I administered a pre- and post-census assessment.

Sample

Participants in the pre- and post-study were K-12 teachers from the Northeast Ohio region who voluntarily participated in the EESC. The independent variables I used in this study were gender, years of teaching experience, type of school (i.e. Cleveland Municipal School District [CMSD], first/inner ring [public], private or parochial, charter, or other public), and the subject in which they were licensed.

Twenty-five women and thirteen men completed the survey. 42 percent of all respondents had 16 or more years experience as a teacher, 18 percent had 11-15 years, 16 percent claimed 6-10 years, 21 percent had 1-5 years of experience while only 1 participant specified no years of experience. Thirty-one participants were currently teaching in public schools, while 5 taught in private or parochial schools and 2 were in charter schools. Just under 60 percent of all participants had licensures in science, and the remaining participants were certified to teach mathematics or had general licensures (both at roughly 21 percent). The demographic characteristics of the respondent sample are presented in Table 1.

Demographic Characteristics of Respondent Sample				
		Gender		
		Male	Female	
		N=13 (34.2%)	N=25 (65.8%)	
		Licensed Subjects		
	Science	Mathematics	General/Other	
	N=22 (57.9%)	N=8 (21.1%)	N=8 (21.1%)	
		Experience		
0 years	1-5 years	6-10 years	11-15 years	16+ years
N=1 (2.6%)	N=8 (21.1%)	N=6 (15.8%)	N=7 (18.4%)	N=16 (42.1%)
		Type of School		
CMSD	First/Inner Ring	Private/Parochial	Charter	Other Public
N=8 (21.1%)	N=1 (2.6%)	N=5 (13.2%)	N=2 (5.3%)	N=22 (57.9%)

Table I. Demographic characteristics of respondent sample

Instruments

In the summer of 2010, I created and administered a pre- and post-survey to EESC participants assessing the level of importance they place on engineering, their familiarity with engineering, their opinions of characteristics of both engineers and engineering, how they envision incorporating engineering into their classrooms, and their perceived barriers in doing so (Appendix A). The qualitative portion was developed to identify specific changes in thought and included the following open-ended questions:

1. What do you know about engineering?
2. What do you know about engineers?
3. How can engineering be taught in the classroom?
4. What are the biggest barriers you face when attempting to alter your curricula?

The quantitative section of the survey was modified from an instrument created by Yasar, Baker, Robinson-Kurpius, Krause and Roberts (2006). Initially included were 39 items with four response options, ranging from "not at all" or "strongly disagree" to "very much" or "strongly agree." To establish validity, I did a factor analysis using Statistical Package for the Social Sciences (SPSS) to determine the constructs of the new instrument. The analysis extracted four factors; *Importance of Engineering, Familiarity with Engineering, Characteristics of Engineers, and Characteristics of Engineering*. As a result, the survey was reduced to 35 items, as some had low loadings or were loaded onto multiple factors. The factor loadings, means, and standard deviations are presented in Table 2.

$\alpha = 0.621.$

Reliability of the entire quantitative section was analyzed and determined to be acceptable to make judgments based on the data (). Reliability was also computed for each factor. The first factor, *Importance of Engineering*, included 18 items and had a reliability coefficient of The second factor, *Familiarity with Engineering*, included 10 items and had a reliability coefficient of The third factor, *Characteristics of Engineers*, included 3 items and had a reliability coefficient of The fourth factor, *Characteristics of Engineering*, included 4 items and had a reliability coefficient of

Factor 1: Importance of Engineering (alpha = 0.873)	**Factor Loadings**	**Mean (SD)**	
		Pre	***Post***
I would like to be able to teach my students to understand the use and impact of engineering.	0.830	3.84 (0.37)	3.89 (0.31)
I would like to be able to teach my students to understand the science and/or math of engineering.	0.743	3.89 (0.31)	3.95 (0.23)
I would like to teach my students to understand the design process.	0.730	3.70 (0.52)	3.84 (0.37)
I would like to be able to teach students to understand the problems to which engineering can be applied.	0.726	3.82 (0.39)	3.89 (0.31)
My motivation for teaching science/math is to promote an understanding of how engineering affects society.	0.672	3.11 (0.69)	3.32 (0.78)
I am interested in learning more about engineering through in-service training.	0.665	3.79 (0.41)	3.84 (0.37)
I would like to be able to teach students to understand the process of communicating technical information.	0.659	3.66 (0.58)	3.61 (0.55)
My motivation for teaching science/math is to prepare young people for the world of work.	0.652	3.71 (0.52)	3.63 (0.49)
My motivation for teaching science/math is to promote an enjoyment of learning.	0.599	3.82 (0.39)	3.79 (0.41)

I believe engineering should be integrated into the K-12 curriculum.	0.592	3.71 (0.52)	3.82 (0.46)
I am interested in learning more about engineering through workshops.	0.591	3.87 (0.34)	3.95 (0.23)
I am interested in learning more about engineering through college courses.	0.581	3.00 (0.90)	3.32 (0.81)
In a science/math curriculum, it is important to include the use of engineering in developing new technologies.	0.572	3.53 (0.51)	3.76 (0.49)
I am interested in learning more about engineering through peer training.	0.564	3.26 (0.76)	3.53 (0.60)
My motivation for teaching science/math is to help students develop an understanding of the technical world.	0.511	3.45 (0.60)	3.55 (0.50)
My motivation for teaching science/math is to educate scientists, engineers and technologists for industry.	0.459	2.97 (0.79)	3.13 (0.74)
In a science/math curriculum, it is important to include planning of a project.	0.435	3.71 (0.52)	3.84 (0.37)
How important should pre-service education be for teaching engineering?	0.418	3.51 (0.65)	3.73 (0.45)
Familiarity with Engineering (alpha = 0.749)			
How familiar are you with engineering?	0.747	2.97 (0.76)	3.23 (0.67)

Have you had any specific engineering courses outside of your pre-service curriculum?	0.652	2.19 (1.08)	2.19 (1.18)
How confident do you feel about integrating more engineering into your curriculum?	0.646	3.11 (0.77)	3.46 (0.61)
Was your pre-service curriculum effective in supporting your ability to teach engineering at the beginning of your career?	0.602	1.97 (1.03)	2.11 (1.01)
Did your pre-service curriculum include any aspects of engineering?	0.569	1.94 (0.98)	1.97 (0.94)
Barrier in integrating engineering – lack of training.	0.567	3.03 (1.08)	3.03 (1.06)
I use engineering activities in the classroom.	0.561	2.84 (0.99)	2.89 (0.94)
Barrier in integrating engineering – lack of time for teachers to learn about engineering.	0.560	3.11 (0.74)	3.08 (0.72)
I know the national education standards related to engineering.	0.516	2.05 (1.05)	2.19 (1.00)
My school supports engineering activities.	0.429	3.00 (0.91)	3.03 (0.99)
Characteristics of Engineers (alpha = 0.778)			
A typical engineer works well with people.	0.734	3.38 (0.59)	2.89 (0.61)
Most people feel that minority students can do well in engineering.	0.691	2.84 (0.73)	2.59 (0.60)

Most people feel that female students can do well in engineering.	0.686	2.81 (0.78)	2.76 (0.68)
Characteristics of Engineering (alpha = 0.621)			
Most people feel that male students can do well in engineering.	0.668	3.43 (0.50)	3.78 (0.52)
A typical engineer does well in science.	0.614	3.49 (0.51)	3.62 (0.49)
A typical engineer has good math skills.	0.450	3.57 (0.50)	3.70 (0.46)
A typical engineer earns good money.	0.413	3.32 (0.53)	3.27 (0.51)

Table II. Factor loading, pre and post means, and standard deviations of 39 survey items

Procedure

The survey was administered in the morning of the first day and at the end of the last day of the EESC. Consent forms were obtained from all participants. There was no time limit given though participants were informed that the survey would take approximately 15 – 20 minutes to complete. No participants asked to take part declined to do so. Teachers were not compensated for participating in the surveys, and were all instructed that the responses would be kept completely confidential. The quantitative data collected from the surveys were analyzed using SPSS statistical software. The qualitative data were reviewed to identify recurrent themes, were grouped into categories, and further coded by number of similarly-themed responses.

Data Analysis

$t(36) = 3.96, p =< .001.$

After reliability and validity were established, data was analyzed. The quantitative data was examined for significant differences among the first four factors using a paired samples *t*-test, and if found, the items within that factor were examined using an independent *t*-test. Data analysis showed that significant increases from pre to post results were present in the factors *Importance of Engineering, Familiarity with Engineering,* and *Characteristics of Engineering,* The factor *Characteristics of Engineers* and had significant decreases from pre to post, The items with the most significant changes can be seen in Table 3.

Factor 1: Importance of Engineering	**Mean (SD)**	
	Pre	***Post***
I am interested in learning more about engineering through college courses.	3.00 (0.90)	3.32 (0.81)
In a science/math curriculum, it is important to include the use of engineering in developing new technologies.	3.53 (0.51)	3.76 (0.49)
Familiarity with Engineering (alpha = 0.749)		
How familiar are you with engineering?	2.97 (0.76)	3.23 (0.67)
How confident do you feel about integrating more engineering into your curriculum?	3.11 (0.77)	3.46 (0.61)
Characteristics of Engineers (alpha = 0.778)		
A typical engineer works well with people.	3.38 (0.59)	2.89 (0.61)
Most people feel that minority students can	2.84 (0.73)	2.59 (0.60)

do well in engineering.			
Characteristics of Engineering (alpha = 0.821)			
Most people feel that male students can do well in engineering.		3.43 (0.50)	3.78 (0.52)

Table III. Most significant items in each factor from pre to post

The four factors were then explored for any gender differences using an independent samples *t-test*. Significant differences were found in the factor *Familiarity with Engineering.* All pre and post items for this factor are categorized by gender, with items that remained significant from pre to post highlight in bold, and can be seen in Table 4.

Familiarity with Engineering				**Male**			**Female**		
Items		***t***	***p***	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**
	Pre	3.93	**.000**	13	**3.54**	0.52	25	**2.68**	0.69
	Post	1.74	**.091**	12	**3.50**	0.52	25	**3.10**	0.71
	Pre	3.54	**.001**	13	**2.92**	1.04	25	**1.80**	0.87
	Post	3.28	**.002**	12	**3.00**	1.21	25	**1.80**	0.96
	Pre	3.72	**.001**	13	**3.69**	0.48	25	**2.84**	0.75
	Post	1.47	.152	12	3.67	0.91	25	3.36	0.64
	Pre	2.96	**.006**	13	**2.62**	1.04	24	**1.67**	0.87
	Post	3.01	**.005**	12	**2.75**	0.87	25	**1.80**	0.91
	Pre	3.29	**.002**	13	**2.62**	0.96	24	**1.63**	0.82
	Post	3.65	**.001**	12	**2.75**	0.87	25	**1.60**	0.91
	Pre	-1.09	.284	13	2.77	1.17	25	3.16	0.99
[redacted]									
	Pre	2.92	**.006**	13	**3.46**	0.66	25	**2.56**	1.00
	Post	2.08	**.045**	12	**3.33**	0.89	25	**2.68**	0.90
	Pre	-1.62	.114	13	2.85	0.80	25	3.24	0.66
	Post	-2.61	**.013**	12	**2.67**	0.78	25	**3.28**	0.61
	Pre	3.00	**.005**	13	**2.77**	1.09	25	**1.76**	0.93
	Post	2.12	**.041**	12	**2.67**	1.07	25	**1.96**	0.89
	Pre	0.99	.327	13	3.23	0.93	25	2.92	0.91
	Post	0.95	.348	12	3.25	0.97	25	2.92	1.00

Table IV. Significant gender differences by item: Factor 2

The qualitative portion consisted of open-ended questions. Responses had the same themes in the pre- and post- survey for questions 1, 2, and 4, but different themes emerged in the post-survey for question 3. The responses were coded into themes and then counted to determine a frequency for each category of response and can be seen in Table 5.

CHAPTER V

RESULTS

Quantitative data revealed that the importance placed on engineering increased from pre- to post-survey, as did participants' familiarity with engineering. Females' responses were the driving force behind the increase in *Familiarity with Engineering*. *Characteristics of Engineering* also increased, signifying a more myopic view of engineering, and *Characteristics of Engineers* decreased, indicating that stereotypes and biases of engineers amplified after the conference. The items with the most significant changes can be seen in Table 4. There were also significant differences in gender for specific items from pre to post. Overall, males claimed to be more familiar with engineering than females and more confident in integrating engineering into their curriculum. Pre-post differences by gender were found in three items and are located in Table 3.

Though the items "Most people feel that minority students can do well in engineering," "Most people feel that female students can do well in engineering," and "Most people feel that male students can do well in engineering" were indirect measures used to determine bias, the results from the study showed that not only did conference participants think most people believe that minority students lack the skill necessary to succeed in engineering, but that belief significantly *increased* after the conference. Though not significant but important to note, the belief that most people think female students also lack the skill needed to be accomplished in engineering was also raised. Respondents' beliefs in a male's ability to do well in engineering significantly increased.

For each qualitative question, four themes emerged which can be seen in Table 5. In response to the first question, "What do you know about engineering?" there was an evident decrease in the belief that engineering consists of solving problems, though the other themes remained steady from pre- to post. Participants were then asked, "What do you know about engineers?" Two of the themes for this question differed in that the belief that engineers build and design things went down, but describing engineers as people knowledgeable in math and science went up. The responses to the third question, "How can engineering be taught in the classroom?" were very interesting. Not only did the themes change from pre- to post, but whereas just over a quarter of the pre-survey responses stated that including engineering in science and math curriculum was how engineering could be taught, less than 10 percent responded the same on the post-test. There wasn't much difference in frequencies of responses for "design," but on the post-survey, not one response mentioned "building" and over thirty percent mentioned "project-/problem-based learning" as a way to teach engineering in the classroom.

The pre- and post-survey responses for the last question, "What are the biggest barriers you face when attempting to alter your curricula?" were completely unexpected. Although assumptions were that time, a lack of knowledge, money issues, and meeting standards would emerge as themes, the similarity in responses from pre to post in all four on the post-survey was unpredictable.

Discussion

Interest in engineering seemed to increase at the end of the conference. Participants were more interested in taking university-level engineering courses and beliefs about integrating engineering into science and mathematics to develop new technologies increased. Respondents' familiarity and confidence with engineering also increased statistically; however, these data seem to conflict with the qualitative data that suggest teachers need more knowledge in order to teach engineering. Another key finding is that after the conference, there was a significant decrease in beliefs that infusing engineering into math and science was a good way to include engineering into the classroom, demonstrating a lack of knowledge how engineering is connected to other STEM subjects. It was also evident by the responses that though educators felt confident participating in hands-on activities, they were still unsure of how to incorporate them into classroom lessons and teach them without assistance. What is telling is that the barriers most teachers perceived in altering their curricula remained steady after the conference. These barriers – a lack of time, content knowledge, money, and understanding how to incorporate engineering into their standards – keep them from altering their curricula, indicating a lack of explicit instruction on engineering concept knowledge, its relation to other STEM subjects, and an uncertainty in how to include engineering into their existing curricula without spending a lot of time or money in doing so.

The stereotypes and biases held by teachers of engineers and engineering increased after the conference. This could be because the contact they had with engineers during the conference was limited or impersonal. An observation by the researcher was that the participants had more one-on-one interaction with fellow teachers who led hands-on activities during the first day than they did with engineers who mostly gave presentations throughout the conference.

Implications

Such data emphasizes the need for more preparation for these professional development opportunities. During the EESC, teachers enjoyed the hands-on activities, but expressed a need for more explicit engineering concept knowledge. Explicit instruction is one of the most popular forms of teaching that allows the teacher to deliver large amounts of information in a short amount of time. Using explicit instruction would facilitate a stronger comprehension of engineering concepts and the design process to teachers who may be completely unfamiliar with the subject matter (Adams & Engelmann, 1996; Tillema & Knol, 1997). Explicitly teaching about core concepts is necessary to build and increase a teacher's understanding and help the teacher relay that information to their students (Loucks-Horsley, Stiles & Hewson, 1996; Maldonado, 2002). Research on teacher professional development shows that emphasis on increasing content knowledge, focusing on what and how to teach the content, and how students will most effectively learn that content knowledge is imperative (Kennedy, 1999; Loucks-Horsley, Hewson, Love & Stiles, 1998; Maldonado, 2002).

After the conference, teacher participants also stated that they were not sure how the different lessons would fit into their existing standards, and that they lacked money and time to try. Because most teachers that come to these workshops do not teach engineering, specific information should be relayed on the interdisciplinary nature of STEM subjects and how engineering fits into the bigger picture. Interdisciplinary examples of relationships between all STEM subjects are easy to find and should be utilized. Teachers need to know that engineering in the classroom can be used to teach science and mathematics, rather than added on to an already overstuffed curriculum (which would take more time), and can be done relatively inexpensively. Consider planning professional development activities that are specific. If the goal is to incorporate engineering into an existing, non-engineering classroom, give teachers enough concept knowledge to be comfortable with engineering, teach them how each lesson can be used to meet their particular standards, and show them how to teach the lesson.

Surprisingly, teacher's biases regarding engineering and engineers increased after the conference. Because teachers came out of the conference with less diverse views of engineers, it is important that future engineers involved in K-12 professional development come from a multitude of groups that are more representative of the teacher's students, as exposure is the easiest and most successful method (Chubin, May, & Babco, 2005). If the engineers the teachers interact with do not reflect the diversity of their classroom, their stereotypes about who can be engineers will be reinforced and relayed – both consciously and not – back to their students. If a female or minority teacher successfully incorporates engineering into her or his classroom, she or he instantly becomes a role model for other students in her class by eliminating the bias regarding who can and cannot practice engineering.

One way to eliminate the stereotype that engineers do not work well with people is by working in teams – something engineers rely on to do their jobs. Seeing engineers work in teams would help eliminate the stereotype that they do not work well with people. In the case of the EESC, engineers could be paired up with teachers to lead the lessons in these workshops. Teacher participants could then be explicitly taught the engineering concepts behind the lesson by the engineer and learn how it could be taught to students in the classroom and how concepts could be incorporated into existing standards and from the teacher. This would not only give teacher participants more confidence to incorporate engineering into their classrooms, but would also increase their exposure to engineers, helping to dispel the biases they hold about engineers and engineering.

CHAPTER VI

CONCLUSION

Teachers that attend professional development workshops expect to be taught by experts in their field to increase their confidence in the material they wish to incorporate into their classrooms. There is little literature available to educate teachers about engineering in the classroom, and even less available on how to meet standards while doing it. If we are to expect our teachers to reform and improve their STEM teaching by using engineering as a vehicle through which to do so, we must create an accepted model for K-12 engineering professional development.

The results from this study show that professional development must be explicit in how engineering concepts fit in with the lessons being taught and how those weave into the prescribed standards. Increased engineer diversity and teamwork in K-12 engineering professional development is imperative in order to disperse stereotypes of who can or cannot be an engineer. In order to secure a place in K-12 education, it is imperative that we continue to reach out to teachers, work with them to incorporate engineering into their classrooms, and continue to evaluate these professional development programs to improve their success. Hopefully these attempts will continue to build upon research that will extol the benefits of using engineering in the K-12 classroom.

BIBLIOGRAPHY

Adams, G., & Engelmann, S. (1996). *Research on direct instruction: 25 years beyond DISTAR.* Seattle, WA: http://eric.ed.gov/ERICWebPortal/search/detailmini.jsp?

nfpb=true&&ERICExtSearch_SearchValue_0=ED413575&ERICExtSearch_SearchType_0=no&accno=ED413575

.

Adams, R. S., J. Turns, and C. J. Atman. 2003. Educating effective engineering designers: The role of reflective practice. *Design Studies* 24 (3): 275–94.

Arafah, M., Trombetta, A., Jackson, D., Duffy, S. (2010). Engineering in K-12: Addressing the need for change in Ohio STEM education. Presented at the Purdue University P-12 Engineering and Design Education Research Summit. OR: Seaside.

Arafah, M. (2010). [2010 Engineering Education Survey]. Unpublished raw data.

Asayesh, G. (1993). Staff development for improving student outcomes. *Journal of Staff Development, 14(3),* 24-27.

Augustine, N. (2007). *Is America Falling Off the Flat Earth?* Washington, DC: National Academies Press.

Augustine, N., Barrett, C., Cassell, G., Grasmick, N., Holliday, C., Hackson, S., Jones, A., Levin, R., Mote, D., Murray, C., O'Donnell, P., Raymond, L., Richardson, R., Vagelos, P., Vest, C., Whitesides, G., & Zare, R. (2010). *Rising above the gathering storm, revisited: Rapidly approaching category 5*. Washington, DC: National Academies Press.

Balkcom, S. (1992). Education research consumer guide. Office of Research, Office of Educational Research and Improvement of the U.S. Department of Education.

Borko, H., & Putnam, R. T. (1995) *Expanding a teacher's knowledge base: A cognitive psychological perspective on professional development*. New York: Teachers College Press.

Bottoms, G., & Anthony, K. (2005). Project Lead the Way: A pre-engineering curriculum that works. Southern Regional Education Board. Retrieved from http://www.sreb.org/programs/hstw/publications/2007pubs/07v29_Research_Brief_PLTW.pdf.

Bottoms, G., & Uhn, J. (2007). Project Lead the Way works: A new type of career and technical program. Southern Educational Review Board. Retrieved from http://www.sreb.org/programs/hstw/publications/briefs/05v08_Research_PLTW.pdf.

Boyles, N. (2001). *Teaching written response to text: Constructing quality answers to open-ended comprehension questions* (2^{nd} ed.). Gainesville, FL: Maupin House Publishing.

Brophy, S., Klein, S., Portsmore, M., & Rogers, C. (2008). Advancing engineering education in P-12 classrooms. *Journal of Engineering Education, 97*, 369-387.

Business-Higher Education Forum. (2006). Collaborating to address the math and science teacher shortage: A state-university-business partnership.

Carey, S. (1991). Knowledge acquisition: Enrichment of conceptual change? In S. Carey & R. Gelman (Eds.), *Epigenesis of the mind: Essays in biology and cognition*. Hillsdale, NJ: Erlbaum.

Carlson, L. E., and J. F. Sullivan. 1999. Hands-on engineering: Learning by doing in the integrated teaching and learning program. *International Journal of Engineering Education* 15 (1): 20–31.

Cavanaugh, S. (2006). Math, science academies favored to challenge top-tier students: Funders see graduates as helping U.S. stay competitive [Electronic Version]. *Education Week*. Retrieved from http://www.edweek.org/ew/articles/2006/12/06/14academies.h26.html.

Chi, M. (2005). Commonsense conceptions of emerging processes: Why some misconceptions are robust. *Journal of the Learning Sciences, 14,* 161-199.

Chubin, D., May, G., Babco, E. (2005). Diversifying the engineering workforce. *Journal of Engineering Education,* 94(1): 73-86.

Cognition and Technology Group at Vanderbilt (CTGV). 1997. *Jasper Project: Lessons in curriculum, instruction, assessment, and professional development*. Mahwah, NJ: Lawrence Eurlbaum.

Crespo, M., & Pozo, J. (2004). Relationships between everyday knowledge and scientific knowledge: Understanding how matter changes. *International Journal of Science Education, 26,* 1325-1343.

Cummings, S., & Taebel, D. (1980). Sexual inequality and the reproduction of consciousness: An analysis of sex-role stereotyping among children. *Sex Roles* 6 (4): 631-44.

Custer, R., Hailey, C., Cunningham, C., Erekson, T, & Householder, D. (2008). Professional development for engineering and technology: A national symposium. Proceedings and Future Agenda for a NSF-funded symposium. Dallas, TX.

Diakidoy, I., & Iordanou, K. (2003). Preservice teachers and teachers' conceptions of energy and their ability to predict pupils' level of understanding. *European Journal of Psychology of Education, 23,* 357-368.

Donohue, T. (2010).Testimony to the House Committee on Science and Technology on The Reauthorization of the America COMPETES Act. Retrieved from https://www.uschamber.com/issues/testimony/2010/100119_americacompetes.htm.

Garet, M., Porter, S., Andrew, C., Desimone, L. (2001). What makes professional development effective? Results from a national sample of teachers. *American Educational Research Journal, 38(4),* 915-45.

Gonzales, P., Guzman, J., Partelow, L., Pahlke, E., Jocelyn, L., Kastberg, D., & Williams, T. (2004). Highlights from the Trends in International Mathematics and Science Study (TIMSS) 2003. U.S. Department of Education. Washington, DC: National Center for Education Statistics.

Gonzales, P., Williams, T., Jocelyn, L., Roey, S., Kastberg, D., Brenwald, S. (2008). Highlights From TIMSS 2007: Mathematics and science achievement of U.S. fourth- and eighth-grade students in an international context. Washington, DC: National Center for Educational Statistics.

Hotaling, L., McGrath, M., McKay, C., Shields, S., Lowes, C., Cunningham, et al. (2007). Engineering Our Future New Jersey. Paper presented at the American Society for Engineering Education Annual Conference and Exposition Proceedings. HI: Honolulu. Retrieved from http://www.soa.asee.org/paper/conference/paper-view.cfm?id=4611.

Kaser, J. (2006). *Mathematics and science specialty high schools service a diverse student body: What's different?* Pittsburg, PA: Learning Research and Development Center, University of Pittsburgh.

Katehi, L., Pearson, G., & Feder, M. (Eds.). (2009). National Academy of Engineering and National Research Council report: Engineering in K-12 education. Washington, D.C.: The National Academies Press.

Kennedy, M. (1999). Form and substance in mathematics and science professional development. *NISE Brief 3(2).* Madision, WI: University of Wisconsin.

Kouzes, J. and Posner, B. (2002). *The leadership challenge*. (3rd ed.). New York, NY: John Wiley & Sons, Inc.

Loucks-Horsley, S., Stiles, K. & Hewson, P. (1996). Principles of effective professional development for mathematics and science education: A synthesis of standards. *NISE Bried 1(1),* Madison, WI: University of Wisconsin.

Loucks-Horsley, S., Hewson, P., Love, N., & Stiles, K. (1998). *Designing professional development for teachers of science and mathematics*. Thousand Oaks, Calif.: Corwin Press.

Maldonado, Luz. (2002). Effective professional development: Findings from research. College Entrance Examination Board.

McKay, M., & McGrath, B. (2007). Real-world problem-solving using real-time data. *International Journal of Engineering Education, 23*(1): 36-42.

Means, B., Confrey, J., House, A., & Bhanot, R. (2008). STEM high schools: Specialized science technology engineering and mathematics secondary schools in the U.S. Menlo Park, CA: SRI International.

Mundry, S. (2005). Changing perspectives in professional development. *Science Educator*, *18*, 9-15.

National Center for Education Statistics. (2003). *Qualifications of the public school teacher workforce: Prevalence of out-of-field teaching*. Washington, DC: U.S. Department of Education.

National Science Foundation. (2010). *Science and Engineering Indicators 2010 (NSB 10-01*). Washington, DC: Author. Retrieved from http://www.nsf.gov/statistics/seind10/pdf/seind10.pdf.

OECD (2010), *PISA 2009 results: What students know and can do – Student performance in reading, mathematics and science (Volume I).*

Ohio Department of Education (ODE). (2010). Ohio's science education standards: Introduction for reviewing the draft science standards documents. Retrieved from http://education.ohio.gov/GD/DocumentManagement/DocumentDownload.aspx?DocumentID=83216.

Organization for Economic Cooperation and Development (OECD). (2009). Education at a glance 2009: OECD Indicators. Paris, France.

Reiner, M., Slotta, J., Chi, M., & Resnick, L. (2000). Naïve physics reasoning: A commitment to substance based conceptions. *Cognition and Instruction, 18,* 1-34.

Schnittka, C. (2008). Engineering design activities and conceptual change in middle school science. Doctoral Dissertation, University of Virginia, Charlottesville, VA.

Schwartz, D., S. Brophy, X. Lin, and J. Bransford. 1999a. Software for managing complex learning: Examples from an educational psychology course. *Educational Technology Research and Development 47* (2): 39–59.

Schwartz, D. L., X. Lin, S. Brophy, and J. D. Bransford. 1999b. Toward the development of flexibly adaptive instructional designs. In *Instructional design theories and models*, ed. C. Riegliuth. Hillsdale, NJ: Lawrence Erlbaum.

Smith, C., Maclin, D., Grosslight, L., & Davis, H. (1997). Teaching for understanding: A study of students' preinstruction theories of matter and a comparison of the effectiveness of two approaches to teaching about matter and density. *Cognition and Instruction, 9,* 221-283.

Subotnik, R. F., Rayhack, K., & Edmiston, A. (2006). *Current models of identifying and developing STEM talent: Implications for research, policy and practice* Washington, DC: American Psychological Association.

Task Force on the Future of American Innovation. (2006). Measuring the moment: Innovation, national security, and economic competitiveness. Retrieved from http://futureofinnovation.org/PDF/BII-FINAL-HighRes-11-14-06_nocover.pdf.

Tillema, H., & Knol, W. (1997). Promoting student teacher learning through concept change or direct instruction. *Teaching and Teacher Education*, 13(6): 579-595.

U.S. Department of Education. Office of the Under Secretary, Planning and Evaluation Service, Elementary and Secondary education Division. (2000). *Does professional development change teaching practice? Results from a three-year study.* Washington, D.C.

World Economic Forum. (2009). *The global competitiveness report 2009-2010*. Retrieved from http://www.weforum.org/pdf/GCR09/Report/Countries/United %20States.pdf.

Yasar, S., Baker, D., Robinson-Kurpius, S., & Roberts, C. (2006). Development of a survey to assess K-12 teachers' perceptions of engineers and familiarity with teaching design, engineering, and technology. *Journal of Engineering Education*, 205-216.

Yip, D. (1998). Identification of misconceptions in novice biology teachers and remedial strategies for improving biology learning. *International Journal of Science Education, 20,* 461-477.

APPENDIX

APPENDIX A

2010 Engineering Education Survey

ID: _______________

Gender	Male ❑	Female ❑
How long have you been teaching?		
What is your licensure grade band?		
What subjects are you licensed in?		
My school is part of: (Circle one)	CMSD Charter Public Private or Parochial First/Inner Ring	

Please answer the following questions to the best of your ability.

I. Importance of Engineering

	Not at All	Not Much	Somewhat	Very Much
I would like to be able to teach my students to understand the use and impact of engineering.	❑	❑	❑	❑
I would like to be able to teach my students to understand the science and/or math of engineering.	❑	❑	❑	❑
I would like to teach my students to understand the design process.	❑	❑	❑	❑
I would like to be able to teach students to understand the problems to which engineering can be applied.	❑	❑	❑	❑
My motivation for teaching science/math is to promote an	❑	❑	❑	❑

understanding of how engineering affects society.				
I am interested in learning more about engineering through in-service training.	❑	❑	❑	❑
I would like to be able to teach students to understand the process of communicating technical information.	❑	❑	❑	❑
My motivation for teaching science/math is to prepare young people for the world of work.	❑	❑	❑	❑
My motivation for teaching science/math is to promote an enjoyment of learning.	❑	❑	❑	❑
I believe engineering should be integrated into the K-12 curriculum.	❑	❑	❑	❑
I am interested in learning more about engineering through workshops.	❑	❑	❑	❑
I am interested in learning more about engineering through college courses.	❑	❑	❑	❑
In a science/math curriculum, it is important to include the use of engineering in developing new technologies.	❑	❑	❑	❑
I am interested in learning more about engineering through peer training.	❑	❑	❑	❑
My motivation for teaching science/math is to help students develop an understanding of the technical world.	❑	❑	❑	❑
My motivation for teaching science/math is to educate scientists, engineers and technologists for industry.	❑	❑	❑	❑
In a science/math curriculum, it is important to include planning of a project.	❑	❑	❑	❑
How important should pre-service education be for teaching engineering?	❑	❑	❑	❑

II. Familiarity with Engineering

	Not at All	**Not Much**	**Somewhat**	**Very Much**
How familiar are you with engineering?	❑	❑	❑	❑
Have you had any specific engineering courses outside of your pre-service curriculum?	❑	❑	❑	❑
How confident do you feel about integrating more engineering into your	❑	❑	❑	❑

curriculum?				
Barrier in integrating engineering – lack of teacher knowledge.	❑	❑	❑	❑
Was your pre-service curriculum effective in supporting your ability to teach engineering at the beginning of your career?	❑	❑	❑	❑
Did your pre-service curriculum include any aspects of engineering?	❑	❑	❑	❑
Barrier in integrating engineering – lack of training.	❑	❑	❑	❑
I use engineering activities in the classroom.	❑	❑	❑	❑
Barrier in integrating engineering – lack of time for teachers to learn about engineering.	❑	❑	❑	❑
I know the national education standards related to engineering.	❑	❑	❑	❑
Barrier in integrating engineering – lack of administration support.	❑	❑	❑	❑
My school supports engineering activities.	❑	❑	❑	❑

III. Characteristics of Engineers

	Strongly Disagree	**Disagree**	**Agree**	**Strongly Agree**
A typical engineer has good verbal skills.	❑	❑	❑	❑
A typical engineer works well with people.	❑	❑	❑	❑
Most people feel that minority students can do well in engineering.	❑	❑	❑	❑
Most people feel that female students can do well in engineering.	❑	❑	❑	❑
A typical engineer has good writing skills.	❑	❑	❑	❑

IV. Characteristics of Engineering

	Strongly Disagree	**Disagree**	**Agree**	**Strongly Agree**
Most people feel that male students can do well in engineering.	❑	❑	❑	❑
A typical engineer does well in	❑	❑	❑	❑

science.				
A typical engineer has good math skills.	❑	❑	❑	❑
A typical engineer earns good money.	❑	❑	❑	❑

Please answer to the best of your ability.

What do you know about engineering?

What do you know about engineers?

How can engineering be taught in the classroom?

What are the biggest barriers you face when attempting to alter your curricula?