INFLUENCE OF TEACHER TRAINING AND PROFESSIONAL DEVELOPMENT ON K-12 ENGINEERING TEACHER QUALITY

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Abstract

There is an increasing demand for individuals with engineering education and skills of varying fields in everyday life. With the proper education African Americans can help meet the demand for a highly skilled and educated workforce. Researchers have assumed the mediocre engineering workforce is a result of students' collegiate educational experiences. Studies have shown collegiate experiences are impacted by experiences in K-12 education. Although many factors contribute to this mediocre workforce, most noted by researchers is the academic unpreparedness of freshman engineering students. This is a direct result of the quality and competence of teachers present in the classroom. This paper was an effort to systematically address one of the main factors impacting the mediocre engineering workforce, quality of K-12 engineering teachers in public schools.

The purpose of this study was to assess the relationships between teacher quality and instruction, and African American students' developing mathematics, science, critical thinking, and problem solving skills needed for college engineering programs. Of the 30 students surveyed 15 students were majoring in engineering. Four of the 15 students were interviewed in further detail and found that high school teacher instruction and interaction play a role in interest and majoring in college engineering programs. These results can provide valuable results if certification renewal requirements are enforced and alternative secondary career and technical education (CTE) certification programs are available and easily accessible.

1.0 Introduction

"John Adams and Benjamin Franklin believed that a sound education is essential for cultivating moral citizens, Thomas Jefferson argued that an educated populace is a prerequisite for a vibrant democracy, and George Washington wanted to establish a national university"[1]. Teachers are the driving force in education at all levels. Society assumes teachers are prepared to develop lifelong learners that are capable of competing with international counterparts, but the increasing mediocre workforce disagrees. To have a long-lasting and effective change in engineering education it must be a collaborative effort between industry, government, foundations, and other countries[2]. This study discusses the most notable factor impacting the mediocre workforce, inadequate preparation in K-12 education, as a result of teacher quality and competence.

1.1 Key factors impacting mediocre workforce

Enrollment has increased in postsecondary institutions, but decreased in science, technology, engineering, and mathematics (STEM) disciplines[3]. The continuous shortage of quality U.S. engineers is being addressed by researchers at various levels. Some researchers are only looking at this shortage as a result of the college experience. "Nationwide, less than half the freshman who start in engineering graduate in engineering, and at least half of this attrition occurs during the freshman year"[4] further supporting the need to address retention of freshman engineering students[5,6]. Although there are collegiate factors that contribute to this shortage, a students performance at the collegiate level is related to his/her K-12 educational experience. This means the U.S. has to turn back "the rising tide of educational mediocrity" threatening the competitiveness of the U.S. in this global economy[7].

A students' academic ability has a strong influence on his/her persistence and success in college. This academic ability is a result of his/her K-12 preparation[8-11]. Compared to white students, many minority students have a weak foundation in mathematics and science and this persists throughout college. This hinders students from pursuing and being successful in STEM careers[12]. The performance gap between Whites and minorities continues as evidenced by the National Assessment of Educational Programs (NAEP) test[13], Scholastic Aptitude Test (SAT), and American College Testing. K-12 education has provided white students with a stronger foundation compared to minority students[14-16]. Many minority students in K-12 education are plagued with issues that most white students do not encounter.

A large percentage of minorities attend public high schools in deprived communities. These schools are known to suffer from a lack of funding, ineffective teachers, and a lack of technology programs. The lack of adequate funding hinders inner city schools from providing up-to-date tools[17], books, laboratories, and advanced courses. Ineffective teachers are tantamount to unqualified teachers and many are currently in the classroom motivating and preparing the next generation of African American scientists and engineers. This in turn has a negative impact on learning at any grade level. "Lack of effective teachers and financial resources undermines both achievement and participation in mathematics and science"[18]. Less than eighteen percent of students, of which six percent is minority, have the pre-requisite math and science courses to enroll in post-secondary engineering programs. A large percent of the student population is not prepared for STEM fields[19].

1.2 Engineering in K-12 education

Technology affects daily life through the use of such items as cellphones, laptops, desktops, high-definition televisions, etc. This forces society to acknowledge the need for technology to be included in the K-12 curriculum[20,21]. Technology is not simply the application of science, for this definition omits the knowledge and process involved. Technology education is not the use of devices as instructional aids in classroom, nor is it vocational education where only skills are taught. "Technology education involves teaching the design, engineering, and technological issues related to conceiving, building, maintaining, and disposing of useful objects and/or processes in the human-built world"[22]. It is evident engineering education is critical to the future of this society in designing and developing the latest innovations in technology.

Science and math are part of the core curriculum, whereas students are only exposed to technology and engineering in K-12 through CTE courses. Enrollment in technology and engineering courses boost student interest in these fields and strengthens students occupational skills, which will aid in creating a more diverse and qualified workforce. The National Center for Education Statistics reports in 2004-2005 approximately 9,209,384 of 14,707,911 students were enrolled in a high school CTE program. In 2005 there were approximately 29,057 public and 11,188 private schools with secondary grades, but only approximately 6% (2,415) of the schools offered a special program in science/technology. One of the most significant labor shortages the United States has is technologically oriented people. The Commission on the Advancement of Women and Minorities in Science, Engineering, and Technology Development[23] notes the alarming shortage of engineers and technical workers can be minimized by allowing "women, underrepresented minorities, and persons with disabilities" (p. 27) to be represented in "the U.S. science, engineering, and technology workforce" (p.27).

Attracting qualified students to engineering schools has been increasingly difficult, especially with the number of students enrolled in engineering programs decreasing in the U.S.[24]. Enrollment rate in undergraduate engineering programs in the U.S. has dropped dramatically in the past two decades and is a serious concern for government, industry, and educators[2,25-29]. During the same timeframe the need for quality engineers has increased. In addition, retention of undergraduate engineering students has become increasingly critical because approximately one-half of the students entering college do not graduate[25]. Currently only two of every 100 high school graduates earn engineering degrees and only five of every 1,000 female or minority graduates become engineers. If the U.S. is to be remotely competitive in the global market having a leading position in advanced technology is necessary.

1.3 Teacher certification and renewal

The No Child Left Behind Act (NCLBA) of 2000 was passed under the reign of George W. Bush and guides/directs in school districts in placing "highly qualified teachers" (HQ) for core courses in the public school classroom. Core courses include English, reading or language arts, mathematics, science, foreign languages, civics and government, economics, arts, history, and geography, Teachers become HQ by having full state certification within their content area, have a license to teach within a given state, and not have had the license or certification waived.

Secondary (7-12 grade) CTE teachers must have worked in industry in his/her content area a minimum of five years with a Bachelor's Degree to apply for a career and technical trade and industrial education (CTTIE) certificate. To renew a CTTIE certificate at least three semester hours in professional CTTIE courses must be earned annually. The CTTIE coursework are focused around foundation, management, safety, testing, evaluation, and methods of teaching vocational technical education.

All educators are encouraged to continue their professional learning throughout their careers. Certification renewal or upgrade is achieved by obtaining continuing learning units (CLUs). Not all CLUs earned for renewals or upgrades do not meet the content-specific nature of CLUs required for HQ status. At the present time, the only two groups of educators that are required to earn CLUs are (1) educators seeking the NCLB highly qualified status under Louisiana's HOUSSE option, and (2) educators with a Level 2 or Level 3 Professional License.

However, having a college degree and certification in desired content area does not guarantee the teacher will be effective in the classroom. He/she is not guaranteed to have a deep understanding of his/her content area. Ideally, a certified teacher should be placed in his/her certification area; however this is not always the perfect situation. The government and state departments have continued to uphold this flimsy framework for teacher quality. NCLBA only stipulates training in content area prior to obtaining certification; however, teachers have not gained all they need prior to receiving certification[30]. In the end, poor teacher quality discourages students from entering engineering fields[31].

1.4 Knowledge base of teachers.

This knowledge for teachers to be effective in the classroom is a collaboration that includes: subject knowledge[32-34] [SK]; general pedagogical knowledge[32-34] [GPK]; expertise[32]; pedagogical content knowledge[32-34] [PCK]; curriculum knowledge; knowledge of learners; knowledge of educational texts; and knowledge of educational ends, purposes, and values[34]. Since 1987, researchers have condensed Shulman's identifiers of knowledge base to the following: SK[32,33,35] GPK, and PCK[32,33,36,37].

Teachers' awareness of GPK and SK is a vital part of pedagogical content knowledge (PCK)[33,38]. GPK is an instructor's knowledge of learning theories and classroom management. Engineering SK is an instructor's knowledge of various engineering topics and their structure. Without a clear and deep understanding of SK teachers will be unable to relate procedures to other incidents. A teacher's mathematical or science knowledge and student achievement support the aforementioned claim that greater SK increases a teacher's ability to develop deep understanding for the student[39-40].

Engineering SK and GPK provide a basis for an engineering teacher's PCK which drives the instructional process. The students' depth of engineering is dependent on the teacher's deep understanding of the SK and their ability to teach it. PCK is a teacher's knowledge of their content area and how to teach it. In so doing, teacher's must be aware of students and their misconceptions and difficulties, link content area to real-world applications, differentiate according to students' learning style, use multiple strategies to enhance student learning process, and have a classroom management system for lessons and activities. Limited PCK limits the teacher in ways they can foster the students learning; limit themselves in linking subject matter to real-life examples; and becomes more teacher-centered instead of student-centered[41].

1.5 Professional Development for High School Engineering Educators

Effective professional development (PD) is the skills and knowledge attained to enhance, adjust current knowledge, and support teachers after initial training to improve teachers' professional performance[42,43]. PD is necessary because the initial training teachers receive will not encompass everything and because knowledge grows with practice. Significant changes have occurred in professional development in the last 20 years to include lifelong learning opportunities, assessments and evaluations as a result of educational reform[44]. More believe that educational success of students depends on the competence of the teaching force[45-50].

Engineering PD programs available to high school teachers include: Engineering the Future (EtF): Science, Technology, and the Design Process, Project Lead the Way (PLTW), The Infinity Project, and Increasing Student Participation, Interest, and Recruitment in Engineering and Science (INSPIRES). These engineering PD programs met three criteria: focused on engineering-oriented content, included "best practices" and creative design practices, had an established track record for professional development, and were grounded in a coherent and documented model for PD[51]. These programs attempt to prepare teachers for the complex role of teaching secondary engineering education. Although only a few are discussed, at the time these were the programs that met the criteria.

PLTW and The Infinity Project are only available to educators through school agreements. However, quality PD opportunities should be accessible to all educators[5]. EtF focused on technological literacy and was concerned with problem-solving and critical thinking. The PD activities presented followed this same focus and failed to make the necessary connection to engineering. The main issue of technology literacy programs is how engineering will be incorporated into the curriculum, especially when project design may rely heavily on mathematics and science.

PLTW/AOE, *The Infinity Project,* and INSPIRES had a pre-engineering focus. These three programs have been seen as a pipeline to increase interest in engineering. These programs either used a step-by-step process or trial-and-error approach to design. This is not the typical approach engineers take, they "predict the behavior of the design and the success of a solution before it is implemented"[52]. These programs are actually a model for post-secondary engineering curriculum and rely heavily on mathematics and science and as a result should strengthen a student's skill in these areas. The drawback is because of the rigor imposed on math and science skills only a select population of students will be targeted to participate in such programs.

The two models reviewed the technology literacy model and pre-engineering model, causes confusion of what engineering is in the K-12 curriculum and what PD opportunities should be available to teachers. This further supports the argument that engineering content is not clearly defined for the K-12 curriculum and this spills over into PD for teachers as well. In addition, based on the literature presented teacher capabilities vary in technology education due to science and math requirements. PD opportunities discussed for secondary engineering education were designed for teachers to experience curriculum in the manner it is to be implemented in the classroom. The PD activities were geared towards demonstrating how teachers should implement curriculum instead of placing more emphasis on how science and math connected to engineering. As a result, the intensity of science and math was limited in the PD activities and instruction was not differentiated for teacher ability level.

2.0 Methodology

This mixed-methods study was performed in order to show the need for reinforced teacher certification criteria and alternative programs for CTE high school teachers. A questionnaire was designed by the researcher to assess the extent of teacher qualifications and instruction on student interest in pursuing and persisting in college engineering programs for African American

students'. This study aims to find the difference in teacher SK and student achievement in engineering.

2.1 The quantitative approach

2.1.1 Hypothesis and alternative hypothesis

1. There is no difference in teacher subject knowledge and student achievement in high school engineering courses. $H_0 : \mu_1 = \mu_2$
2. There is a difference in teacher subject knowledge and student achievement in high school engineering courses. $H_1 : \mu_1 \neq \mu_2$

An alpha level of 0.05 has been established for this experiment.

2.1.2 Instrumentation and Participants

The survey instrument was given to thirty college students, classified at least as juniors. The students were minorities majoring in STEM disciplines. Of the 30 students surveyed 30% (9) were females and 70% (21) were males. Fourteen students (46.7%) were juniors and sixteen students (53.3%) were senior college students.

2.1.3 Data Analysis

Using SPSS, central tendency, frequency statistics and Spearman's correlation coefficient were calculated. A correlation was also done to determine the strength of the relationship between the variables.

2.2 The qualitative approach

2.2.1 Instrumentation and Participants

The purpose of this qualitative study was to determine the influence teacher quality and instruction have on college students' interest and success in engineering programs. A ten question interview was developed and administered to four college students. The four college students, two girls and two guys, were randomly selected from the 15 engineering majors.

2.2.2 Data Analysis

In order to gain an in-depth understanding of students' perceptions of teacher quality and instruction on their high school experience a semi-structured interview was administered. Each interview was transcribed verbatim, and all student responses were accounted for in the coding.

3.0 Results

			Difficulty in 1st 2 years	Difficulty b/c I did not participate in HS engr prgm	Considered changing major b/c difficulty in college	Teachers of HS CTE course were certified/qualified	Engineering classes/programs not offered b/c lack of qualified/certified teachers
Spearman's rho	Difficulty in 1st 2 years	Correlation Coefficient	1.000	.656(**)	.559(**)	.174	.013
		Sig. (2-tailed)	.	.000	.001	.358	.945
		N	30	30	30	30	30
	Difficulty b/c I did not participate in HS engr prgm	Correlation Coefficient	.656(**)	1.000	.800(**)	.116	-.009
		Sig. (2-tailed)	.000	.	.000	.542	.963
		N	30	30	30	30	30
	Considered changing major b/c difficulty in college	Correlation Coefficient	.559(**)	.800(**)	1.000	.138	-.031
		Sig. (2-tailed)	.001	.000	.	.468	.869
		N	30	30	30	30	30
	Teachers of HS CTE course were certified/qualified	Correlation Coefficient	.174	.116	.138	1.000	-.641(**)
		Sig. (2-tailed)	.358	.542	.468	.	.000
		N	30	30	30	30	30
	Engineering classes/programs not offered b/c lack of qualified/certified teachers	Correlation Coefficient	.013	-.009	-.031	-.641(**)	1.000
		Sig. (2-tailed)	.945	.963	.869	.000	.
		N	30	30	30	30	30

** Correlation is significant at the 0.01 level (2-tailed).

Table 1: Correlation Results for Difficulty In College and Qualified Teachers

Category	Engr. Classes	Engr. Teacher	Tech. Clubs	Projects/ Competitions	Corporate Speakers	Engr. Week	Ambition/ desire	Prior knowledge
High School Influences	2	1	1	1				
Engr. Program Positives		2	1	2	1	1		
Contributions to Success	2						2	2

Table 1: Number of Students Responding, by Category, to HS Influences, Positives of Engr. Program and Contributions to Success

Category	Lack of diverse fields	Lack of hands-on activities	Lack of equipment	Lack of preparation	Lack of adv. Engr. applications	Lack of dedication	None
Engineering Program Negatives	1	1	1				
Contributions to Lack of Success				2	1	1	1

Table 2: Number of Students Responding, by Category, to Negatives of Engr. Programs and the Contributions to Lack of Success in College

Category	Loved teacher techniques	Loves engr.	Thinks creatively	Knows how to teach	Degree in Engr.	Positive attitude	Extensive engr. background	Patience
Feelings Towards Engr. Teacher	3							
Teacher Qualifications		1	1	2	1	1	4	1

Table 3: Number of Students Responding, by Category, to Attitudes towards Teachers and Teacher Qualifications

4.0 Discussion

A strong positive correlation was found $(rho(28) = .656, p < .01)$ between students' having difficulty in the first two years of college and non-participation in high school engineering programs and $(rho(28) = .559, p < .01)$ between students' having difficulty in the first two years of college and retention. Many students who majored in engineering did not have the luxury of participating in a high school engineering program or curriculum. Even still, this did not deter him/her from majoring in engineering. However, students felt by not being afforded those opportunities increased their difficulty in college programs as freshmen and the likelihood to switch to another major.

Three of the four students interviewed attended a HS that offered an engineering program or CTE courses. Those same three students' were also enrolled in HS engineering program at their high school. One student did not attend a high school that offered a HS engineering program but strongly felt her high school needed to implement one. However, all four students felt their perspective school districts were lacking a HS devoted solely to engineering and felt it necessary to implement one. One female student said, "I do think there should be because engineering is a growing field and it should be recognized." Another female student attended HS in a very small school district and stated, "There is only one public high school, so I do believe there should be some type of program implemented." It was a general consensus among the students' that any future engineering programs that are implemented should offer classes giving students' insight

into engineering. Several students suggested Drafting, Senior Design, Calculus, and even an Engineering Seminar as part of the courses.

A strong negative correlation was found $(rho(28) = .-.641, p < .01)$ indicating a statistically significant relationship between qualified/certified teachers of HS CTE courses and availability of engineering courses. In order for a vast amount of engineering programs or courses to be offered there has to be a vast pool of qualified teachers to pull from. When this pool of qualified individuals is limited, the programs and courses that can be offered are limited as well. Students as a result are at a disadvantage compared to students who have participated in high school engineering programs or courses. Based on these results the null hypothesis is rejected at the .01 significance level.

Of the three students who were enrolled in a HS engineering program, two students were influenced by engineering classes, one student was influenced by their engineering teacher, one student was involved by their involvement in technology clubs, and one student was influenced by their involvement in projects and competitions in HS. Several students felt those same HS influences were positive aspects of their engineering program and have contributed to their success in current college classes. However, all four students interpreted success as not having a failing grade in any course instead of equating success to having an A or B in the course, or understanding what they have learned. Two students felt the engineering teacher, projects, and competitions were positive aspects of the engineering program. One student felt the technology clubs, corporate speakers, and engineering week activities were positive aspects of the engineering program. Two students felt their enrollment in HS engineering classes has strongly contributed to their success in their college courses. All four students felt their success in their current college courses is strongly due to their ambition, desire, and prior knowledge of engineering.

All three students who were enrolled in a HS engineering program loved the techniques the teacher used in presenting the engineering principles and theories. However, they also felt the teacher only presented projects and theories related to mechanical engineering because her degree was in this content area. The teacher failed in presenting projects related to their interests. All four students were asked what qualifications they felt a teacher should possess. It's a consensus among the students that an individual who teaches any HS engineering courses should have an extensive engineering background. In addition, they felt a HS engineering teacher should possess a love for engineering, be able to think creatively, knows how to teach, maintains a positive attitude and is also patient in dealing with student attitudes and learning styles.

5.0 Conclusion

"Engineering education is the activity of teaching engineering and technology, at school, college, and university levels. The goal of engineering education is to spread technological literacy, increase student interest in technical careers through science and math education and hands on learning" (Douglas et. al, 2004). Engineering is basically the application of mathematical and physics principles. The engineer must be able to think and make conclusions on data that is presented to them. For many students this is a difficult task, as they are accustomed to rote memorization rather than critical thinking. It is the thinking process that makes a successful

engineer. The future of engineering relies heavily on the output of a skilled and educated work force needed to sustain America's competitiveness in the world and the need to survive. To facilitate an interest in engineering and gain support in educating the future engineers, teachers should be effective in the classrooms.

Although this study was small, the results are representative of many other programs in public high schools as well. Students carry an inadequate K-12 education with him/her throughout their college experience, affecting the quality of the future workforce. If these inadequacies are given room to flourish graduating seniors' ability to effectively use engineering, math, science and technical skills and apply problem solving skills will continue to decrease.

Quality programs are limited because of the availability of resources, especially qualified K-12 engineering teachers. The NCLB assures teachers in the classrooms are "highly qualified", but this does not guarantee quality teachers. According to the high school engineering curriculums discussed teachers may be certified in any area, receive minimum training, and be placed in the classroom with the hopes of students receiving a quality education. Essentially teachers are not teaching in the area they are certified in, and are therefore not "highly qualified".

Quality of teachers is becoming an increasing concern due to increasing dropout rates, low college enrollment, low retention rates, and an increasing mediocre workforce. The pool of qualified engineering graduates is impacted by educators and his/her content area knowledge. Teachers expert knowledge in his/her content area and how to teach it, aids in developing students' depth of engineering and interest in engineering fields. The government requires teachers to develop this expert knowledge on the path to obtaining a teaching degree. However, learning is a continuous process. As technology changes, teachers' expertise must also change, which affects student academic achievement. However, teachers are not partaking in quality learning opportunities or they are not easily available after his/her initial training.

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