EXAMINATION OF ENGINEERING DESIGN TEACHER SELF-EFFICACY AND KNOWLEDGE BASE IN SECONDARY TECHNOLOGY EDUCATION AND ENGINEERING-RELATED COURSES

DISSERTATION

Presented to

The faculty of the Graduate School

Southern University and A & M College

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of the Requirements for the Degree of

Doctor of Philosophy

In

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by

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“Dedication”

This dissertation is dedicated to Almighty God, my Heavenly Father, my Provider, my Redeemer, my Anointer, my Deliverer, and to whom all praises are due. With God all things are possible. It is because of my faith in God that I have been afforded this opportunity and have remained steadfast on this journey. He has truly blessed me and worked through others in my life to provide needed support, guidance, and a listening ear.

I also dedicate this dissertation to my wonderful family. I am particularly grateful for the unconditional love from my husband Brad, who has supported me during my many years of research. Your love for our two beautiful children has been instrumental on this journey. Mixon and Bradley Jr., you are the joy of our lives, and provide me with inspiration for the future. All of you, on countless occasions, have reminded me of what is most important in this world.

I must also thank my mother, mother-in-law, and cousin for their help and support with childcare and encouragement. Finally, I dedicate this work to my late grandparents, Robert and Mary Esther Pierce, both of whom believed in diligence, hard work, and the pursuit of excellence.

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ABSTRACT

This research titled Examination of Engineering Design Teacher Self-Efficacy and Knowledge Base in Secondary Technology Education and Engineering-Related Courses has been conducted by Vessel, Kanika in partial fulfillment of the requirements for the Ph. D. conferred from Southern University and A & M College in December 2011 under the advisement of Dr. Joseph Meyinsse of the Science/Mathematics Education Department and Dr. Eyassu Woldesenbet of the Mechanical Engineering Department.

There is an increasing demand for individuals with engineering education and skills of varying fields in everyday life. With the proper education students of high-needs schools can help meet the demand for a highly skilled and educated workforce. Researchers have assumed the supply and demand has not been met within the engineering workforce as a result of students' collegiate educational experiences, which are impacted by experiences in K-12 education. Although factors outside of the classroom contribute to the inability of universities to meet the increasing demand for the engineering workforce, most noted by researchers is the academic unpreparedness of freshman engineering students. The unpreparedness of entering freshman engineering students is a result of K-12 classroom experiences. This draws attention not only to the quality and competence of teachers present in the K-12 classroom, but the type of engineering instruction these students are receiving. This paper was an effort to systematically address one of the more direct and immediate factors impacting freshman engineering candidates, the quality of secondary engineering educators.

Engineers develop new ideas using the engineering design process, which is taught at the collegiate level, and has been argued to be the best approach to teach

technological literacy to all K-12 students. However, it is of importance to investigate whether technology educators have the knowledge and understanding of engineering design, how to transfer that knowledge in the classroom to students through instructional strategies, and their perception of their ability to do that. Therefore, the purpose of this study is to show the need for examining the degree to which technology and non-technology educators are implementing elements of engineering design in the curriculum.

CHAPTER I: INTRODUCTION

Historically, the U.S. has excelled in the design of products, processes, and new technologies. The historical national strength the U.S. exhibits in engineering design should be used as a vehicle for mathematics and science education.

Integrating engineering design in technology education can be a means to addressing retention and dropout rates in secondary and undergraduate engineering courses and programs by providing supplementary instruction in applied mathematics and science. There is a strong emphasis on targeting students at an early age with an educational focus on engineering design because it will expose more students to technical career opportunities, resulting in a potential increase in the pool of engineering and science specialists in the United States.

Various studies address the issue of retention and the needs for raising interest in undergraduate engineering programs (Astin, 1984; Astin & Astin, 1992; Bell, 2008; Berger & Milem, 1999; Besterfield-Sacre et al., 1997; Clough, 2004; Felder et al., 1993; GAO, 2007; Lotkowski et al., 2004; NSF, 2007; Seymour & Hewitt, 1997; Tinto, 1993; Tyson et al., 2007; Veenstra et al., 2009; Wulf & Fisher, 2002; Zinatelli & Dube, 1999). Although researchers discussed several factors, inadequate preparation in K-12 education was a strong contributing factor to low interest and retention rates in undergraduate engineering programs.

In general the knowledge base of teachers is becoming an increasing concern due to increasing dropout rates, low college enrollment, and low retention rates. It is accepted that the quality of engineering graduates is impacted by the quality of K-12 educators and his/her content area knowledge. A teacher's expert knowledge in his/her content area and the underlying pedagogy in are critical in developing students' in-depth understanding of engineering and their interest in the field of engineering. There is an abundance of literature describing the knowledge base required for teaching science and mathematics in K-12; however, there is very little similar literature in the field of technology education and engineering in K-12 CTE courses. Furthermore, research findings suggest that secondary CTE teacher candidates are not as academically prepared, especially in reading and writing, as secondary candidates (Cramer, 2004). This indicates a gap in educational preparation between secondary CTE candidates and secondary candidates. As technology changes, teachers' expertise must also change, which affects teachers' self-efficacy and his/her attitude in regards to teaching engineering.

Background of the Problem

This section will discuss (1) the shortage of engineers, (2) K-12 technology education, (3) engineering design over engineering in K-12 education, and (4) the social concerns pertaining to cooperative learning.

Shortage of Engineers

There is an increased demand for colleges and universities to produce more flexible, innovative engineering students (Council on Competitiveness, 2005; National Science Foundation, 2007; Task Force on the Future of American Innovation, 2005). The American Association for Engineering Education (Gibbons, 2010) reports undergraduate enrollment in engineering programs reached 427,503 full-time students in the fall of 2009. Enrollment fluctuated in the mid 2000's, but rose steadily over the past four years accounting for a 16% growth since 2005 (see Table 1). The number of bachelor's degrees conferred in engineering has remained nearly unchanged since 2008, edging slightly higher to 74,387 in 2009. The totals have remained surprisingly steady, growing only one percent since 2005. Although there is an increase in overall undergraduate engineering enrollment, the data is different across disciplines and degree levels as seen in Table 2. Degrees in electrical/computer engineering (2006-2009) and computer science (2005-2009) continued to fall, although enrollment in these fields ticked upward slightly over the past two years. Degrees in the mechanical, metallurgical and materials engineering fields slightly increased. Fields of aerospace (2003-2009), biomedical (2002-2009), chemical (2007-2009), civil and environmental fields (2006-2009) flourished. The energy-related fields of mining, nuclear, and petroleum engineering have grown by over 150 percent since 2003.

Table I

Undergraduate engineering enrollment by discipline, 2000-2009 (Gibbons, 2010)

Undergrad	2000		2001		2002		2003		2004	
Enrollment	Full Time	Part Time	Full Time	Part Time	Full Time	Part Time	Full Time	Part Time	Full Time	Part Time
Aerospace	8,422	420	9,410	346	9,386	386	10,834	476	11,436	476
Architectural	2,360	97	2,404	110	2,537	102	2,793	126	2,878	126
Biological/Agricultural	2,375	76	2,503	56	2,816	58	2,878	68	2,629	68
Biomedical	6,262	78	7,093	72	9,178	146	10,716	230	12,566	230
Chemical	25,118	1,655	25,534	1,392	22,641	1,328	21,926	1,310	22,088	1,310
Civil	37,310	3,750	37,449	3,769	39,031	3,451	41,442	3,911	43,590	3,911
Civil/Environmental[1]	-	-	-	-	-	-	-	-	-	-
Computer Science (inside eng.)	30,063	3,349	33,695	3,778	32,668	4,077	35,448	4,400	31,646	4,400
Electrical/Computer	98,578	12,370	102,943	12,173	102,983	11,158	99,658	11,525	91,366	11,525
Engineering (general)	6,037	422	7,520	547	7,864	413	7,607	536	7,052	536
Engineering Management	543	56	595	52	663	65	921	62	911	62
Eng. Science & Eng. Physics	1,584	73	1,761	57	2,310	88	2,246	48	2,332	48
Environmental	740	49	729	51	734	56	850	77	793	77
Industrial/Manufacturing	12,377	1,015	13,076	1,053	13,376	1,116	13,621	1,122	13,573	1,122
Mechanical	64,005	6,843	66,608	6,880	71,902	6,345	76,482	7,255	80,863	7,255
Metallurgical & Materials	3,268	125	3,063	117	3,087	126	3,181	110	3,215	110
Mining	502	37	482	36	456	47	450	20	566	20
Nuclear	709	20	845	28	960	39	1,259	42	1,371	42
Other	40,613	1,809	44,061	1,702	44,497	1,576	42,760	2,045	45,393	2,045
Petroleum	1,269	45	1,300	54	1,491	72	1,631	51	1,828	51
Total	342,135	32,289	359,071	32,273	368,580	30,649	376,703	33,414	376,096	33,414

“Table I (continued)”

Undergrad	2005		2006		2007		2008		2009	
Enrollment	Full Time	Part Time	Full Time	Part Time	Full Time	Part Time	Full Time	Part Time	Full Time	Part Time
Aerospace	15,882	588	15,945	654	16,551	633	17,561	664	18,108	601
Architectural	4,392	134	3,986	187	4,205	199	4,033	130	3,618	179
Biological/Agricultural	2,978	72	3,038	68	3,103	103	3,191	78	3,778	96
Biomedical	14,213	464	15,411	481	16,153	518	17,798	519	19,558	504
Chemical	21,727	1,323	23,455	1,269	25,852	1,431	28,636	1,326	32,050	1,476
Civil	42,007	3,448	44,389	3,783	47,296	3,709	50,167	4,430	53,436	4,784
Civil/Environmental[1]	1,264	185	1,790	245	2,437	259	2,546	247	2,929	235
Computer Science (inside eng.)	27,577	4,678	27,062	4,355	27,348	4,202	27,766	4,081	29,959	4,092
Electrical/Computer	79,883	8,977	75,302	8,979	72,353	8,389	73,343	8,158	75,061	7,952
Engineering (general)	16,140	680	18,139	526	21,944	1,039	22,856	1,186	22,903	1,226
Engineering Management	1,239	37	1,014	35	1,034	31	1,224	23	1,036	24
Eng. Science & Eng. Physics	3,161	486	3,533	525	2,510	105	2,643	99	2,497	84
Environmental	2,007	112	2,270	128	2,761	171	3,180	308	4,027	338
Industrial/Manufacturing	13,065	1,170	12,970	1,054	12,921	1,019	13,476	1,184	14,224	1,033
Mechanical	78,202	6,636	80,288	6,786	82,246	6,843	85,249	7,089	91,856	7,082
Metallurgical & Materials	3,577	175	3,862	184	4,019	210	4,312	164	4,520	146
Mining	626	26	764	37	836	51	881	51	974	68
Nuclear	1,562	61	1,667	75	1,771	64	1,832	41	2,207	60
Other	35,943	1,865	36,503	1,877	36,955	1,897	38,468	1,922	40,536	1,912
Petroleum	2,131	95	2,814	83	3,395	98	4,029	128	4,226	193
Total	367,576	31,212	374,202	31,331	385,690	30,971	403,191	31,828	427,503	32,085

Table 2

Bachelor's degrees in engineering fields of study, 2000-2009 (Gibbons, 2010)

Undergrad Enrollment	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Aerospace	1,296	1,558	1,711	2,011	2,232	2,371	2,722	2,788	2,930	3,057
Architectural	559	554	513	627	590	722	631	625	646	723
Biological/Agricultural	583	549	556	603	601	635	646	659	623	631
Biomedical	1,156	1,138	1,315	1,628	2,019	2,410	2,917	2,969	3,237	3,644
Chemical	6,023	5,740	5,529	5,233	4,801	4,521	4,452	4,551	4,850	5,185
Civil	8,653	8,027	8,066	8,192	8,142	8,247	8,935	9,402	10,132	10,508
Civil/Environmental[1]	-	-	-	-	-	212	291	445	464	558
Computer	3,972	4,519	4,720	5,746	5,838	5,455	4,901	4,046	3,808	3,394
Computer Science (inside eng.)	5,510	6,062	6,842	8,649	9,156	8,419	7,330	6,446	5,964	5,652
Electrical	11,211	11,096	11,402	11,994	12,500	12,459	11,915	11,467	10,790	9,859
Electrical/Computer	2,126	2,444	2,597	2,782	2,700	2,924	2,825	2,425	2,216	2,194
Engineering (general)	944	992	1,069	1,105	1,138	1,179	1,176	1,246	1,160	1,246
Engineering Management	186	187	227	296	302	303	238	274	331	309
Eng. Science & Eng. Physics	535	475	489	451	501	383	431	460	472	431
Environmental	588	510	465	516	576	522	437	454	486	503
Industrial/Manufacturing	3,555	3,474	3,575	3,769	3,790	3,647	3,664	3,503	3,367	3,510
Mechanical	12,992	12,921	13,247	13,801	14,182	14,947	16,063	16,701	17,324	17,375
Metallurgical & Materials	904	791	838	859	817	840	909	963	1,095	1,035
Mining	164	150	112	96	85	92	120	119	153	190
Nuclear	134	118	145	135	202	275	342	402	415	378
Other	2,478	2,627	3,106	2,422	2,488	2,724	2,902	2,942	3,211	3,351
Petroleum	251	268	257	250	233	315	339	428	496	654
Total	63,820	64,200	66,781	71,165	72,893	73,602	74,186	73,315	74,170	74,387

Attracting qualified students to undergraduate engineering programs is of concern since the need for quality engineers has increased. The Bureau of Labor Statistics (BLS; 2009) reported that 150,931 engineers were needed in 2008 but 74,170 students graduated from U.S. engineering programs with a Bachelor's degree. The BLS projects a 10.1% increase from 2008 to 2018. In addition, retention of engineering students has become increasingly critical because only about one-half of students entering colleges as engineering majors complete degree requirements (French et al., 2005). It is evident from these reports that it is necessary to increase students' interest and competence in the engineering fields to increase the number of new college graduates needed to replace retiring engineers and produce engineering graduates with a variety of specialties. Students start to envision what they want to be as an adult before entering college. Therefore, it is necessary to review the literature on K-12 education. Students start to envision what they want to be as an adult before entering college. Therefore, it is necessary to review the literature on K-12 education.

K-12 Technology Education

It is necessary to understand how students are exposed to technical fields in K-12 education and why this exposure is necessary. 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 (Rose & Dugger, 2002; ITEA, 2000; NAE NRC, 2002). 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 the 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 (Yasar et al., 2006). It is evident that technology education is critical to the future of this human-built world and engineering plays a role in designing and developing the latest innovations in technology.

In order for students to participate in engineering activities and functions successfully and the process of developing advanced technology, they must be technologically literate (ITEA, 2000; ITEA, 2003; NAE NRC, 2002). By exposing students to a more comprehensive methodology that generates technology would increase the technological literacy in students. In a world infused with technology, it is becoming increasingly important that students know about the role of engineering in creating the technologies they use. However, clear guidelines on a method for delivering technological literacy have not been established, but many in the field of technology education suggest engineering or engineering design as an avenue to achieve this goal (Daugherty, 2005; Lewis, 2004; Rogers, 2005; Wicklein, 2006).

Engineering Design over Engineering in K-12 Education

Engineering is a field of applied science whereas engineering design is an iterative process taken to design or solve a problem based on certain constraints. Engineering has undoubtedly been woven into technology education curriculum through the Standards for Technology Literacy (Grimsley, 2002; Rogers, 2005; Schroll, 2002; Wicklien, 2003). The technology standards seek to increase the technology literacy of students by focusing on design, engineering, and technology. However, this focus is not consistent in high schools across the U.S.

Educational outcomes for technology education programs have standards specifically for engineering design. Therefore, technology education programs with an engineering design focus seems more plausible. Engineering design could be considered as a potential contributor to the field of technology education because of the increased rigor as students apply math and science skills and knowledge to technological problems (Custer, Daugherty, & Meyer, 2009). The presence of engineering in K-12 classrooms is an important phenomenon because of the implications of engineering education for the future of science, technology, engineering, and mathematics (STEM).

Engineering Design Knowledge Base

Several studies exist on the importance of engineering design in technology education. However, limited studies exist on the knowledge base technology education teachers need to deliver the *STL* effectively. The studies that do exist suggest that the barrier to implementing *STL* effectively on the K-12 educational level is due to a lack of engineering design knowledge. This will ultimately affect the level of instruction technology education teachers will be able to provide.

Yasar et al. (2006) assessed teachers' knowledge and needs of design, engineering, and technology (DET) for this very reason. DET encompasses the broader meaning of technology education (NRC, 1996). The researchers surveyed 98 Arizona science teachers and reported that teacher knowledge and teacher training were expressed as the main barriers to integrating DET concepts. The teachers in the study did not possess high self-efficacy to integrate DET into the curriculum and deliver effective instruction to their students.

Merrill et al. (2008) used a mixed method quasi-experimental, pretest, posttest, no control group to explore the extent to which students understood and were able to demonstrate an understanding of the core conceptual knowledge needed for students to understand and be able to do engineering design. Eight technology education teachers participated in five days of professional development to develop a series of units on constraints, optimization, and predictive analysis. Students achieved small gains, but it indicated significant improvement in understanding of COPA concepts. The results indicated that engineering concepts could be successfully delivered to a broad spectrum of students. Even though the study had a positive outcome, it was evident to the researchers that in order to better develop these engineering concepts for students technology education teachers need to develop stronger subject knowledge that has more of a focus on conceptual knowledge, applying mathematical and scientific knowledge, and the processes involved in engineering design.

Donan (2003) was the first to use a descriptive design to determine the level of acceptance of national content standards by technology education teachers, determine the level of need for in-service training of technology education teachers, and how well STL standards fit within existing curricula in the state of TN. Three-hundred-fifty-six TN technology education teachers were surveyed, but only 30.9% returned a completed survey. Eighty-two percent of those teachers were willing to adopt *STL*. Although the teachers felt their students had the ability to acquire the knowledge, they did not feel they possessed strong subject knowledge or a high self-efficacy to present the material to the students.

Kelley (2008) conducted a descriptive study to examine the current status of 1043 high school technology education teacher practices with respect to engineering design. The survey instrument was developed from previous studies (Asunda & Hill, 2007; Childress & Rhodes, 2008; Smith, 2006; Gattie & Wicklein, 2007) and consisted seven subsets: engineering design, engineering analysis, application of engineering design, engineering communication, design thinking, engineering and human values, engineering science. The survey results indicated teachers were not equipped with the level of math and science needed to teach engineering design, and were unable to stress certain components of engineering design because they lacked the knowledge to do so effectively.

Teacher Self-Efficacy

It is evident from the studies mentioned above that teachers are weak in engineering design subject knowledge. The studies allude to teachers having a low self-efficacy when they report their inability to deliver instruction effectively. There is a limited amount of studies that discuss teacher self-efficacy toward engineering concepts. Studies in other areas, like mathematics and science, stress the importance of a high self-efficacy for teachers to understand teachers attitude toward their content, confidence in subject knowledge, and their ability to deliver effective instruction (de Laat & Watters, 1995; Enochs & Riggs, 1990; Ginns & Watters, 1994; Ramey-Gassert, Shroyer, & Staver, 1996; Riggs, 1995; Riggs & Enochs, 1990; Watters & Ginns, 1995). These studies suggest that students who are subjected to teachers with a low content self-efficacy will be at a disadvantage.

The most notable study researching an individual's engineering design self-efficacy was conducted by Carberry, Ohland, and Lee (2009). They conducted an exploratory pilot study to develop an instrument to measure an individual's self-efficacy regarding the engineering design process used by the Massachusetts Department of Education (MA DOE). During the pilot study, the instrument was administered to individuals with a range of engineering experience. The instrument measured four constructs (confidence, motivation, expectancy for success, and anxiety) on a 100-point range with 10-point intervals. Experience in the engineering field was a strong factor in participants' self-efficacy. Individuals with high self-efficacy were shown to have a high confidence, motivation, and outcome expectancy level. Individuals with low self-efficacy were shown to have the exact opposite. Results showed that both the MA DOE model for the engineering design process and the 32-item instrument were appropriate tools to measure engineering design self-efficacy.

Teacher efficacy is an important variable in teacher effectiveness and is consistently related to positive teaching behaviors and student outcomes. When teachers have a positive self-efficacy he/she is more likely to provide students with clear, concise feedback allowing students to move beyond performance comparisons and use mastery experiences in formation of his/her self-efficacy beliefs. However, if a teacher has low self-efficacy then efficacy building experiences are at a minimum. This responsibility to increase interest and aid in developing K-12 student's self-efficacy in engineering falls on K-12 teachers. However, this can only be achieved if educators receive on-going rigorous training and to develop high self-efficacy. Based on the decline in engineering degrees in certain fields and the increase in need for quality engineers, K-12 teachers have not been successful in preparing a large pool of students interested in majoring in engineering.

Research Questions

The following research questions will be addressed:

1. To what extent do motivation, expectancy for success, and anxiety influence the engineering design self-efficacy of secondary STEM educators?
2. To what extent do motivation, expectancy for success, and anxiety influence the engineering design knowledge base of secondary STEM educators?
3. To what extent do the demographic variables (age, college major, highest degree, certification area, gender, and years of teaching) influence the engineering design self-efficacy of secondary STEM educators?

4 To what extent do the demographic variables (age, college major, highest degree, certification area, gender, and years of teaching) influence the engineering design knowledge base of secondary STEM educators?

Hypotheses

H_{o1}: Motivation, expectancy for success, and anxiety will be significant predictors of the engineering design self-efficacy of secondary STEM educators.

H_{o2}: Motivation, expectancy for success, and anxiety will not be significant predictors of the engineering design knowledge base of secondary STEM educators.

H_{o3}: The demographic variables (age, college major, highest degree, certification area, gender, and years of teaching) will be significant predictors of the engineering design self-efficacy of secondary STEM educators.

H_{o4}: The demographic variables (age, college major, highest degree, certification area, gender, and years of teaching) will not be significant predictors of the engineering design knowledge base of secondary STEM educators.

Limitations

The teachers' participation was based on their willingness to participate in this study. Some participants taught multiple types of courses. There was limited capital to encourage participation in the study due to the number of items in the survey.

Delimitations

There were (1) only 9 technology teachers who taught engineering courses, (2) students and teachers are not randomly selected, and (3) only teachers and students in local school district were utilized.

Definition of Terms

For the purposes of this study, the following terms are operationally defined:

- **Accreditation Board for Engineering and Technology (ABET)** – a program for building engineering as a profession by evaluating post-secondary engineering programs through guidance, training, education, and recognition
- **Area CTE schools** – provide career and technical education part-time to students who receive all or most of their academic instruction at their home school and typically serve multiple schools (Levesque et al., 2008)
- **Content area** – broad term for content knowledge that covers several disciplines
- **Middle school grades** – three year period consisting of grades six through eighth
- **Post-secondary** – grades above twelfth grade, or university level

- **Region** – geographic region in which the school is located. Northeast includes CT, ME, MA, NH, NJ, NY, PA, RI, and VT; Midwest includes IL, IN, IA, KS, MI, MN, MO, ND, NE, OH, SD, and WI; South includes AL, AR, DC, DE, FL, GA, KY, LA, MD, MS, NC, OK, SC, TN, TX, VA, and WV; and West includes AK, AZ, CA, CO, HI, ID, MT, NV, NM, OR, UT, WA, and WY.
- **Gatekeeping** – process of controlling the rate at which students progress to more advanced levels of study in the academic setting
- **Secondary education** –consists of grades sixth through twelfth
- **Vocational Education/Career and Technical Education (CTE) Courses** – courses which provide students with an enriched education through career and technical related courses such as agriculture, business, cooperative education, environmental education, health education, home economics, industrial arts, marketing, office technology, secretarial, computer and information sciences, and engineering technologies.

CHAPTER II: REVIEW OF THE LITERATURE

The events leading to curriculum reform centuries ago still plague engineering education at all levels today (NSF, 2007). Changes in economy at the global level (NSF, 2007), industry fluctuations, faculty shortages, instructor content knowledge, shifts in economy, student attitudes, and decline in math and science literacy are still affecting the future of the engineering field. The future engineers of this economy are K-12 and undergraduate students (Denton, 1998). Collegiate engineering programs are rigorous programs; therefore, students should have exposure to a program of this rigor prior at an early age (Watson and Froyd, 2007; Holland, 1997; Bombaugh, 2000; Barton, 2002; Dawes, Horan, & Hackett, 2000). Several researchers argue pre-college engineering education is beneficial to the enhancement of the engineering pathway (Erekson and Custer, 2008; May & Chubin, 2003).

The published national test scores and workforce statistics show that K-12 students and teachers continue to have a poor understanding of math and science. More importantly, minimal teacher content knowledge and exposure to engineering in high school has an adverse affect on student's attitude towards obtaining a career in a technical field. To this point, little research exists that looks at teacher knowledge base and engineering design self-efficacy in engineering-related courses in secondary grades. This chapter discusses implementation of engineering education in K-12, teaching engineering design, status studies in technology education, research on technology education with an engineering design focus, knowledge base of teaching, pre-college factors affecting retention and success of freshman engineering students, and industry view of engineering education.

Implementation of Engineering Education in K-12

Science, technology, engineering, and mathematics (STEM) fields as a whole have numerous comprehensive studies. Individually, more research has been done in the area of science and mathematics than in technology and engineering. Engineering education is slowing creeping its way into the K-12 curriculum. This is more of a reason for educators at every grade level to be concerned with improving the quality of engineering education, increasing diversity, and increasing student retention to meet the needs of industry. The pathway engineering education has taken into the K-12 educational system has undergone numerous reforms, which sought to create a viable future for all (Dewey, 1900, 1916).

Historical View of Technology Education in K-12

Vocational education began in the 19th century (Castellano & Stringfield, 2003) and was targeted at students not expected to finish high school (poor, disabled, and the limited-English proficient; Thompson, 1973). Government and state laws and policies have a significant role in shaping the pathway of high school education reform. Government and state influence is seen in curriculum policies affecting graduation requirements, student testing, high school exit exams, school evaluation, teacher certification, and curriculum material selection. This study does not include studies of effect of individual state policies on Career and Technical Education (CTE) reform efforts because of the broad variation in state policies and their effects on specific local reforms.

The Smith-Hughes Act of 1917 initially funded vocational education at the secondary education level exposing high school students to technical careers (Rampp et. al., 1998). In the 1930s a committee appointed by President Franklin D. Roosevelt evaluated the vocational education and thought it too job specific and did not have the flexibility for employment opportunities (Martinez Jr., 2007). World War II brought a different outlook on vocational education, shifting its focus to concentrated occupational programs to support the efforts of the war.

In the 1940's the courses for vocational education began to lose their edge, and implied students enrolled in theses courses were not capable of being successful in a technical field. This blatant realization helped policy makers to broaden the principles surrounding vocational education with the Vocational Education Act of 1963, renamed Carl D. Perkins Vocational Education Act of 1984 (Martinez Jr., 2007), and the 1974 Equal Education Opportunity Act (Viteritti, 2004). This ensured that all individuals would have access to educational programs and funds would be provided for students with academic, socioeconomic, or other handicaps (Martinez Jr., 2007). The vocational education preparation of secondary youth was still of major concern.

Reforms of the 1990s

The 1990s brought about a vast amount of educational reform such as the Carl D. Perkins Vocational and Applied Technology Education Act Amendments of 1990, the Educate America Act of 1994, the School-to-Work Opportunities Act of 1994, the Workforce Investment Act of 1998, the reauthorized Perkins Act of 1998 (Martinez Jr., 2007), development of *Jackson's Mill Industrial Arts Curriculum* Theory (Snyder and Hales, 1981; Wright, 1992), and the *Standards for Industrial Arts Program (SAIP)* now known as the *Standards for Technology Education* Programs (Dugger, 2002). *Jackson's Mill Industrial Arts Curriculum* Theory was the starting point of the modern era of technology education by providing a needed systematic refocus of the formerly known industrial arts curriculum.

The most notable reform of the 1990's was the Carl D. Perkins Act of 1990 (Perkins II) and the reauthorized and revised Carl D. Perkins Act of 1998 (Perkins III). Perkins II was too broad, not very rigorous, did not provide training opportunities, and was not linked to high school and post-secondary education. Linking CTE to high school and post-secondary education would achieve occupational and academic competencies, but the specific details were left to state and local governing boards. If students were to have any success in the classroom the focus of vocational education still needs to be redirected. Reauthorization Act of 1998 (Perkins III) reformed secondary schools to weave CTE into current programs.

Career and technical education is described as an initiative "that offers a sequence of courses that provide individual with coherent and rigorous content aligned with challenging academic standards and relevant technical knowledge and skills needed to prepare for further education and careers in current emerging professions". Later in the same section it reads: "include competency-based applied learning that contributes to the academic knowledge, higher-order reasoning and problem-solving skills, work attitudes, general employability skills, technical skills, and occupation-specific skills, and knowledge of all aspects of industry, including entrepreneurship of an individual" (p. 4). Section 123b of the Improvement Act states "providing career and technical education students with the academic and career and technical skills (including the mathematics and science knowledge that provides a strong basis for such skills) that lead to entry into technology fields, including non-traditional" (p. 43).

The technology educational reforms of the 1990s were still attempting to answer the initial call of 1950 for the improvement of standards, collaborations and connections between vocational education, academic education, and private sector business and industry. Legislative acts over the past 100 years have formed the field of CTE but the 1990s allowed the CTE field to provide new direction for its programs. As education transitioned to the 21st century the International Technology Education Association (ITEA) in conjunction with the National Science Foundation (NSF) and the National Aeronautics and Space Administration (NASA) developed the *Standards for Technological Literacy: Content for the Study of Technology (STL)*, which outlined what students should know and be able to do in relation to technology (ITEA, 2000). The primary goal of technology education became "the ability to use, assess, and understand technology" (ITEA, 2000, p.7).

21^{st} Century Engineering Education

The enactment of the Carl D. Perkins Career and Technical Education Improvement Act of 2006 has maintained current developments and instituted innovative direction for secondary and postsecondary programs (Martinez Jr., 2007). Under this act CTE programs develop the following: (1) academic and technical standards for intensive careers, (2) promote greater fluency between secondary and post-secondary CTE programs, (3) increase state and local government flexibility in program involvement and implementation, (4) support for best practices, (5) support for leadership and professional development, (6) increase stakeholder opportunities, and (7) support lifelong learning opportunities. Initially, the inception of vocational education programs was only for education at the prebaccalaureate level. The Carl D. Perkins Act of 2006 allowed students to participate in CTE programs that would eventually lead to careers with baccalaureate degrees. CTE programs are not training programs but a way to reinforce concepts students learn in academic settings to real-world relevance. CTE is multi-disciplined, encompassing arts, alternative energy sources, communications, computers, electronics, networking transportation, manufacturing, ecology, etc. Technology education teachers, by virtue of this fact, require more in-depth content and pedagogical content knowledge related to more subject areas than most teachers.

Engineering education in K-12 curriculum is continuing to gain attention (ITEA, 2002; McAdoo, 1998). In other literature engineering has been used interchangeably with technology and design, or engineering design (United Kingdom Qualifications and Curriculum Authority, 2007; Curriculum Council, 1998; Newfoundland and Labrador

Department of Education, 2007; Strategy, 2007; ITEA, 2002). However, because it is not clearly defined it has not been recognized as a school discipline.

Therefore, current pre-engineering programs are introduced through CTE programs with the support of engineering and engineering technology professionals (Thomas, 2003). In order to meet the growing need for engineers in the 21st century, students must be provided with pre-engineering programs that allow them to explore their strengths and interests in engineering and engineering technology (Thilmany, 2003; American Society for Engineering Education, 1987; National Research Council, 1996; International Technology Education Association, 2002).

Standards for Secondary Engineering Education

Sets of standards have been developed as an attempt to integrate engineering and technology into curricula. The U.S. Department of Education developed the Mid-Continent Research for Education and Learning (McREL, 2004) Standards, as an effort to provide standards integrated with STEM and other school subjects. In the late 1980s the National Council of Teachers of Mathematics developed the first set of national standards for mathematics in public schools. The standards placed a strong emphasis on problem solving and the use of mathematics in other STEM areas such as technology and engineering (Commission on Standards for School Mathematics, 2000).

Three notable sets of science content standards were developed between the 1980s and 1990s. *Scope, Sequence, and Coordination of Secondary School Science* was developed by The National Science Teachers Association (1992). These standards laid foundation for later work of integrating science and technology. *Science for All Americans* in 1989 and *Benchmarks for Science Literacy* in 1993 were both developed by

Project 2061 of the American Association for the Advancement of Science. Both sets of standards placed emphasis on the curriculum integration of mathematics, science, and technology. The *National Science Education Standards* were developed by The National Research Council (1996) as an effort to integrate technology and engineering.

The *Benchmarks for Science Literacy* (American Association for the Advancement of Science [AAAS], 1993), the *National Science Education Standards* (NRC, 1996), and the *Standards for Technology Literacy* (ITEA, 2000) outline the skills and knowledge students should gain through technology education. Among the sets of science content standards mentioned, the set most closely related to engineering and technology is the *Benchmarks for Science Literacy*.

The Curriculum Council in Australia developed a refined set of content standards at the high school level with an emphasis on concepts related to engineering. The engineering design process was integrated into the CTE curriculum as an effort to raise student achievement.

The Massachusetts Department of Education (2001) was the first state to develop its own set of content standards for its own pre-engineering curriculum. However, these standards are not as extensive as the standards developed by McREL or the Benchmarks for Science Literacy, and are more closely aligned with *STL*. The *Standards for Technological Literacy: Content for the Study of Technology (STL)* was published by the International Technology Education Association (ITEA) in 2000. The 20 standards placed emphasis on students understanding a number of concepts related to technology and engineering. The *STL* were developed to provide a set of nationally recognized standards for technological literacy for state departments of education and technology education teachers.

Massachusetts was the first state in 2001 to develop engineering curriculum standards as part of its state standards (Massachusetts DOE, 2006). Other states have incorporated the national technology standards, STL, into the curriculum (International Technology Education, 2000). STL was developed by ITEA with the assistance of engineering societies and endorsed by the National Academy of Engineering, (Dearing & Daugherty, 2004). Infusing engineering into the technology education curriculum provides a suitable foundation for teaching technology education (Grimsley, 2002; Rogers, 2005; Schroll, 2002; Wicklien, 2003). The standards "provide an opportunity to move technology education and pre-engineering closer together and have helped illustrate the mutual relationships and benefits of technologically literate secondary students to the engineering profession" (Dearing and Daugherty, 2004, p. 8). *STL* is a defined set of twenty technological literacy standards grouped into five general categories: the nature of technology, technology and society, design, abilities for a technological world, and the designed world. For each standard, benchmarks of academic achievement have been defined for educational grade levels K-2, 3-5, 6-8, and 9-12. Noteworthy, is the inclusion of "design" as one of the general groups. Students began to make plans to attend college, trade school, or the workforce in secondary grades and this level will be the focus of this research. This is not to disregard the importance of introducing engineering concepts into earlier grades, but there is a certain amount of structure of technology education at this level.

Dearing and Daugherty (2004) generated a core list of pre-engineering concepts from the STL standards students should learn in high school technology programs with an engineering focus. The National Science Foundation-funded Principles of Engineering, AIT/CORD's Principles of Technology curriculum, Project Lead the Way curriculum, American Institute of Physics, American Society of Engineering Educators, the National Research Council, the National Academy of Engineering, the Massachusetts Science and Technology-Engineering Curriculum Framework, and experts in technology education, technology teacher education, and engineering education assisted in identifying the concepts from STL standards students should know in order to be prepared for postsecondary engineering education programs. Eighty-seven concepts were initially identified and after a pilot study process the list was reduced to 64 concepts. A consensus was reached among the experts on the importance of general engineering, technological literacy, and interpersonal skills in high school engineering programs. In order to deliver these concepts effectively, program guides, curriculum materials, professional development programs, and workshops for technology education teachers need to be at the forefront of educational reform (Dearing & Daugherty, 2004; NSF, 2007).

Existing Efforts to Identify and Integrate K-12 Engineering Concepts

Currently, there is not a consistent framework for understanding and implementing engineering design content into secondary CTE classes (Wicklein, Smith, & Kim, 2009). Technology education is a field of study that seeks to promote technological literacy for all students. The standards discussed in this study do not mandate a particular curricular approach and technology education programs in the U.S.

employ various approaches (Boser, Palmer, & Daugherty, 1998; Satchwell & Dugger, 1996; Wicklein, Smith, & Kim, 2009). Engineering design appears frequently in the literature because the field has begun to broaden its perspective and embrace ties with other disciplines (Dearing & Daugherty, 2004). Conceptually, there is a close relationship between engineering and technology education since “both engineering and technology treat solving practical problems as their philosophical nucleus” (Dugger, 1994, p. 7). Several researchers suggest that implementing engineering into K-12 curricula will increase math and science literacy (Watson and Froyd, 2007; Holland, 1997; Bombaugh, 2000; Barton, 2002; Dawes, Horan, & Hackett, 2000).

Several researchers suggest the best approach for infusing engineering into CTE is by establishing engineering design as a focus (Custer, Daugherty, & Meyer, 2009; Dearing and Daugherty, 2004; Fales, Kuetemeyer, & Brusic, 1998; Hailey et al., 2005; Lewis, 2005; Wicklein, 2006; Wright, 2002). The basis for the assertion is fivefold: (1) engineering design is better understood and valued than technology education; (2) engineering design elevates the field of technology education to a higher academic and technological level; (3) engineering design provides a defined framework to design and organize curricula; (4) engineering design provides an ideal platform for integrating mathematics, science, and technology; and (5) engineering provides a focused career pathway for students (Wicklein, 2006).

Design is an important skill for K-12 engineering and technology educators who emphasize the need to develop K-12 students the ability to understand and perform design. Eide, Jenison, Mashaw, and Northrup simply stated: “Engineering Design is a systematic process by which solutions to the needs of humankind are obtained" (2001, p. 79). Ulman (2003) chose to define engineering design by its outcomes. He writes,

> "The engineering design process centers around four representations used to describe technological problems or solutions (a) Semantic – verbal or textual explanation of the problem; (b) Graphical – technical drawing of an object; (c) Analytical – mathematical equations utilized in predicting solutions to technological problems; (d) Physical – constructing technological artifacts or physical models for testing and analyzing" (p. 34).

Design is outlined in *STL* as a subject and as a process (ITEA, 2000). The *STL* describe engineering design as: "Engineering design demands critical thinking, the application of technical knowledge, creativity, and an appreciation of the effects of a design on society and the environment: (ITEA, 2000, p. 99). Two years later the Standards defined engineering design as "The systematic and creative application of scientific and mathematical principles to practical ends such as the design, manufacture, and operation of efficient and economical structures, machines, processes, and systems" (ITEA, 2002, p. 238). ABET has carefully and descriptively defined engineering design by stating:

> Engineering design is the process of devising a system, component, or process to meet desired needs. It is s a decision-making process (often iterative), in which the basic sciences, mathematics, and engineering sciences are applied to convert resources optimally to meet a stated objective (Edie et al., 2001, p. 79-80).

Dym, Agogino, Eris, Frey, and Leifer (2005) stated that "Engineering design is a systematic, intelligent process in which designers generate, evaluate, and specify concepts for devices, systems, or processes whose form and function achieve clients' objectives or users' needs while satisfying a specified set of constraints" (p. 104). It is easy to see from the numerous definitions that engineering design is no easy term to define. Multiple and complex interpretations of engineering design stem from the many terms and concepts embedded within the various definitions.

There are a number of common key concepts embedded within these definitions such as systematic (Dym et al., 2005; Edie et al., 2001); ITEA, 2002); iteration (American Society of Mechanical Engineers in Moriarity, 1994; Dym, 1994; Gonnet, Henning, & Leone, 2007; Hill, 2006; Middendorf & Engelmann, 1998); constraints and criteria (ASME in Moriarty, 1994; Dym et al., 2005; Eide et al., 2001; Wilson, 1965); and analysis through mathematics and scientific application is often cited as a key step in the engineering design process. 'Engineering Design' defined:

> Engineering design, also referred to as technological design, demands critical thinking, the application of technical knowledge, creativity, and an appreciation of the effects of a design on society and the environment. The engineering design process centers around four (4) representations used to describe technological problems or solutions: (1) semantic – verbal or textual explanation of the problem, (2) graphical – technical drawing of an object, (3) analytical – mathematical equations utilized in predicting solutions to technological problems, (4) physical – constructing technological artifacts or physical models for testing and analyzing (International Technology Education Association, 2000; Ulman, 2003).

It is evident from the literature and Table 3 there are certain aspects inherent to the engineering design process which are not included in technological problem solving (Fales, Kuetemeyer, & Brusic, 1998; Wright, 2002; Hailey et al., 2005).

Table 3

A comparison of design processes

	Engineering Design Process (Eide, et al., 2001		Technology Education Design Process (ITEA, 2000)
1	Identify the Need	1	Define Problem
2	Define Problem	2	Brainstorming
3	Search for Solutions	3	Research & generate ideas
4	Identify constraints	4	Identify criteria
5	Specify evaluation criteria	5	Specify constraints explore possibilities
6	Generate alternative solutions	6	Explore possibilities
7	Analysis	7	Select an approach
8	Mathematical predictions	8	Develop a design proposal
9	Optimization	9	Test & evaluate the Design
10	Decision	10	Refining the design
11	Design specifications	11	Communicating results
12	Communicate design specifications		

Based on the material presented here to define engineering design, it is clear that technology education has several hurdles to address: defining engineering design, how to teach engineering design and knowing what is currently being taught in technology education. Not only is obtaining consensus of one clear definition of the terms engineering, design, and engineering design nearly impossible, so is the field of engineering education to come to a consensus on one engineering design model. Engineering design is an iterative process, requires a foundation in mathematics and science, and grounded in domain specific knowledge and experience. Engineers rely on a variety of strategies and the Table 4 showcases suggested steps of the engineering design process for relevant studies. The general consensus between the studies is the engineering design process should identify the problem, generate possible solutions, evaluate those solutions, select a solution, and represent and document the solution. Although researchers agree on the general design procedure, they disagree on the knowledge base required to teach engineering design. It is clear that individuals who teach engineering need to have a foundation in science, mathematics, and a domain-specific knowledge. However, it is not clear that they should also have a foundation in engineering design content knowledge as well.

Table 4

Researcher(s)/Suggested steps of engineering design

Cross (2000)	Middendorf & Engelmann (1998)	French (1992/1999)	Dym (1994a)	Hubka (1982)	National Research Council (1996)
1. Clarifying objectives 2. Establishing functions 3. Setting requirements 4. Determining characteristics 5. Generating alternatives 6. Evaluating alternatives 7. Improving details	1. Problem definition 2. Problem evaluation (need analysis, specifications, feasibility) 3. Synthesis (study of patents, development of alternate design concepts, determination of most creative step) 4. Analysis (mathematical models, computers simulations, test of physical models, optimization of design) 5. Communicate and manufacture	1. Clear statement of the problem 2. Generate broad solutions 3. Conceptual design 4. Trade-offs 5. Selecting and sizing major subsystems 6. Rules of thumb 7. Detailing and refining	1. Clarifying the requirements of the client 2. Identifying the environment 3. Modeling the behavior 4. Identifying the constraints (manufacturing, marketing, economic) 5. Testing and evaluating the proposed design 6. Examination of whether there is a more economic or efficient design 7. Documenting the completed design for the client (p. 22)	1. Iteration 2. Abstraction 3. Concretization 4. Improvement	1. Identify a problem or need to improve on current technology 2. Propose a problem solution 3. Identify the costs and benefits of solutions 4. Select the best solution from among several proposed choices by comparing a given solution to the criteria is was designed to meet 5. Implement a solution by building a model or simulation 6. Communicate the problem, process, and the solution in various ways

Identifying Core Concepts in Engineering

Engineering is not defined as a core subject in K-12 education; therefore, identifying core concepts in engineering to include in a high school program is not an easy task. Several initiatives have been developed to infuse engineering into K-12 education as an avenue to bring about technological literacy (Custer, Daugherty, & Meyer, 2009; Dearing and Daugherty, 2004; Lewis, 2005).

Custer, Daugherty, and Meyer (2009) conducted a qualitative study to identify and refine a conceptual foundation for engineering in secondary school education. Data was collected primarily through four sets of documents and three focus group sessions. The four sets of documents reviewed identified the core engineering concepts were the following: engineering and technology philosophy writings, curriculum materials focused on secondary level engineering, curriculum standards documents developed for the STEM disciplines and relevant National Academy of Engineering reports, and five survey research studies relevant to K-12 engineering. The curricula reviewed were the following: A World in Motion (SAE International); Design and Discovery (Intel Corporation); *Materials World; Engineering by Design; Engineering the Future; Exploring Design and Engineering; Ford Partnership for Advanced Students; INSPIRES, Project Lead the Way* and *The Infinity Project*. The curricula standards reviewed included the following: *Benchmarks for Science Literacy* (AAAS, 1993/2009), *Criteria for Accrediting Engineering Programs* (ABET, 2000), *National Science Education Standards* (NRC, 1996), *Principles and Standards for School Mathematics* (NCTM, 2000), and the *Standards for Technological Literacy* (ITEA, 2000). The five research studies included the following: Childress and Rhodes (2008), Harris and Rogers (2008), Childress and Sanders (2007), Smith (2006), and Dearing and Daugherty (2004).

Focus group sessions consisted of engineering education faculty from selected departments and practicing engineers from local firms to express their perception of engineering concepts. As a group the list of concepts were classified into three categories: concepts core to engineering, those that were engineering concepts, and those that were conceptual. As a result 100 themes emerged, and after further review a list of thirteen concepts appropriate for secondary level of engineering education: analysis, constraints, design, efficiency, experimentation, functionality, innovation, modeling, optimization, prototyping, systems, trade-offs, and visualization. However, this study only investigated engineering concepts appropriate at the secondary level and may not necessarily be applicable across the entire K-12 spectrum. The researchers concluded that teaching engineering emerged engineering draws on knowledge from other academic disciplines, specifically mathematics and science. In addition, the social aspect of engineering is important because engineers reflect on the values, needs, impacts on societies and culture.

Teaching Engineering Design

Rogers (2005) examined infusion of the PLTW pre-engineering curriculum into technology education programs of Indiana middle schools and high schools. The sample consisted of 76 PLTW teachers and 76 non-PLTW teachers. Both groups were given an instrument that listed two learning activities for seven PLTW courses, resulting in 14 pre-engineering learning activities (PLTW, 2005). PLTW teachers had completed the PLTW professional development institute at Purdue University and were currently teaching

PLTW courses. The response rate was 44.7% for PLTW teachers and 36.8% for non-PLTW teachers. Both PLTW teachers and non-PLTW teachers viewed pre-engineering education as a valuable component of technology education, but more PLTW teachers felt pre-engineering education was a "very valuable" component of technology education. The sample included 61.8% of teachers who were members of ITEA. Technology teachers who were not members of ITEA valued pre-engineering as a component of technology education more than ITEA members. Teachers with advanced degrees had a more positive view of engineering education as well. However, PLTW teachers are nearly twice as likely to rate pre-engineering as a very valuable component that are non-PLTW teachers. Non-ITEA members were more likely to rate pre-engineering as a very valuable component of technology education that were ITEA members.

Yasar et al. (2006) developed a survey to assess K-12 teachers' perceptions of engineering and their familiarity with teaching design, engineering, and technology (DET), which is used to encompass the broader meaning of technology education (NRC, 1996). The need arose to assess teachers' knowledge and needs of DET because many states included DET standards, but teachers generally did not teach DET because of the level of math, reading, and writing. The final draft of the instrument resulted after five field studies and contained 69-items and ten categories: pre-service training in DET or science, what curriculum activities should be included, desire to teach DET, importance placed on teaching DET, DET self-efficacy, motivation to teach DET, perceived barriers, perception of a typical engineer, perceptions of which students should pursue DET, and perceptions of school counselors. The 69-item instrument was then administered to 98 Arizona science teachers (13 elementary, 42 middle, 35 high school; 56 female, 42 male) in the state of Arizona. A principal component factor analysis reduced the instrument to 41-items and extracted 4 factors (importance of DET, familiarity with DET, stereotypical characteristics of engineers, characteristics of engineering) accounting for 43.5% of the variance. It was evident from the results other factors affected teachers' familiarity with DET and need to be researched. However, the article does not mention if all the initial ten factors formed the resulting four factors after the factor analysis.

DET was perceived to be more important and the characteristics of a typical engineer were more familiar to female teachers than their male counterparts. Importance of DET was rated highest by middle school teachers in the study and they were also more interested in learning about DET. Teacher knowledge and teacher training were expressed as the main barriers to integrating DET concepts by teachers with at least Teachers with at least 11 years of experience. It was a consensus among the teachers that they did not possess the confidence to integrate DET, were not very familiar with DET because of lack of administrative support, lack of knowledge, lack of training during pre-service education and other opportunities for training, and a lack of time to learn about DET. Although DET is not a priority in American schools, it is a priority in K-12 classrooms of many other countries (ACE, 1992; Department of Education and Science/Welsh Office, 1990; Ministry of Education, 1995; Department of Education Northern Ireland, 1992). However, it was difficult for experienced teachers to implement DET for the first time. This study only surveyed science teachers in Arizona; therefore, it cannot be generalized to teachers who do not teach in Arizona or who do not teach science but teach DET in other technology education courses.

Merrill et al. (2008) used a mixed method quasi-experimental, pretest, posttest, no control group to transfer knowledge to students using a National Center for Engineering and Technology Education (NCETE) cohort of practicing and pre-service technology teachers. As a culminating activity the purposive sampling of teacher designed and developed a unit of instruction to deliver these three core engineering concepts to secondary level technology education students. This study explored the extent to which students understood and were able to demonstrate an understanding of constraints, optimization, and predictive analysis (COPA), the core conceptual knowledge needed for students to understand and be able to do engineering design. During the 2005-2006 school year, eight technology education teachers from multiple schools, one mathematics and one science teacher were involved in the study. The participants completed 5 days of professional development and helped to develop the 20-class session unit of instruction and the supporting activities. A 10-item test instrument targeting each of the three engineering concepts was developed by a research team and a technology education teacher, who had a mechanical engineering degree. It is clear from the mean score gains from pretest to posttest that student learning was achieved as a result of students' participation in the engineering design unit of instruction. Although gains were small it did indicate significant improvement in understanding of COPA concepts. There was no difference in performance in gender, ethnic group, and mathematics/science background performance differences, indicating that engineering concepts can be successfully delivered to a broad spectrum of students. The outcomes of the pretest and posttest indicated that the test instrument was capable of detecting student learning at various levels of conceptual difficulty, but there are specific areas of need in order to better develop these engineering concepts. Technology education teachers, existing and preservice, need to be better equipped to develop and teach engineering design concepts that are infused into the curriculum. This integration of engineering design and technology education means technology education teachers need to develop pedagogical skills that include more focus on conceptual knowledge, apply mathematical and scientific knowledge, and the processes involved in engineering design.

Wicklein, Smith, Kim (2009) used a Delphi model to explore how the engineering design process should be taught to secondary students enrolled in Technology Education classes. Participant suggestions and opinions were interpreted using descriptive and ordinal level data collection and analysis. A 48-item list resulted after the fourth round of the Delphi study, and were considered valid for identifying the essential aspects and related academic concepts (math, science, and engineering) of an engineering design process. The development of a curriculum that emphasizes engineering design should be prefaced by the creation of a framework which provides insight from experts in the area of engineering design and extends the current Standards-based context of curriculum development. Currently there is no overarching framework for understanding and implementing engineering design content into secondary technology education classes. This overarching strategy of creating and implementing a solid engineering design focused curriculum framework is significant to avoid a haphazard and disjointed experience for students and also for teachers attempting to use engineering design as a curriculum organizer. There are numerous approaches to the delivery of technology education content currently practiced in the U.S., and this fragmented approach has led to confusion. Integrating engineering design concepts into technology education classes could provide increased rigor as students apply academic skills and knowledge to technological problems. Engineering design can in fact be considered as a potential contributor to the field of technology education. A curriculum focused on engineering design could add significantly to student learning and the knowledge base with regard to synthesizing a variety of variables (science, technology, engineering, and mathematics) to solve ill-structured problems.

Status Studies in Technology Education

Donan (2003) used a descriptive design to determine the level of acceptance of national content standards by technology education teachers, determine the level of need for in-service training of technology education teachers, and how well STL standards fit within existing curricula in the state of TN. This was the first study at that time to analyze the perceptions of teachers and their willingness to adopt a set of national standards for technological literacy. The study was limited for the following reasons: (1) relied on the accuracy of mailing addresses for technology education teachers that was provided by the TN Department of Education; and (2) the return rate determined the validity of the mailed instrument. The study was conducted under the assumption that the returned questionnaires represented the population and that the technology education teachers were familiar with STL, TN Technology Education Standards, and Technology Education Curriculum Framework. Three hundred fifty-six TN middle and high school technology teachers were administered a survey based on a Likert scale. An attempt was made by the researchers to contact individuals who submitted incomplete surveys. All surveys submitted where missing information could not be obtained were discarded. The data was analyzed using Chi square with Fishers Exact test of probability. Of the 356 TN technology education teachers, 30.9% returned a completed survey 82% were willing to adopt *STL* content standards. If at least 10% or more of technology teachers did not endorse a content standard, then further investigation was necessary due to the number of students that would be affected. Four content standards were not endorsed by more than 10% of the technology education teachers. Technology teachers felt these four content standards were more related to the social sciences, inappropriate for technology education in middle school and high school, or more appropriate for a high school vocational agriculture curricula. Overall the technology education teachers felt they could not teach the curricula effectively or present the material to the students effectively because of weak SK. Only 20% of technology education teachers somewhat agreed their students' had the ability to acquire the content explicit in the standards. Only 47% of technology education teachers believed their students possessed ability to acquire.

Kelley (2008) conducted a descriptive study to examine the current status of technology education teacher practices with respect to engineering design. The sample consisted of high school teachers in the ITEA membership database and non-ITEA teachers, whether they taught engineering design or not in the classroom, for the 2007-2008 school year in the U.S. Study consisted of 1043 high school technology teachers. The survey instrument was developed from previous studies (Asunda & Hill, 2007; Childress & Rhodes, 2008; Smith, 2006; Gattie & Wicklein, 2007) and consisted seven subsets: engineering design, engineering analysis, application of engineering design, engineering communication, design thinking, engineering and human values, engineering science. Each of these studies used surveys or semi-structured interviews to locate the suggested learning outcomes and assessment strategies necessary to implement engineering design in high schools and the results of the surveys were verified and authenticated.

Many technology education programs are designed to teach engineering concepts and or engineering design in K-12. However, little was known about the extent to which technology educators were implementing elements of engineering design in their curriculum. Critical content and assessment practices for integrating engineering design in technology education (Asunda & Hill, 2007; Childress & Rhodes, 2008; Gattie & Wicklein, 2007; Smith, 2006). Surveys were used to identify those leararning objectives and assessment strategies. The learning objectives were then grouped into constructs.

The study sought to better understand the learning objective and assessment strategies by asking the participants to respond to frequency, delivery style, assigned student problems and projects, as well as teaching conditions with respect to availability of required materials. Each item received a mean score based on the time per typical use. *Use of computer-aided design to connect technical drawings* had the highest mean of 3.35, indicating technology education teachers emphasize design through the use of computer-aided design in their technology education programs. Spending a large amount of instruction time and practice time on computer-aided design can limit technology instructors of time needed to teach other fundamentals of engineering design. *Develop basic student's skills in the use of tools* had the highest mean score of 3.32 indicating the foundation of technology education has not changed. Of course students need to develop tool skills in a program that has been integrated with engineering design but there must be a proper balance of instructional time to teach fundamentals of engineering design.

Three constructs, *Engineering and Human Values, Engineering Science, and Engineering Analysis,* received low mean scores indicating teachers have yet to acquire fundamental knowledge of engineering science.   Teachers were not equipped with the level of math and science needed to teach engineering design. Based on the low mean scores in these constructs teachers are unable to emphasize certain components of engineering design because they lack the knowledge to do so effectively. Technology education teachers place less emphasis on the analysis and optimization steps of the engineering design process, which are what make it different from the technological design process (Hailey et al., 2005; Hill, 2006; Gattie & Wicklein, 2007).

Research on Technology Education with an Engineering Design Focus

Technology education with an engineering design emphasis has the potential to increase interest and improve competence in mathematics and science among K-12 students. Technological literacy would improve by exposing students to a more comprehensive methodology that generates the technology. However, this would mean increased mathematics and science requirements for technology teachers and technology teacher educators.

Using a modified Delphi approach Childress and Rhodes (2008) used a modified Delphi approach to develop engineering outcomes that should be included in a high school technology education program. The technology program focused on providing students with technological literacy. The Delphi approach is a mixed-methods approach involving focus groups and administration of an instrument to a panel of experts. The panel of experts included individuals who were nominated by a prominent employee of the National Research Council and by a former employee of the Accreditation Board for

Engineering and Technology. The individuals included engineers, engineering educators, government employees and learned society employees. Each participant of the study had to be nominated by a prominent employee of the National Research Council and by a former employee of the Accreditation Board for Engineering and Technology. The focus groups conducted in Fall 2005 were used to collect input on what engineering concepts should be taught at the high school level.

The instrument consisted of pre-selected outcomes from the focus groups, the American Association for the Advancement of Science (1993), McREL (2004), NRC (1996), ITEA (2000), MA DOE (2001), Dearing and Daugherty (2004), NCTM (2000), Koehler, Faraclas, Sanchez, Latif, and Kazarounian (2005), and Bordogna (1997). This resulted in a 47-item instrument which was administered to the panel of experts to rate each outcome item on a five-point Likert Scale. Consensus was achieved for any item having at least a mean rating of 3 or 4. After six rounds of inquiry using the modified Delphi approach consensus was achieved for 43 outcomes. This indicates that the standards published by the organizations and research studies are valid in terms of engineering outcomes. The panel of experts outcome items into groups of conceptual alikeness. The panel of experts agreed on the following grouping summaries: engineering design, application of engineering design, engineering analysis, engineering and human values, engineering communication, engineering science, and emerging field of engineering. These engineering outcomes could be used to review existing pre-engineering programs, as contexts to make mathematics and science more practical and motivating, and to develop K-12 standards that help teachers teach mathematics and science concepts in the classroom.

Gattie and Wicklein (2007) surveyed 283 K-12 ITEA technology teachers' perspectives and attitudes regarding infusion of engineering design into technology education. These results cannot be generalized to the population of technology education teachers because not all are members of ITEA. The sample was 87.2% male and 92.5% of the sample taught at the high school level. Surveys were received from the following regions: 104 (36.7%) from the East region, 67 (23.6%) from the East Central region, 76 (26.8%) from the West region and 36 (12.7%) from the West region. Only 65% of the participants had a Masters Degree. However, 59.2% of ITEA technology teachers had a Master's degree in a field other than industrial arts and technology education. Only 30% of the participants had a B.S./B.A. degree, of which 43.8% was in industrial arts and 25% was in technology education. Ninety-percent of the technology education teachers were teaching topics/courses related to engineering or engineering design, but only 45.4% of the instruction was related in any way to engineering or engineering design. Table 5 shows teachers consensus on different aspects of infusing engineering design into technology education.

Table 5

Teacher consensus results on infusing engineering design into technology education

Results	Percentage of teacher consensus
Engineering design curriculum would clarify the focus for technology education	93%
Increase the overall academic value of technology education	94.9%
Provide a platform for integration with other school subjects	96.7%
Improve the technological literacy content within technology education	88.7%
Improve the instructional content for technology education	88.4%
Increase student interest in mathematics	89.3%
Provide additional learning opportunities for students	94.4%

A large percentage of the participants (91.2%) would need assistance in identifying appropriate instructional content; 93.8% would need assistance integrating the appropriate levels of mathematics and science into the instructional content; and 85.3% would need to gain the appropriate levels of mathematics and science knowledge to teach engineering design. It was a consensus among the ITEA technology education teachers that engineering design adds value to technology education, but realizes their own limitations due to academic training and educational resources.

Secondary Engineering Teacher Quality and Knowledge Base

Based on the time students spend with teachers in the classroom, it singles out the importance of teacher quality and knowledge base. Both are important in order for classroom instruction to be meaningful and effective. Teachers need to be experts in his/her content area, possess experience, and know how to teach his/her content area (Darling-Hammond, 2000a/2000b; Darling-Hammond and Youngs, 2002; Goldhaber, 2002; Hanushek et al., 2005; Wayne and Youngs, 2003). Most successful teachers have adequate preparation in the subject matter they teach (cf. Armour-Thomaset et al., 1983; Haberman, 1984). Due to the time spent in the classroom with teachers, they will undoubtedly be one of the main influences on student achievement.

The NCLB Act of 2000 was passed under the reign of George W. Bush and guides school districts in placing "highly qualified teachers" (HQ) in the classroom. Teachers become HQ by having full state certification within their content area, have a license to teach within a given state, and have not had the license or certification waived. However, having a college degree and certification in desired content area does not guarantee the teacher will be effective in the classroom (Donan, 2003). 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. NCLB Act only stipulates training in content area prior to obtaining certification; however, teachers have not gained all they need prior to receiving certification (Public Agenda, 2006). Preparation of actual qualified teachers should include education and training in specific curriculum areas as well as the study of actual teaching techniques and instructional strategies (Bryne, 1983; c.f. Compston, 1998; Darling-Hammond, 1998; Shanker, 1996). In the end, poor teacher quality discourages students from entering engineering fields (GAO, 2006).

Pre-Training Experiences

To further uphold the framework of the NCLB Act each state requires core content teachers to be certified in his/her area to teach in the classroom. Unlike core content teachers CTE teachers are required to have work experience in his/her area prior to being in the classroom under the Smith-Hughes Act of 1917 (Erekson & Barr, 1985). However, individuals are not leaving industry to become K-12 CTE teachers, even with the increased unemployment rate in the U.S. Individuals who prefer to teach in the K-12 educational system than work in industry are limited because of state requirements for certification. Individuals desiring to teach core content areas or CTE obtain certification through one of two pathways, the traditional program or the alternate certification alternate program.

Traditional teacher certification program

All 50 states offer a traditional degree program requiring individuals to have a bachelor’s degree and complete an approved teacher preparation program. However, specific requirements differ for core content areas and CTE. Individuals pursuing employment in core content areas are required to obtain a bachelor’s degree in education and successfully pass required state exams.

Very few states offered traditional teacher certification program in CTE, especially in trade and industrial areas (Zirkle, Martin, & McCaslin, 2007). Bachelor’s degree requirements for individuals pursing employment in CTE varied from state to state depending on the state. Some states required the degree be in education, some required content area major, some required the degree be in any subject, and other states did not specify. In addition to the bachelor’s degree requirement and completing an approved teacher program, CTE teachers are required to pass an entry and/or exit test for certification for some states. Required tests may include the Praxis series (basic academic skills, teaching pedagogy and principles, and content area) and performance exams.

Alternative teacher certification program

Alternative certification programs are designed to certify teachers who have not completed an undergraduate degree in the field of education. Alternative teacher certification programs vary extensively from state to state, and even within states, for core areas and CTE. Individuals who choose the alternative certification pathway may earn certification more quickly than going through the traditional undergraduate teacher education program. Alternative certification in core areas are offered through course taking from an accredited college or university program, or successful completion of an intense modified curriculum (Zirkle, Martin, & McCaslin, 2007).

In many states CTE certification can only be obtained through an alternative certification pathway. Many states offered alternative CTE certification require some work experience in addition to a college or high school diploma. Education and work experience varied depending on the amount of the individual’s occupational experience. Zirkle, Martin, and McCaslin, (2007) note the following:

- Few states’ alternate routes to certification provided a genuine alternative pathway into the teaching profession.
- Instead of offering a real alternative, most states’ alternate routes either mirrored traditional routes or appeared to be little more than emergency certificates in disguise.

- Although all but one state claimed they have an alternate route, only five states offered a genuine alternate route that provided an accelerated, responsible and flexible pathway into the profession for talented individuals.
- Alternate route admissions criteria in only 19 states were flexible to the needs and backgrounds of nontraditional candidates.

Only 14 states appropriately limited the amount of coursework that can be required of alternate route teachers. Only 20 states allowed broad usage of their alternate routes across subjects, grades and geographic areas, and also allowed organizations other than higher education institutions to train teachers.

Concerns with alternative CTE certification programs

The Carl D. Perkins Vocational and Technical Education Act of 1998 was implemented to guide secondary CTE programs in strengthening the emphasis on academics (Castellano et al., 2004). Cramer (2004) examined how well prepared CTE teachers were compared to teach courses and programs where the emphasis was on academics. The sample consisted of 200, 000 elementary, secondary, and secondary CTE teacher candidates who completed the Praxis series exams (Praxis I, II, and Principles of Learning and Teaching) between 1994 and 1999. The individual test results were used to examine the academic skills and pedagogical knowledge of elementary, secondary, and CTE candidates. Results showed CTE certification candidates were not academically or pedagogically prepared as secondary candidates and were not academically prepared in reading or writing as elementary candidates. This study suggested CTE work experience requirement and teacher preparation programs currently do not support placing emphasis of academic skills. In addition, most prospective teacher candidates were older and possibly out of school for a long period contributing to weak academic and pedagogical knowledge.

Teacher Knowledge Base

College accreditation boards assess what is taught in post-secondary programs, which determines what knowledge future collegiate educators should know. Teacher knowledge in K-12 education is primarily assessed by The Praxis Series of the national Educational Testing Service (ETS) for most states. The Praxis series provides tests for most states to use as part of their teacher certification process. Colleges and universities also use the program to qualify individuals for entry into teacher education programs. The Praxis I Academic Skills Assessment measures basic reading, writing, and mathematical skills of prospective teachers. The Praxis II Subject Assessment measures prospective teachers subject knowledge in the area he/she is seeking certification. The Praxis II Principles of Learning and Teaching (PLT 7-12) assessment measures general pedagogical knowledge for teaching grades 7-12 by using a case study approach.

The Accreditation Board for Engineering and Technology (ABET) identifies what is to be taught in post-secondary engineering programs. Unlike post-secondary engineering programs, an attempt to incorporate engineering into the K-12 curriculum brings a major issue to the forefront, the challenge of what to teach and how to teach it appropriately (Brophy et al., 2008). This issue continues to challenge K-12 curriculum because engineering education is not clearly defined at this stage. Engineering is not one of the core courses (English, math, science, social studies) for K-12 curriculum and therefore, what is taught and how it is taught varies from school district to school district.

Inconsistency in what is taught contributes to varied levels of readiness for undergraduate engineering programs. Although not the focus of this research, development of a K-12 engineering curriculum needs to be implemented to have consistency across school districts.

Without having a clear definition of K-12 engineering education means inconsistencies in teacher preparation and qualifications, but also an area of minimal research (Daugherty, 2008; Hynes, 2009). Regardless of content area teachers are employed in, teachers should receive training prior to employment and ongoing professional development to be effective in the classroom (Hynes, 2009; International Technology Education Association, 2002; Massachusetts DOE, 2006). Secondary teachers in engineering education need opportunities to learn about and develop skills related to engineering, opportunities to learn how to teach engineering, tools and motivation to continue their learning, and long-term professional development to support the changes in engineering education to be successful.

The knowledge for teachers to be effective in the classroom is a collaboration that includes: subject knowledge (SK; Hynes, 2009; Viiri, 2003; Shulman, 1987); general pedagogical knowledge (GPK; Viiri, 2003; Hynes, 2009; Shulman, 1987); and pedagogical content knowledge (PCK; Hynes, 2009; Viiri, 2003; Shulman, 1987). Researchers, college professors, and industry partners must question what methods will be used to prepare teachers (Lewis, 2005; McCormick et al., 1994).

Assessment of K-12 Teacher General Pedagogical and Subject Knowledge

Research shows that teachers who major in the subject-area taught have more of an impact on student achievement than teachers majoring in an out-of-field discipline, including those who major in education (Goldhaber & Brewer, 1999). In 2001, the National Association of State Directors of Teacher Education and Certification (NASDTEC) published alarming data. Less than one-third of all states required teachers to have had an academic major in the subject to be taught and only two-thirds required perspective teachers to pass a subject-matter exam for initial licensure. Failure on the states part to ensure subject-area competence raises the question whether state certification is able to guarantee whether a certified teacher is necessarily a qualified teacher.

Other research shows that additional content-related coursework taken by teachers has a positive effect on student learning while additional coursework unrelated to content area taken by teachers had a negative effect on student learning (Monk, 1994). This argument was also later supported by NSB (1998) where additional graduate coursework in a specific content area and a high level of achievement were directly related to improved student achievement. Teachers with limited knowledge avoid teaching certain subjects, fail to challenge misconceptions, discourage student interaction, and avoid class discussion or other teaching situations that would expose their limited knowledge (McNamara, 1991; Ball and McDiarmid, 1989). Most important factor in improving student achievement is teacher knowledge of subject and ability to teach it effectively (Darling-Hammon & Ball, 1998; Greenwald, Hedges, & Laine, 1996; Ferguson, 1991)

Teachers' awareness of GPK and SK is a vital part of pedagogical content knowledge (PCK) (Viiri, 2003; Williams, 2008). 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. PCK is the professional skills teachers need to communicate specialized knowledge of his/her field to students and includes the methods and activities used by teachers in the learning process. Cramer (2004) investigated the Praxis Series test data from 1994 to 1999 for elementary, secondary, and secondary vocational education teacher candidates. The data was used to examine how well-prepared secondary vocational education teacher candidates were able to support and reinforce students on academic skills. This study does not reflect the entire population of teachers because those who graduate from alternative certification programs may not take Praxis exams. In addition, vocational education teachers are most likely to enter teaching from business and industry, and may not be required to take all or any parts of the Praxis Series test. Therefore, the sample does not represent the entire set of vocational education teachers either. The study examined the GPK through the PLT 7-12 assessment scores from 1994 to 1999. The GPK score is a measure of a teachers understanding of how to integrate learning and development theories in practice and connect it to student learning. Teacher candidates with a low PLT assessment score are less likely to use a range of teaching methods and activities and can not easily adjust his/her professional practices to create successful learning environments for students. The most notable difference in this study was in the PLT scores (.24 to .50) for secondary candidates and secondary vocational education candidates. Secondary vocational teacher candidates scored lower than secondary candidates each year on the PLT assessment.

This may indicate that vocational teacher candidates do not understand as well as secondary candidates on how to incorporate learning and development theories in practice and connect it to student learning.

Secondary teacher candidates had the highest score in reading, writing, and mathematics each year of the longitudinal study. Small effects appeared in mathematics. Mathematics scores for secondary vocational education teachers were slightly higher than elementary teacher candidates each year of the study, which may be due to the use of math in many vocational education fields. Small medium effects appeared between secondary candidates and secondary vocational education candidates in reading and writing, .23 to .37 and .24 to .43, respectively. The reading scores for secondary vocational education candidates were consistently lower than elementary teacher candidates each year of the study. Similar to the reading scores, secondary vocational education candidates had the lowest writing scores each year of the study, slightly lower than elementary teacher candidates. This study alludes to the need to increase the requirements for subject knowledge.

Each year secondary vocational education candidates consistently passed the Praxis Series assessments at lower rates than secondary candidates and at lower rates than elementary teacher candidates in reading and writing. This pattern of passing scores suggests vocational education candidates are less likely to have acquired the academic skills adequate for a beginning teacher.

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 (Borko et al., 2000; Borko & Putnam, 1996). Based on the limited research on teacher SK and student achievement in engineering more research needs to be conducted, and this study aims to contribute to this area of research.

Teacher Self-efficacy.

A teacher's priority is to alter a student's current knowledge into a deeper conceptual knowledge by transferring his/her SK. A teacher's confidence in his/her SK affects how well he/she participates in and understand his/her own content (Ramsey-Gassert et al., 1996). This in turn addresses a teacher's self-efficacy, an individual's belief that they can affect change (Bandura, 1997). It is a dynamic trait that can change over time and is influenced by experiences. This personal belief affects whether the desired behavior is initiated, how much effort is put forth, and the persistence of the behavior (Hackett & Betz, 1989). Therefore, self-efficacy, knowledge, and action are interrelated (Bandura, 1982, 1986). Self-efficacy is based on four factors: mastery experiences, vicarious experiences, social persuasion, and physiological states (Bandura, 1977, 1986). The first factor, mastery experiences, is the most influential in a person's self-efficacy. Mastery experiences refer to past personal performances and future reflections in which activities are considered failures or successes. Vicarious experiences refer to development of self-efficacy in an activity after observing other individuals perform the activity successfully. Verbal persuasion refers to developing self-efficacy when others tell a person he/she has the ability to complete a certain task successfully. Physiological states refers to the development of self-efficacy when participating in activities that illicit emotional arousals.

Several researchers feel a high self-efficacy is attained in the student if the teacher has a little more SK than the student (Hoy & Davis, 2006; Beijaard, et al., 2000). Self-efficacy reflects a teacher's confidence in their SK and ability to present information to students', which determines how seriously the students' perceive them. If a teacher is not taken serious by his/her students then his/her confidence is decreased leading to a lower self-efficacy, and as a result they are not effective in the classroom, having adverse affects on student achievement. Hoy and Davis (2006) explain a high self-efficacy is evident when teachers' are more thorough in their planning, which increases student achievement. A low self-efficacy is evident when teachers' have low self-confidence, minimal to no depth in lesson, trouble preparing lesson plans, and less diligent in developing knowledge base (Hoy & Davis, 2006). Hoy and Davis (2006) also identify one of the factors contributing to a teacher's self-efficacy is SK.

Ashton (1984) asserts teacher self-efficacy is the best construct to demonstrate a consistent relationship to student achievement. Reviewing responses of middle school teachers on the Thematic Appreciation Test assisted in identifying characteristics distinguishing high self-efficacy teacher from low self-efficacy teachers. High self-efficacy teachers felt they had a positive impact on student learning, expected students to meet high expectations, felt responsible for students learning, set goals for themselves and students, felt he/she had a positive affect, felt confident he/she could influence student learning, and involved students in the decision-making process. Low self-efficacy teachers felt frustrated and discouraged about teaching, had low expectations for behavior and achievement, placed responsibility for learning on students, had a bureaucratic learning environment, and struggled with students whose goals and concerns did not coincide with theirs.

There are several research studies in math and science supporting the argument that a teachers self-efficacy reflects their confidence in SK and ability to develop knowledge base in their students (de Laat & Watters, 1995; Enochs & Riggs, 1990; Ginns & Watters, 1994; Ramey-Gassert, Shroyer, & Staver, 1996; Riggs, 1995; Riggs & Enochs, 1990; Watters & Ginns, 1995). There are not as many studies in engineering or technology. Therefore, the subsequent research studies in math and science will be discussed to lay a foundation for the importance of high self-efficacy for teachers of engineering-related courses.

The results from a Science Teacher Efficacy Beliefs Instrument (STEBI-A) administered to thirty seven primary teachers' suggest self-efficacy is a useful construct to understand attitudes towards teaching science (de Laat and Watters,1995). The instrument was comprised of two scales, the self-efficacy belief scale and an outcome expectancy scale. Understanding teachers' self-efficacy provided a standard for monitoring change. Teacher with a high self-efficacy had a strong interest and formal background in science. Teaching outcomes of generally good teachers may be ineffective if the teacher has a low teaching self-efficacy. Students who were subjected to teachers with a low science self-efficacy were disadvantaged because those teachers had a deficiency in the teaching of science.

Engineering-Related Teacher Self-Efficacy.

Teachers in K-12 engineering education do not always have an engineering background, but teach engineering-related courses. Engineering-related courses include math, science, and technology education courses.

Robinson and Maddux (1999) conducted a pilot experimental study to determine secondary mathematics and science preservice and inservice teacher attitudes towards engineering. Although this study does not investigate teacher self-efficacy it was relevant. Without a clear definition of engineering education in K-12 students may rely on the knowledge of science and mathematics teachers regarding the field of engineering. The study also gives the results of student attitudes towards engineering. Both groups were administered a 25-question attitude survey before and after a capstone engineering course. The teacher participants consisted of eleven preservice and inservice science and mathematics teachers (pretest – posttest design) and a fifteen teacher control group (posttest only). The high school participants consisted of a four-group pretest – posttest design. Two classes of thirty-one were randomly selected as control groups and two classes of thirty-three were selected as treatment groups. A teacher who had just finished the capstone course planned a three-week unit on engineering principles and design. After the capstone course the attitudes of pre-service and inservice teachers and high school students were more favorable toward engineering. However, the study did not have statistical significance because of its small sample size. This study was important because students interested in engineering sometimes are taught engineering content by their math and science teachers. It’s important to know the teachers attitude towards the content their teaching.

Baker et al. (2007) used an interpretive analysis method to assess the tinkering self-efficacy and technical self-efficacy from nine participants (five females and four males) enrolled in a 15-week Science Education graduate course on design, engineering, and technology. All participants were either enrolled in the master or doctoral science program, had a strong background in science and mathematics, and had experience teaching science in the K-12 education system and/or at the university as teaching assistants. The graduate students enrolled in the course to strengthen their ability to transfer engineering concepts to pre-engineering classrooms. The data was collected from focus groups, weekly reflections on classes and reading, and pre-test and post-test course questions. Although a small sample, the study suggests an increase in tinkering and technical self-efficacy impacts students attitudes and interest in engineering, especially for women. The initial tinkering and technical self-efficacy was higher for males than females. There was an increase in tinkering and technical self-efficacies for all students; however, there was only a slight increase for male students due to an initial high self-efficacy. Research studies of this nature can prove beneficial for educators whose goal is to integrate engineering into the K-12 curriculum.

STEM Self-Efficacy Beliefs

Research on teacher self-efficacy of engineering-related courses and self-efficacy toward engineering concepts is rarely analyzed. However, there are several studies on the self-efficacy beliefs of STEM students and interest of women and minorities to pursue careers in male-dominated technical and scientific fields. Hackett and Betz (1989) were the first to use self-efficacy to explain the career choices of women in male-dominated fields. Low self-efficacy limits career exploration and development, resulting in gender dominance in certain career fields (Lapan, Boggs, & Morrill, 1989; Lent et al., 1991).

According to Bandura (1986), a student's perceptions or beliefs about his/her capabilities has a stronger and more effective influence on future behaviors or attainments than a student's knowledge, skills, and previous accomplishments. Self perception plays a role in the career assessment and career development process. Since Hackett and Betz (1989), researchers have shown self-efficacy beliefs of STEM students in persistence, achievement, interest, and career choice. Table VI shows a breakdown of the research studies in each STEM area.

Table 6

Summary of STEM research studies in certain areas

Area	Research Study
Persistence	Brainard, Laurich-McIntyre, & Carlin (1995); Lent et al. (2003); Robinson & McIlwee (1989); Sax (1994); Schaefers, Epperson, & Nauta (1997)
Achievement	Hacket & Lent (1992); Lent, Brown, & Larkin (1984); Lent et al. (2003); Schaefers, Epperson, & Nauta (1997)
Interest	Hacket & Lent (1992); Lent, Brown, & Larkin (1987); Lent, Lopez, & Bieschke (1991); Lent et al (2003); Schmidt et al. (2001); Lent, Brown, & Larkin (1984); Lent, Brown, & Larkin (1986); Campbell & Hackett (1986); Hackett, Betz, O'Halloran, & Romac (1990); Hackett & Campbell (1987); Hackett & Lent (1992); Lent & Hackett (1987); Zelden & Pajares (2000)
STEM Career Choice	Betz & Hackett (1981); Betz & Hackett (1983); Gwilliam & Betz (2001); Hackett & Betz (1989); Lent, Lopez, & Bieschke (1991); Rotberg, Brown, & Ware (1987); Taylor & Betz (1983); Taylor & Popma (1990); Bradburn (2005)

Carberry, Ohland, and Lee (2009) conducted an exploratory pilot study to develop an instrument to measure student's self-efficacy regarding engineering design. Collecting information on the student level of self-efficacy in reference to engineering tasks can be valuable information for educators in planning, structuring, and developing engineering courses. Content validity, criterion-related validity, and construct validity were used to develop the 36-item instrument. The sample consisted of 15 engineers, 7 engineering education graduate students, 23 engineering students, 13 non-engineers with a science background, and 24 non-engineers without a science background for a total of 82 individuals. The instrument had four constructs (confidence, motivation, expectancy for success, and anxiety) measured on a 100-point range with 10-point intervals. Each construct contained items related to the engineering design process used by the Massachusetts Department of Education (MA DOE). The participants were divided into three groups: high self-efficacy, intermediate self-efficacy, and low self-efficacy. The participants engineering design self-efficacy was highly dependent on experience in engineering. Individuals with high self-efficacy had high confidence, motivation, and outcome expectancy and low anxiety. Individuals with intermediate self-efficacy had a medium score for all four constructs. Individuals with low self-efficacy had low confidence, motivation, and outcome expectancy and high anxiety. Results showed that both the MA DOE model for the engineering design process and the 32-item instrument were appropriate tools to measure engineering design self-efficacy.

Hutchinson-Green, Follman, and Bodner (2008) interviewed twelve students (seven men and five women) enrolled in a first-year engineering course at Purdue University. Although there are four sources to self-efficacy, this study was only concerned with the affect of vicarious experiences on self-efficacy. The researchers argued first-year students build self-efficacy mainly through vicarious experiences because students have had few personal experiences on which to reflect. The data was collected using semi-structured, open-ended interviews and a modified efficacy instrument designed specifically for a first-year engineering course. The data suggested that when students have few mastery experiences to reflect on to build self-efficacy students are prone to rely heavily on performance comparisons. Women in the study often felt their performance was inferior to peers, resulting in a lower self-efficacy. Whenever men in the study felt they outperformed their peers, their self-efficacy increased. Building self-efficacy solely on performance comparisons leads to inaccurate self-efficacy beliefs. Therefore, it is necessary for educators to provide students with opportunities to build self-efficacy through mastery experiences.

Career related self-efficacy instruments designed for general implications are not as productive as instruments designed for specific career skills (Bandura, 1986). Osipow and Temple (1996) designed the Task-Specific Occupational Self-Efficacy Scale (TSOSS) from skill statements of *Selected Characteristics of Occupations Defined in the Dictionary of Occupational Titles* (U.S. Department of Labor, 1981). Although the TSOSS was used in several studies, more research needs to be conducted because in some studies the expected relationships were small or relatively weak (Osipow & Temple, 1996; Temple, 1991).

Gwilliam and Betz (2001) assessed the relationship of five existing measures of self-efficacy for math- and science-related behavioral domains to each other, and as predictors to pursue science-related fields for African American and European American students. The participants in the study consisted of 399 multi-level college students enrolled in an introductory psychology course at a large Midwestern university. The instruments used in the study were three measures of investigative self-efficacy (Skills Confidence Inventory (SCI), Self-Efficacy Questionnaire (SEQ), and Self-Efficacy Rating Scale (SERS)), the Mathematics Self-Efficacy Scale (MSES), and Lent, Brown, and Larkin's (1984) measure of self-efficacy for Scientific and Technical Fields (STF). The study indicated that SCI, SEQ, and SERS were highly reliable and related to MSES, and moderately related to science-career related choices. However, STF did not relate to any of the other measures but did show that self-efficacy influences persistence of behavior choices. The STF is only appropriate when administered to a group of students who have made tentative decisions regarding a career in science, technology, or engineering.

Very few of the STEM career choice studies investigated the causal links among career-related choices, self-efficacy, and behavior. Several researchers examined the effect of manipulating success or failure on self-efficacy and interest, and found predicted differences (Campbell & Hackett, 1986; Hackett, Betz, O'Halloran, & Romac, 1990; Hackett & Campbell, 1987; Hackett & Lent, 1992; Lent, Brown, & Larkin, 1986; Lent & Hackett, 1987). Causal research may include experiences that strengthen technical and scientific self-efficacy leading to more complete career exploration. The timing and duration of the intervention is important developmentally. Dawes et al. (2000) experimentally evaluated a technology education program designed to provide mastery experiences and designed to improve career decision making. Ninety-seven seventh graders (48 female and 49 male) and seventy-two eighth graders (30 female and 42 male) attending a public school in a large Southwestern city were randomly assigned to either a published technology education program or to a control curricula. Within the duration of the seven week program students were allowed to pick three out of twenty modules. Students selected modules where he/she had high self-efficacy or interest. The experiment provided students with an opportunity to make informed decisions instead of building interest in a career field. As a result, students did have successful performance accomplishments, but did not have an increased interest in technology and science careers.

Amato-Henderson et al. (2007) surveyed 204 middle and high school students at a Youth Engineering and Science Expo (Yes! Expo) in Detroit, MI and claimed students who reported knowing an engineer would report a higher engineering self-efficacy. A modified *Longitudinal Assessment of Engineering Self-Efficacy* (LAESE) instrument was administered to measure demographics, engineering self-efficacy, course enrollment and extra-curricular behavior, and expectations and perceptions of the YES! Expo. The modified LAESE eliminated items only relevant to college students. Only students who completed the pre-event survey one to two days before the event and the post-event survey within two weeks of attendance were included in the data analysis. The study did not result in any significant differences between the pre-event assessment and the post-event assessment scores [t(203) = .764, p = .446]. No significant interactions existed between gender, school level, and knowing an engineer. A significant positive correlation did exist between the pre-event and post-event assessment self-efficacy scores (r = 0.609, p<.000). Students who reported knowing an engineer reported a higher engineering self-efficacy score than students who admitted not knowing an engineer.

The four hour trade event was not effective in impacting students' belief in his/her ability to succeed in engineering major or career, or allowed time for mastery of the experience.

Pedagogical Content Knowledge

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. 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 (Davis, 2003); and becomes more teacher-centered instead of student-centered (Veal, Tippins, & Bell, 1998).

Hynes (2009) conducted two pilot studies over two consecutive summers to investigate teachers SK and PCK used in teaching a robotics curriculum. Hynes (2009) suggests that middle school teachers should have a Bachelor's degree in engineering and a Master's degree in teaching to have a strong SK base in engineering and a foundation in teaching. The study followed 12 middle school teachers with backgrounds in mathematics, science, and computer teaching backgrounds and anywhere from one to 17 years of teaching experience. Data collection of teacher and student knowledge surveys, interviews, and observations revealed positive student gains for 24 middle school students in their knowledge of engineering content and their attitude towards engineering. Teachers with a background in science had SK more closely related to engineering SK than other teachers because the National Research Council (NRC) and the MA DOE embeded engineering standards into the science standards (Massachusetts DOE, 2006; NRC, 1996). Data also indicated with more years of experience teachers were able to make more connections between engineering and science for the students, using more student-centered approaches in the classroom. In addition, teacher's with non-teaching backgrounds used knowledge they acquired from non-teaching experiences which contributed to their engineering SK. The study could have been stronger with a larger sample, multiple raters to evaluate the data, and certified teachers with a variety of background and years of experience.

Viiri (2003) investigated the relationship between teachers' PCK and student understanding at a Finland university and concluded that awareness of students' understanding of content impacts students and teachers. This awareness allows students to reflect on their conception, allows teachers' to reflect on their instruction and improve engineering teacher training. The study consisted of three experienced teachers and their first-year civil engineering students, a total of 100 students. The same questionnaire, consisting of 12 questions on moments and forces, was administered to students and teachers. However, teachers were asked to describe their expectations of students' answers and students' reasons for selected responses. Of the 12 questions teachers accurately predicted students' responses on five questions, predicted 66% of students' responses on one question, and 33% or less on the other six questions. The teachers predicted the mean score on the test to be 58.25%, which was close to the actual mean of 54.17%. Although the teachers prediction was close to the actual mean, a success rate less than 60% indicated the students did not learn the content as the teachers intended, or the students were not assessed properly. Students correctness in answering the questions was not of importance. The purpose was to emphasize any patterns or common misunderstandings among the students regarding moments and forces. Based on the results, teachers were not aware of students' thought processes and suggest this be emphasized in teacher education courses. If teachers are serious about improving their PCK they will use students' responses to evaluate their own content knowledge and how they present the material.

Williams (2008) conducted a study in Western Australia focusing on the professional development of secondary engineering teachers using the Developing Professional Thinking for Technology Teachers (DEPTH). Prior to 2005, students were not offered any courses in technology education at the upper secondary level. With the new curriculum initiative, students would have a choice of at least 50 courses in technology education. However, the courses were taught by the current teachers who had little to no experience in the technology areas. In agreement with Viiri (2003), professional development was necessary to develop teacher PCK to improve teaching and learning. Although teachers are responsible for their education, professional development for secondary engineering teachers needs to be a collaborative effort between the teacher, university professor, and industry partner (Williams, 2008; Katz, 1993; Watson and Froyd, 2007; Bombaugh, 2000). Sixteen teachers from sixteen schools were polled using the DEPTH model to identify current gaps in the current professional development structure. As a result, the sixteen teachers were comfortable with GPK but not with SK. The teachers had no prior knowledge of engineering and the only professional development these teachers received consisted of five days. This implies teachers are supposed to provide effective instruction for material that has been crammed into five days. Although this study addresses a consistent issue for secondary engineering teachers, it does not provide any validity and reliability for its methodology.

The study conducted by Khurshid (2008) investigated the relationship between the professional qualifications of teachers and academic performance of tenth grade matriculation students at secondary schools in Buurewala, Pakistan. The objective of the study was to determine the impact of teachers' qualification, teacher professional qualification, and highly qualified teacher status on students' performance. The study consisted of two public schools (one male and one female) and three private schools (one male and two female). The statistics for the top 40 students for 2004 and the top students for 2005 after an annual exam were selected from the Board of Intermediate and Secondary Education, Multan. In addition, 87 male and female teachers of matriculation students were administered a questionnaire requesting information about their academic qualifications, professional qualifications, and experience. Khurshid (2008) assumed teacher training is more important than qualifications of a teacher. The 2004 statistics show the performance of students taught by trained teachers was better than the students taught by untrained teachers, and the opposite occurred in 2005. The study did not provide any explanation for obtaining opposite results in 2005 than in 2004. Although relevant to the issue at hand, it is a weak study because the type of training teachers received is not discussed, a discussion or conclusion of the results is omitted, along with implications for future research are not provided.

Professional Development

The beginning of professional development (PD) is linked to the Teacher Institutes of the early 19th century (Guskey, 1986). As PD continues to evolve there are several definitions presented throughout the research. Guskey (1986) defined PD as a "systematic attempt to bring about change – change in the classroom practices of teachers, change in their beliefs and attitudes, and change in the learning outcomes of students" (p.5). Others view PD as a persistent combination of professional, social, and personal development (Bell and Gilbert, 1994). Clement and Vandenberghe (2000) define PD as "a continuous process determined by the interplay between the individual and the organization, leading to a combination of craftsmanship and mastery" (p.87). Simply, effective PD is the skills and knowledge attained to enhance, adjust current knowledge, and support teachers after initial training to improve teachers' professional performance (Craft, 2000; Evans, 2002). 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 (Day and Sachs, 2004). Several research studies argue that the educational success of students depends on the competence of the teaching force (Darling-Hammond and Hudson, 1990; Darling-Hammond, 2000a/b; Darling-Hammond & Youngs, 2002; Goldhaber, 2002; Hanusek et al., 2005; Wayne & Youngs, 2003). PD is an important component of developing the competence teachers need for student success.

The types of PD have been characterized in numerous ways by researchers. Bolam (1993) identified four types of PD activities including: practitioner development, professional education, professional training, and professional support. Practitioner development is school-based and includes observations and team teaching. Professional education means taking advanced educational courses. Professional training includes activities that emphasize practical skills. Professional support includes activities that emphasize career development and advancement, and mentoring. Lieberman (1995) identified three types of PD activities including: inside/outside the school, informal/formal, and traditional/reform. Day and Sachs (2004) identified two broad types of PD activities: deficit model and aspirational model. The deficit model provides teachers with the knowledge and skills they did not already have and the aspirational model supports teachers in improving their effective instruction. However researchers decided to classify PD activities, the important message is that teachers need to be provided with a variety of activities to enhance their PCK.

Professional Development for Secondary Engineering Education

K-12 teachers lack sufficient backgrounds to effectively integrate engineering into their classrooms (Custer & Daugherty, 2009). In turn several initiatives have emerged to assist teachers in teaching engineering-related curriculum. However, research is still necessary to address best practices, engineering pedagogical content knowledge, or effective design principles for engineering professional development.

The NAE/NRC Committee on K-12 Engineering Education conducted a review of more than thirty K-12 engineering education curricular and professional development programs (Katehi, Pearson, Feder, 2009). Engineering design was predominant in most programs, but key engineering ideas such as constraints, optimization, and analysis was not. These shortcomings may be due to a lack of understanding by curriculum developers or an absence of a clear description of the most important engineering knowledge. The in-service training provided by these programs were associated with existing curricular and many did not provide ongoing support following formal training. The committee did not feel there were currently any pre-service initiatives that would contribute considerably to the future supply of qualified engineering educators. At the K-12 level, specific criteria have not been identified for engineering educators. There are many who complete teacher preparation programs with a strong background in STEM areas, but few if any of them teach engineering classes in K-12 schools.

Custer and Daugherty (2009) conducted a landscape study to examine engineering teacher professional development. The report summarizes three major symposiums and research studies: the *Professional Development for Engineering and Technology: A National Symposium* conducted February 2007, in Dallas, Texas (NSF funded); a multiple case study of engineering professional development projects (Daugherty, 2008); and the *Symposium on Professional Development for Engineering and Technology Education: An Action Agenda* conducted June 2009, in Atlanta, Georgia (NSF Funded). The NSF funded National Symposium in 2007 featured nine refereed papers centered on three major themes: core engineering concepts, pedagogical content knowledge, and effective professional development models. A meta-synthesis of the Symposium outcomes resulted in seven more concrete themes: research agenda, clarifying the philosophical focus, curriculum development, STEM collaboration, professional development models, pedagogical content knowledge, and advocacy.

The multiple case study (Daugherty, 2008) focused on programs designed to prepare secondary teachers to deliver engineering-oriented education. A discriminant sampling technique was used to select the following projects for analysis: *Engineering the Future: Science, Technology, and the Design Proces*™, *Project Lead the Way*™,, *Mathematics Across the Middle School MST Curriculum, The Infinity Project*℠, and *INSPIRES.* Each of the five cases selected for the study had to contain engineering-oriented content, have a reputation for attempting to include “best practices”, and have maturity. As a result, it was clear secondary level engineering-oriented professional development has either a technological literacy or pre-engineering approach. The science, mathematics, and technology teachers in the program had diverse backgrounds in preparation and education and required different professional development needs to incorporate engineering into the curriculum. However, the engineering content was not well-defined for secondary level education, leading individuals to pursue research to identify engineering concepts for secondary level education.

The second NSF funded National Symposium was held in 2009 after analysis of the outcomes of the previous major activities (first symposium and multiple case study research project) to address key issues relevant to secondary level engineering teacher professional development. The issues included: lack of defined engineering content (concepts, processes, skills); pedagogical culture differences (education/scaffold learning and engineering/self-guided learning); different philosophies of secondary engineering (technological literacy and pipeline); and diverse needs of MST Teachers (interrelationship among STEM disciplines). Consistently across these three major activities was the lack of reflection on pedagogy. The professional development activities primarily focused on tools, techniques, processes, and technical details instead of teaching and the learning process.

Hynes (2009) conducted a two week professional development in the study of 12 middle school teachers for a robotics curriculum. The first week exposed teachers to the robotics curriculum and in the second week teachers taught the curriculum to a group of middle school students enrolled in a summer program. Although positive gains were seen, students remained weak in the engineering design process because of teachers inability to explain and model the process effectively. Hynes (2009) suggests for future improvements PD should be geared towards teacher SK and PCK, assess teachers' prior knowledge before attending PD, differentiate teacher learning opportunities, provide teachers with hands-on opportunities, allow teachers to develop software skills, model mathematics and science connection-making, model instructional strategies, and allow teachers to create their own appropriate and real-world applications.

Daugherty (2008) conducted a case study of engineering PD opportunities available for middle and high school teachers. The engineering PD programs in the study 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. The case study used a discriminant sampling technique and multiple instruments (Project Leadership Interview Questionnaire, Instructor Interview Questionnaire, Teacher Survey Questionnaire, and the Focus Group Interview Script). Data was collected using observations and documents. A co-expert and expert panel (two engineering experts and two technology education experts) evaluated the construct validity of each document. There are too many engineering PD opportunities for K-12 teachers to discuss; therefore, the following engineering PD programs selected were based on criteria developed by Daugherty (2008): Engineering the Future: Science, Technology, and the Design Process, Project Lead the Way/Academy of Engineering, The Infinity Project, and INSPIRES. These programs attempt to prepare teachers for the complex role of teaching secondary engineering education. Although only a few were discussed, at the time these were the programs that met the criteria and content targeted towards STL. Teacher's perceptions from Daugherty's study will be discussed with the appropriate engineering PD.

Engineering the Future: Science, Technology, and the Design Process

According to the information posted on their website, Engineering the Future (EtF) is a project initiated by the National Center for Technological Literacy (NCTL) for first or second year high school students who desire to develop technological literacy through engineering. However, in the past teachers in various educational arenas (high school, middle school, community college, home schooling, after school, and other informal education settings) have taken advantage of EtF PD opportunities. EtF is a year-long course providing a framework for students to meet technology standards and develop critical thinking skills to make real-world connections enabling students to see how science, mathematics, and engineering are a part of every day experiences. This program has expanded from eight high schools in 2004 to well over 120 classes in over 80 schools in 2007, and the professional development has reached over 160 teachers in 16 states.

The EtF course consists of a textbook, engineer's notebook, and instructor manual. The textbook is a compilation of the perspectives of 32 practicing engineers, technicians, and students. The scripted instructor manual consists of the course goals related to the students' learning, guiding questions, assessments, activities, lists of materials and vendors, and background information. Most of the activities use common household items and minimal equipment, but still allow students to practice the engineering design process inexpensively.

The PD opportunities are available to teachers in all regions through online workshops and in-person workshops. The purpose of the EtF PD opportunities is to encourage teachers to become independent learners by meeting district requirements and the needs of the students. The in-person PD opportunities include mini-lectures, hands-on activities, and reflections. The online PD opportunities eliminate excessive costs, but still enable teachers to receive support through discussion boards, videos, and independent activities. The in-person workshops are four days, but a half-day workshop must be attended beforehand as a prerequisite. The online course is a minimum of three weeks, but covers the same material as in-person workshops.

Only 2 of the 3 teachers in the study conducted by Daugherty (2008) provided feedback. The two teachers expressed the PD was solely centered on implementing and executing the projects in the classroom. One teacher stressed the purpose for attending the PD was to "grow this course" for curriculum implementation (Daugherty, 2008, p. 89). One teacher used the state standardized test in technology and it supported the content of the course. Instructors for this course felt it a challenge to constantly pursue funding to continue to provide these opportunities and resources for the teachers.

Project Lead the Way and Academy of Engineering

According to the website, Project Lead the Way (PLTW) and Academy of Engineering (AOE) are not-for-profit corporations developed to help students be successful in post-secondary technology programs and careers in STEM fields. These programs use an interdisciplinary approach, weaving themes across core subjects such as math, English, science, and social studies. Common to both programs, the superintendent must be in support of the PLTW/AOE program, agree to a quality of standards, and commit teachers to the summer training. PLTW schools only admit students into the programs that meet certain grade requirements, while AOE programs do not have that requirement. AOE faces a greater challenge of developing independent learners when students are admitted that do not have the minimum math or science skills.

PLTW has been in schools since 1997 and has become the nation's premier program in providing middle schools and high schools a pre-engineering curriculum as an avenue for students to post-secondary engineering programs and careers (McVeary, 2003). Each PLTW school must have a partnership with other school districts, colleges/universities, and industry in order to offer the pre-engineering program. PLTW is designed to increase diversity and encourage more women to be interested in engineering. PLTW is a nationally recognized engineering program developed in response to a growing national need to educate students in science, technology, engineering and math (STEM) and to meet the increasing demand for qualified employees in the technology field. PLTW offers a four-year sequence of high school courses, in addition to the core courses, focusing on basic skills in math, science and technology, problem solving, and communication and teamwork skills. Currently, PLTW is the only engineering program offering the highest rigor in the STEM fields (Cech, 2008). PLTW “serves as a national model for expansion of science and engineering education” (Cech, 2008, p.40). However, “because of the hands-on nature of PLTW classes, implementing the curriculum can cost up to $95,000 per school” (Cech, 2008, p.40). This is extremely costly and not likely to be implemented in every school.

AOE was developed in 2007 through a partnership with PLTW, National Academy Foundation (NAF), and National Action Council for Minorities in Engineering (NACME) for implementation in public high schools only. AOE schools must have a partnership between schools, parents, corporations, mentors, local advisory boards, two- and four-year institutions, and community resources. Academy of Engineering falls under the umbrella of PLTW; therefore, students experience the PLTW curriculum. AOE focuses only on engineering and attempts to meet the increasing demand for qualified employees in the field of engineering by assessing students according to the National College Readiness and National Learning Standards. Unlike PLTW it seeks to increase the percent of women and minorities interested in engineering. Also, AOE permits 80-100 freshman students into the program each year. An AOE academy is designed for anywhere from 240 - 400 students, no more than 100 students per grade level. In 2008, 13 schools became AOE schools and in Fall 2009 an additional 19 schools become AOE schools. It is predicted there will be 110 AOE academies by the year 2012.

As of 2008, PLTW/AOE has almost 3,000 school sites in the 50 states and the District of Columbia, 36 training sites, and has trained over 7,000 teachers and 5,000 counselors. Approximately 250,000 students are enrolled in PLTW courses and more than 500,000 students have had the PLTW experience.

Several different PD models had been developed before finding one that provided consistency. The PD opportunities are only offered to PLTW/AOE schools and include a two-week summer training, and a virtual academy with access to lesson plans. A PLTW/AOE teacher must at least be certified, and have some knowledge of technology, equipment, tools, and labs. Before a teacher can attend the two-week summer training they must pass a pre-assessment skills test. The two-week summer training is an intense10 days, where teachers must complete projects and homework successfully. By chance the teacher does not pass the summer training, PLTW along with the principal develop a plan to help the teacher complete training successfully. The training not only provides the teachers with familiarity of what they are expected to teach, in addition teachers receive 80 contact hours upon completion.

The 12 teachers in the study conducted by Daugherty (2008) expressed only good pedagogy techniques were modeled and a year's curriculum was compressed into two weeks. In lieu of that the teachers felt prepared to implement the course. Two teachers felt the hands-on activities were effective, and two other teachers felt the PD helped "them increase the credibility of what they teach" (Daugherty, 2008, p. 100). One teacher felt it necessary the PD be conducted by instructors that actually do it, and teach it. The teachers felt the challenges would only be in relation to the students: pre-requisite knowledge, lack of motivation, money, time, low level mathematics ability and reading comprehension, and learning new/unfamiliar software and technology skills to implement curriculum successfully.

The Infinity Project

According to the website, *The Infinity Project* was developed in 1999 by Southern Methodist University (SMU) and Texas Instruments, through a partnership between The Institute for Engineering Education, U.S. Department of Education, the National Science Foundation and others. It was initially designed for curriculum development and to raise interest in STEM fields to aid in closing the gap between the number of engineering graduates currently produced in the U.S., and the pool of high-quality engineering graduates in the near future.

The goals of the project are to expose students to the design process, help students develop necessary skills and knowledge to become experts of technology equipment, and help students explore the relationship between humans and technology through a yearlong course. Daugherty (2008) classifies this as a low cost curriculum: $850.00 PD/teacher (maximum of two), $62.63/textbook, $25.00/student manual, $399.00/technology kit/computer (maximum of two students per computer), and $300.00 for shipping and handling. Typically, first time cost should not exceed the cost to purchase three to four classroom computers. The program is currently implemented in more than 37 states across the U.S. and is expanding internationally to Australia, Ireland, Israel, Lebanon, Mexico, and Portugal. Thousands of students have participated in the program, most who have been women and minorities.

Similar to PLTW/AOE, teachers may only participate in PD if their school has implemented *The Infinity* Project. The PD extends over a period of five days providing teachers with the support material to be successful in the classroom to teach *The Infinity Project* curriculum. It exposes teachers to the software, hands-on activities, and lab exercises students will be exposed to. Prior to attending PD teachers are asked to complete a three hour LabVIEW pre-assessment tutorial (Daugherty, 2008). The PD is presented by Master Teachers who are selected through observation and performance while attending PD. The only additional requirement is to attend additional two-week training.

The 26 teachers in the study conducted by Daugherty (2008) indicated they were prepared to implement the curriculum and felt students would be motivated to participate in the curriculum. They felt effectiveness was achieved in the PD through the hands-on activities, labs, and teacher collaboration. Teachers anticipated challenges in computer availability, installing software, managing technology, and personal feeling of preparedness. Teachers also expressed PD did not have enough structure or enough time for some teachers to get acclimated with material. PD Instructors identified the mathematics deficiencies was a challenge when presenting the PD.

Increasing Student Participation, Interest and Recruitment in Engineering and Science

According to Ross and Bayles (2007), INcreasing Student Participation, Interest and Recruitment in Engineering and Science (INSPIRES) is a collaborative project between the University of Maryland Baltimore County and University of Maryland School of Medicine funded through a grant from NSF. *INSPIRES* is open to all teachers who have an interest of implementing in their classroom. “It is designed to target what we believe to be the core engineering skills and concepts that should be addressed at the high school level in order to better prepare students to pursue engineering and technology related careers” (Ross & Bayles, 2007, p. 1). In contrast to PLTW/AOE and The Infinity Project*,* it is not a stand-alone course; it is five modules developed as engineering design challenges. Of the programs mentioned, this program is by far the cheapest. As long as teachers agree to make student assessments accessible all equipment and materials are free. However, there is currently not a measure in place to guarantee teachers are implementing the curriculum.

The PD workshop extends over a period of two days providing teachers with a general overview of the curriculum and presentation of the material in a format similar to what the students would experience. The workshop consists of a PowerPoint lecture, online tutorials and assessments, hands-on activities and follow-up discussions. The teachers were allowed to complete one module from the pre-assessment to the post-assessment, and worked through the online aspect (web-based tutorials and interactive simulation).

One of the 12 teachers in the study conducted by Daugherty (2008) enjoyed implementing scripted curriculums because of the minimum effort in development by the teacher. Teachers found the PD effective because of online module accessibility, hands-on opportunities to work through as a student, and credibility of PD instructors. Teachers pointed out several concerns in implementing the program: preparation to implement curriculum, content needs to be broken down more to the basics, time it takes to prepare skill-wise, and how to effectively implement modules within the current curriculum. PD facilitators felt teachers lacked fundamental skills to implement pre-engineering curriculum effectively and teachers are not stressing the importance to students of mathematics in the curriculum. PD facilitators agree “these challenges cannot be remedied with short/intermittent professional development workshops, but rather demonstrates a need for long-term fundamental shift in the training of technology education teachers” (Ross & Bayles, 2007, p. 9-10). In addition, PD facilitators agree “that successful professional development for technical education needs to be *local and specific to the discipline*” (Ross & Bayles, 2007, p. 7).

Summary

As discussed, some PD opportunities are only available to educators through school agreements. However, quality PD opportunities should be accessible to all educators (NSF, 2007). EtF focused on technological literacy and was concerned with problem-solving and critical thinking. The PD activities offered by EtF followed the same focus but 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” (Wicklein & Thompson, 2008, p. 57). 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, 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. Professional development must then be flexible enough to meet diverse teacher needs, particularly as they relate to varying levels of science, technology, engineering, and mathematics abilities and comprehensive enough to impact all of the teachers to transfer their learning into their classroom practice; a tall order for professional development programs (Custer & Daugherty, 2009).

Factors Affecting Retention and Success of Freshman Engineering Students

Students have a misconception that engineering is only associated with economic growth and defense, and is pursued by individuals who are good in math and science. Many students do not associate engineering with improvement of health, quality of life, or environment. Engineering is not being pursued or peaking the interest of students who prefer to work with others on teams and want to contribute to solving social problems. “In order to align the public perception of engineering with the reality of opportunities in engineering, a conscious and sustained effort is needed to convey the opportunities and excitement of engineering”, (NSF, 2007, p.3).

Enrollment has increased in postsecondary institutions, but decreased in STEM disciplines (Tyson et al., 2007). 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” (Besterfield-Sacre et al., 1997) further supporting the need to address retention of freshman engineering students (NSF, 2007; Felder et al., 1993). 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. Therefore, it is necessary to discuss factors in K-12 education affecting student achievement which affects retention and success of freshman engineering students.

Research on student success and retention has mostly been done for the general student population. There is limited research on the factors affecting retention of students in engineering. Factors from research include: high school academic achievement (Berger & Milem, 1999; Veenstra et al. 2009; Wulf & Fisher, 2002; Tyson et al., 2007); quantitative and analytical knowledge (Clough, 2004; Seymour & Hewitt, 1997; GAO, 2007); study habits and independent learning (Veenstra et al. 2009; Zinatelli & Dubé, 1999; Mina & Gerdes, 2006); commitment to education and career goals (Besterfield-Sacre et al., 1997; Astin & Astin, 1992; Veenstra et al. 2009; Tyson et al., 2007); confidence in quantitative skills (Besterfield-Sacre et al., 1997; Astin & Astin, 1992; Veenstra et al. 2009; Bell, 2008); social engagement (Astin, 1984; Tinto, 1993; Lotkowski et al., 2004; Veenstra et al. 2009); consideration of gender (Tinto, 2006-2007;

Veenstra et al. 2009), race (Tinto, 2006-2007; Veenstra et al. 2009), and social-economic status (SES; Tinto, 2006-2007; Veenstra et al. 2009; Tyson et al., 2007).

Veenstra et al. (2009) developed two regression models to predict freshman engineering student success and retention using the 2004 and 2005 freshman classes. The pipeline model (Johnson & Sheppard, 2002), pathway model (Adelman, 1998), and energy model (Watson & Froyd, 2007) have helped shaped the proposed linear regression model for engineering retention. The previous engineering models were difficult to apply statistically, inducing a need to research more comprehensive models based on the general college student population. The more comprehensive retention models for education, Theory of Involvement, Theory of Student Attrition, and Interactionalist Theory of Student Departure**,** are based on economics, psychology, sociology and organizational models provide a theoretical framework for the current model (Braxton & Hirschy, 2005). The model developed by Tinto created a paradigm shift in educational models on retention. It is the most accepted and empirically tested by researchers (Braxton, 2000). Therefore, it was used as a basis and expanded from three predictors to the nine aforementioned predictors to create a more complete model. The nine predictors influence a student's academic and social integration, which in turn affects the student's success in freshman engineering studies. Of the nine predictors, commitment to the enrolled college and social engagement were not significant factors for engineering success. The success model suggests quantitative skills and overall academic preparedness were the most dominant pre-college characteristics for engineering student success. The grade point average (GPA) along with results from a survey was used to develop a logistic regression model to predict a student's retention decision. GPA was not found to be a significant predictor of freshman retention over a short time period, but a relationship is expected over a longer time period (Veenstra, Dey, & Herrin, 2008; Lee et al., 2008)

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. Compared to white students, many minority students have a weak foundation in mathematics and science and this persists throughout college (Clewell, Anderson, & Thorpe, 1992). This hinders students from pursuing and being successful in STEM careers (May & Chubin, 2003; Sells, 1980). The performance gap between Whites and minorities continues as evidenced by the National Assessment of Educational Programs (NAEP) test (NCES, 1999), Scholastic Aptitude Test (SAT), and ACT. Many minority students in K-12 education are plagued with issues that most white students do not encounter. This continuous poor performance on standardized measures of student learning raises questions about teacher quality and the effectiveness of teacher certification. Certification alone is not enough to ensure teacher quality.

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 provide up-to-date tools (National Governor Association Report, 2007), books, laboratories, and advanced courses. Ineffective teachers is 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" (Craig, 2006). 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 (Leitman, Binns, & Unni, 1995).

Craig (2006) investigated the educational experiences of African American engineering students at HBCU's. The investigator used open and semi-structured interviews to collect data from 66 students (36 persisters and 30 switchers). Six attrition factors, in addition to academic unpreparedness, were found: working long hours, difficulty of the curriculum, poor teaching, incorrect choice of major, poor academic performance, and psychosocial issues. Students who switched majors had a higher rating for inadequate high school preparation when compared to students who persisted in engineering. This perception was supported by them rating their high school preparation as fair or poor, having lower high school grade point averages, and most students having taken at most Geometry or Algebra II. Working long hours and having difficulty within the curriculum decreased a students academic performance and increased their desire to switch majors. The decrease in academic performance also increased psychosocial issues, which also increased a students desire to switch majors. A major limitation to the study was a students honesty and straightforwardness in answering the questions.

Bjorklund and Colbeck (2001) conducted a research study using a purposeful sample of deans, chairs, faculty, industry leaders, and association officers, to offer suggestions on how to promote undergraduate engineering student success through faculty involvement. Although this study was conducted at the collegiate level, the implications for reform can be beneficial for engineering education at the secondary level. The semi-structured interviews of 25 men and 2 women revealed their perceptions on change in engineering education. These 27 individuals were influential leaders in engineering education reform and agreed the most significant areas for reform were the following: design, effective teaching, computer technology, broad-based curriculum, and accreditation. Other changes in engineering education declared not significant were the following: funding, engineering as a professional stone, industry interest in engineering education, and incorporating science in engineering. Bjoklund and Colbeck (2001) provide suggestions to encourage faculty involvement in the changes for engineering education, which will overall promote student success. The following suggestions for faculty "buy-in" were offered as new techniques, but should already be in practice because they come with the territory of being an instructor: attending education and engineering conferences, seek opportunities for practical engineering applications, teach students to become independent learners, and receive training on engineering computer programs and computers as educational tools. Other suggestions for faculty "buy-in" included universities creating a balance between required amount of research and teaching, provide internship programs, provide assessment workshops, reward instructors with promotion and tenure for incorporating recommended changes in the curriculum. It is the responsibility of the instructor to incorporate new techniques and content into the curriculum. Promotion and tenure follows a track record of successful research, publications, and effective teaching. The quality of education a student receives should not be affected by whether an instructor receives a promotion or tenure. Instructors choose to teach, share his/her SK, and develop independent learners; therefore, the instruction students receive should not be dependent on whether teachers receive incentives to enhance his/her engineering PCK.

Industry View of Engineering Education

The Occupational Outlook Quarterly projects engineering employment to increase 11% from 2006–2016. This projection, along with students realizing as adolescents what career is a good fit for them, puts a strain on educators as well as industry (Watson and Froyd, 2007; Holland, 1997). The engineering education students receive is of utmost importance not only to shape quality future engineers, but to meet the growing competitive demand in technology and industrial workers (Terrell, 2007; Brophy et al., 2008). Therefore, the education students receive needs to be a solid foundation that they can build on continuously, from elementary to postsecondary to college. The National Academy of Engineering (2004) and the National Science Foundation (2007) proposed that an engineer should possess the following upon completing an undergraduate engineering program: strong analytical skills; practical ingenuity; creativity; good communication skills; master principles of business and management; leadership; high ethical standards; dynamism, agility, resilience, flexibility; and lifetime learners.

Several research studies support the claim that engineering college graduates have insufficient skills for the work environment, contributing to the mediocrity of today's work environment (Katz, 1993; Watson and Froyd, 2007; Danzberger, 1992). Katz (1993) argued that students are lacking in effective communication, ability to work as a team, and awareness of workplace expectations. Undergraduate and graduate students, three professors, and three professional engineers in environmental engineering were interviewed to obtain their perception about expectations for entry level engineers. While the professionals agree in what engineering students' are lacking, the students interviewed failed to see the need of shifting from the academic student to a professional. The students did realize teamwork was essential working in the engineering profession, but admitted they did not receive much exposure at their academic institution. The students could not see the importance of effective communication, which is necessary in making presentations and communicating with clients. Students were unaware of professional options within the engineering discipline and only understood what was needed on the surface. Students failed to realize budget, ethics, and liabilities are also important in the engineering profession.

The opportunities for on-the-job training for entry level engineers and college students (learning from a seasoned and experienced engineer, the mentor/buddy system, two-year training programs, co-ops and internships) over two decades ago still exist for many companies today. It is of importance to note the training mentioned here is not available to college students until at least their junior year. By this time it is too late. Fortunately, industry realizes the university does not, and cannot teach all the skills necessary in a four-year time period (NSF, 2007). The author makes several suggestions to industry partners to make a strong presence in the education of college engineering students. Katz (1993) suggests industry partners become consultants in the classroom, provide college engineering students with projects, or create learning environments (professionals, college students, and professors) to be more in tune with the workplace. Since this study, industry has attempted to be more involved but they are not held to any standards to maintain this partnership at the university level. It is apparent that current techniques have not been drastic enough to increase the quality of future engineers.

Therefore, educators, researchers, and industry partners need to look beyond the collegiate level to initiate these strategies.

Bombaugh (2000) investigated deep learning through inquiry-based learning, better known as hands-on activities. Advocates saw the need for hands-on activities almost 200 years ago, but it was not until the 1960s after satellite Sputnik, when educators started bringing them into the classroom. The study looks closely at the Global Learning and Observation for the Betterment of the Environment (GLOBE) program and makes two arguments. First, engineers impact society through professional organizations (ASEE, ASME, NSF, etc.), as resource personnel for teaching practices, and in the workplace and should therefore have a stronger presence in engineering education interventions. Second, student attitude and academic preparation for engineering are important and have been stressed for over two decades (Simpson & Oliver, 1990). The GLOBE program provides teacher training, communicates with students, and provides inquiry-based learning opportunities for students with realistic environmental data for 6,000 schools from all 50 states, U.S. territories, and 80 countries. Bombaugh (2000) saw the importance for students to be involved in projects and activities rigorous enough where they can identify themselves in engineering careers. Although student interaction with engineering professionals is critical, it is limited and infrequent. Currently, inquiry-based opportunities where interaction may occur is at science fairs, engineering competitions, and summer or bridge programs. The limitation exists because these activities are based on grade level, enrollment in a particular course, GPA, or SES. Research shows data supporting the use of inquiry-based learning educators still use worksheets and lectures. Although educators are essential for the inquiry-based learning process they are not solely responsible; therefore, industry must have a stronger presence in engineering education (NSF, 2007; Denton, 1998). Of the schools in the GLOBE network, public schools face additional issues. They are plagued by limited monetary resources. As a remedy for public schools, companies began to adopt them to boost the academic program, but this is still lacking for many public middle and high schools. Bombaugh (2000) implies the future direction for engineering education should refine pedagogy at every level of education just as technology is changing, and engineering professionals need to have a stake in this ongoing process.

Watson and Froyd (2007) used theory to develop a model to predict diversity in engineering education and the workforce. Unlike Katz (1993) these researchers believed engineering skills needed for the work environment are strengthened through community building, cognitive ability development, and occupational choice development, especially for the minority population. Interventions for community building involve mentoring programs, minority engineering programs, peer support, and role models where students can identify themselves as belonging in engineering (Watson and Frroyd, 2007; Bombaugh, 2000). Interventions for cognitive ability development mentioned were the same offered by Katz (1993). However, Watson and Froyd (2007) argue that these are just “band-aids” because they do not address deep learning. These pre-college interventions raise interest in engineering, increase likelihood to choose engineering, reinforce surface learning, and if they achieve deep learning in science and math it is without the engineering connection. In addition, these pre-college interventions are only available to a small amount of students. Interventions for occupational choice development have to consider personality type of the student and should begin at a very young age (Wattson and Frroyd, 2007; Gottfredson, 2004). Watson and Froyd (2007) developed a new theoretical model because previous theoretical models were not designed to alter the leaky pipeline. Previous models investigated the three characteristics separately and not the interaction. Therefore, Watson and Froyd (2007) developed an energy model to investigate the complex relationship between community building, cognitive ability development, and occupational choice development. It takes energy to choose, persist, and succeed in engineering and a model without this basis does not reflect the true interaction between the three factors. However, predictions of the interaction of the three factors resulted in difficulties because of their complex relationship. Creating a model does not resolve the dilemmas facing engineering education, especially when considering diversity; it just emphasizes the lack of knowledge of researchers and the delicateness of the issue at hand. In addition the omission of the location of the study, sample, validity and reliability of the model developed provides weaknesses for the study.

Besterfield-Sacre et al. (1997) developed a model to identify students most likely to switch to another major before a student enrolled in college. The study was conducted on 417 students from two consecutive freshman engineering classes. This type of regression model helps engineering departments design better programs and more realistic goals for retention, and freshman advisors assess needs of students for engineering. Retention was linked to student attitude towards engineering professors, pre-requisite knowledge, ability to succeed, study skills, and ability to work as a team. Rigorous pilot testing, Cronback alpha, and verbal protocol analyses were used to validate the 50 question Likert scale survey. Students were classified into three groups:

students who left engineering in good academic standing, students who left engineering in poor academic standing, and students who remained in engineering. Students who left the engineering program in good academic standing did not have as strong an attitude towards engineering as those students who remained in engineering. Students who left the engineering program in poor academic standing had lower confidence, limited math and science interests, forced to major engineering by family influence, and lower confidence in communication skills than students who remained in the engineering program.

Conceptual Framework

Learning in general is contextual and a social activity (see Figure 1). In a contextual sense, individuals learn in relationship to what else they know, what they believe, their prejudices and their fears. As a social activity, learning is closely associated with an individual's connection with other human beings, their teachers, their peers, their family as well as casual acquaintances. This represents a constructivist approach to learning, a philosophy of learning based upon foundational works of Dewey, Piaget, and Vygotsky. This type of approach can increase students' understanding of complex systems as well as increase interest, engagement, and motivation in learning environments (Kelley, 2008). Although most research on systems thinking in science, engineering, and technology programs is at the collegiate level (ABET, 2005; Ben-Ari, 1998; Bransford & Stein, 1993; Mariappan, Monemi, & Fan, 2005; Wankat, 2002) middle school learners have the ability to handle some complex systems thinking (Jacobson & Wilensky, 2006).

Wankat (2002) agreed that a constructivist approach was a means to improving the teaching of engineering and technology education. This researcher suggested the ideal classroom environment should include:

> Learner centered – pay attention to the student's preconceptions, skills, and attitudes;
>
> Knowledge centered – pay attention to the subject, student understanding and mastery;
>
> Assessment centered – use frequent formative assessment by both the teacher and the student to monitor progress; and
>
> Community centered – the context of learning is important. Combined argumentation plus cooperation enhances cognitive development (p. 5).

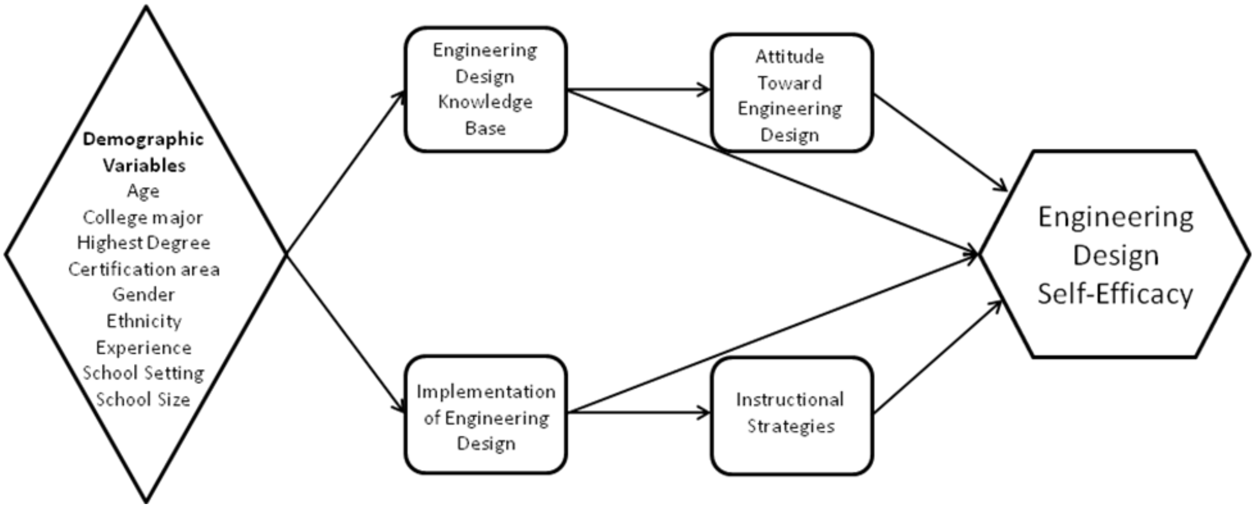

Figure 1: Conceptual Framework

Wankat suggested that the results of such a program would produce students who have the ability to transfer knowledge from one experience to another. Dyer, Reed, and Berry (2006) investigated the relationship between high school technology education and test scores for algebra and geometry. They cited Crawford and the Center for Occupation Research and Development who suggested five key strategies to actively engaging students in a constructivist approach to teaching. These five strategies are:

> Relating – learning in the context of one's life experiences or preexisting knowledge;
>
> Experiencing – learning by doing, or through exploration, discovery, and invention;
>
> Applying – learning by putting the concepts to use;
>
> Cooperating – learning in the content of sharing, responding, and communicating with others; and
>
> Transferring – using knowledge in a new context or novel situation – one that has not been covered in class (Crawford in Dyer, et al., 2006, p. 8)

Both Wankat and Crawford suggest context as a key piece of learning in the constructivist approach. Borko and Putnam (2000) suggest that in order for students to obtain knowledge associated with a particular setting, the learning should take place in or be located in specific physical and social context. Borko and Putnam also argue that in order for learning to be transferred from one experience to another, students must be given multiple similar experiences to make necessary mental connections. In order for students to transfer knowledge from core subjects into their engineering experiences Hanson, Burton, and Guam (2006) argue that contextual learning has to be a vital characteristic of technology and engineering education programs. They propose that context learning is of vital importance in technology education because it serves as the avenue with the No Child Left Behind Act that provides learning opportunities for students to become prepared to work in a global economy. Context of learning is also important in designing a solution and is critical to learning design (Glegg, 1972). Teaching engineering design must be done within a context that is authentic, where the activities include the following: (a) higher order thinking where students manipulate information and ideas; (b) depth of knowledge so students apply what they know, and are connected to the world in such a way that they take on personal meaning; (c) substantive communication among students; (d) supportive achievement of all through communication of high expectations of everyone contributing to the success of the group (Newman and Wehlage cited in Hutchinson, 2002).

With the application of engineering design and systems thinking, students learn how to use critical thinking skills to solve complex problems that are necessary to live and function in the 21st century. No matter what career path students take, they will encounter complex problems that can not be solved with a one-word answer or single textbook answer. The engineering design process and systems thinking not only provides a logical approach to solving these problems, but a set of universal skills vital to function in any career field.

The success of implementing or maintaining an engineering design focus in technology education is not only dependent on the programs ability to articulate that engineering design can generate a type of thinking that can be applied to many occupations, but the teachers self-efficacy as well. This further supports the purpose of this research. The teacher’s ability to provide effective instruction with an engineering design focus is based on Bandura’s (1986) triadic reciprocality of behavior, cognitive factors, and environmental situations. These three factors influence each other in a triangular pattern, providing information that will either positively or negatively reinforce each factor. This includes characteristics of the classroom environment, teacher's own experiences and reflections, and delivery of instruction.

This study focuses on the teacher's perception of their engineering design knowledge base and ability to transfer that knowledge to students through instructional strategies. It was hypothesized that environment intermingled with a teacher's self-perception will play a significant role in the instructional delivery of engineering design to students. It has been shown that teachers who have strong subject knowledge also have high self-efficacy and are effective in the classroom. This research attempts to uncover whether the level of competency in the engineering design process affect teachers' instructional practices in engineering courses.

Summary

Various studies have addressed the low interest and enrollment in STEM fields of science and math. However, limited research has been done in technology and engineering. There is even less research addressing the relationship between teacher self-efficacy and knowledge base. Based on the limited research on the relationship between teacher learning and engineering design content in K-12 engineering education this study aims to contribute to this area of research. The focus of this research is not to make engineering the focus of technology education programs, but argue that adding selected engineering outcomes is useful. By infusing pre-selected engineering outcomes into the technology education curriculum for non-pre-engineering curricula can enhance technology education (Childress & Rhodes, 2006).

CHAPTER III: METHODOLOGY

This chapter presents the methodology that will be used to conduct the research study. It includes a description of the research design, participants and setting, instrument, and the data collection and data analysis procedures.

Research Design

The conceptual model for this study was adapted from Kelley (2008) and by Carberry, Ohland, & Lee (2009). Kelley (2008) focused on the extent to which engineering concepts are incorporated into current high school technology education programs that have an engineering design focus. Current curriculum content that addresses engineering design concepts focus on the following seven areas: (a) engineering design, (b) engineering analysis, (c) application of engineering design, (d) engineering communication, (e) design thinking, (f) engineering and human values, and (g) engineering science. Kelley not only investigated the steps of the engineering design process, but other requisite knowledge to effectively teach engineering design. Carberry, Ohland, & Lee (2009) focused on an instrument to measure students' engineering design self-efficacy. A pilot study was conducted and the instrument was administered to individuals of various engineering backgrounds. Although the instrument is designed for students', the self-identifying questions (confidence, motivation, success, degree of anxiety) are relevant to individuals at any level. The pilot study investigated the relationship between the steps of the engineering design process and confidence, motivation, success, and degree of anxiety.

A principal components analysis was used in this study to explore the relationship between engineering design self-efficacy and the knowledge base of teachers who teach secondary engineering-related courses in a local school district. Little was known about the ability of teachers to teach engineering or the degree of engineering design implementation in secondary school programs. There are several technology education programs and other courses that infuse engineering content in the curriculum or have engineering design as a focus. Some courses did not have an engineering focus, but may indeed have been teaching engineering design content.

Participants and Setting

A non-random purposive sample of 200 secondary (middle and high school) STEM teachers was recruited from secondary schools within a local school district comprising 16 schools (5 middle schools, 9 high schools, 2 combined middle and high schools). The schools selected to participate in this study either offered an engineering program or engineering courses. Data from this study will be used to develop local professional development opportunities for Secondary STEM teachers. Participants were excluded from this study if he/she did not teach a STEM course. Data was collected on size of school and location of school.

Quantitative Instruments

The research instrument adopted for data collection (Appendix) was a questionnaire composed of two sections. The first was based upon the Examination of Engineering Design in Curriculum Content and Assessment Practices in Secondary Technology Education (EEDCCAPSTE) Survey designed by Kelley (2008). The second section was based on the Engineering Design Self-Efficacy (EDSE) Survey. The number of items on each instrument is shown later in Figures 2 and 3.The last section requested the demographic information for each participant.

Engineering Design Self-Efficacy (EDSE) Survey

The EDSE Instrument developed by Carberry, Ohland, & Lee (2009) was designed specifically to measure students' self-efficacy regarding engineering design. The development of the instrument was validated using three types of validity evidence: content validity, criterion-related validity, and construct validity. The most straightforward way to evaluate engineering design is to measure self-efficacy toward each of the eight steps of the engineering design process. The EDSE instrument was based on the engineering design process chosen by the MA DOE – identify a need, research a design need, develop design solutions, select the best possible design, construct a prototype, test and evaluate a design, communicate a design, and redesign. These researchers administered the instrument to 82 individuals, ranging in age from nineteen to fifty-eight years old. Although this instrument was developed to be administered to students, the sample in the pilot study was not limited to students', allowing the instrument to be used for multiple samples.

Content validity was addressed by determining the best way to represent the engineering design content. The researchers used an exploratory factor analysis utilizing varimax rotation and an inspection of the scree plot to determine whether the 32-items regarding the eight steps of the design process related to self-efficacy. One factor accounted for 60.24 percent of the total variance. Factors were discarded if their eigenvalue was less than one. The instrument had an overall Cronbach's α reliability of 0.948. The Cronbach's α values for self-efficacy (0.967), motivation (0.955), outcome expectancy (0.967), and anxiety (0.940) showed a high reliability among the eight steps for a given task-specific self-concept. Similar Cronbach's α values seen in Table 7 for females, males, and the overall subset ensure that gender does not affect the overall reliability of the instrument. These high reliability coefficients among the eight engineering design steps for the gender and non-gendered analysis show overall agreement of individuals across the eight steps for each of the four task-specific self-concepts. The correlation matrix was used to confirm that each step of the engineering design process was significantly correlated to engineering design, $p \leq 1$, for each of the four constructs (see Table 8). This led the researchers to believe the engineering design process defined by the MA DOE adequately aligned to the engineering design process (Carberry, Ohland, & Lee, 2009).

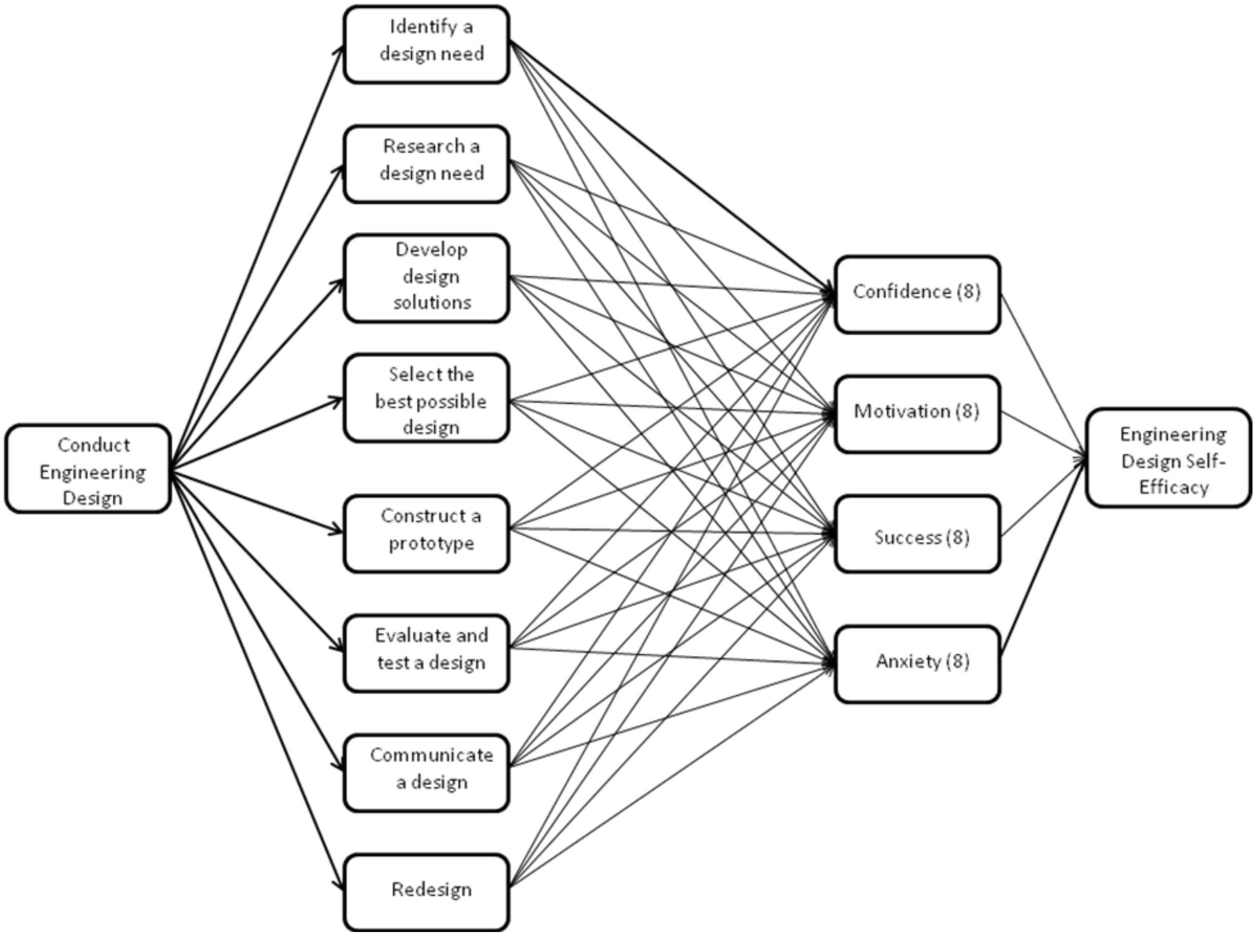

Figure 2: Relationship between engineering design process and self-efficacy

Table 7

Gender specific reliability analysis (Cronbach's α) of the four task-specific self-concepts

Construct	Female (n=26)	Males (n=38)	Overall (n=64)
Confidence	0.963	0.905	0.934
Motivation	0.885	0.878	0.879
Success	0.940	0.857	0.906
Anxiety	0.929	0.955	0.950

Table 8

Correlations between engineering design and the engineering design process steps

	Engineering Design Confidence	Engineering Design Motivation	Engineering Design Success	Engineering Design Degree of Anxiety
Identify a Design Need	0.871	0.755	0.813	0.720
Research a Design Need	0.765	0.667	0.795	0.721
Develop design solutions	0.887	0.897	0.878	0.791
Select the best possible design	0.811	0.785	0.747	0.721
Construct a prototype	0.864	0.757	0.874	0.778
Evaluate & test a design	0.845	0.723	0.872	0.675
Communicate a design	0.773	0.697	0.763	0.585
Redesign	0.887	0.839	0.920	0.739

Criterion-related validity was addressed by determining what criteria would sufficiently measure the level of understanding of engineering design for an individual. The researchers assumed engineering experience was the best criterion; pointing out that individuals with more engineering experience were more likely to have higher engineering design self-efficacy than individuals with less engineering experience. Participants were first grouped based on engineering experiences, according to their responses about their undergraduate degree and current profession. Participants were further grouped to fit into three categories: high self-efficacy, intermediate self-efficacy, and low self-efficacy.

Participants were then grouped based on their average engineering design scores, which is the value recorded for each construct. A one-way ANOVA was performed to compare the means of confidence, motivation, expectancy for success, and anxiety toward engineering design on the three self-efficacy groups. A Tukey post hoc test was used to compare the mean scores. The results showed that the mean scores for the three groups were significantly different, suggesting that confidence, motivation, expectancy for success, and anxiety toward engineering have a significant role in measuring an individual's level of engineering design self-efficacy (Carberry, Ohland, & Lee, 2009). Engineering design (ED) scores were obtained from the first item of the scale referring to *conduct engineering design*. Pearson correlations for self-efficacy ($r = 0.890$), motivation ($r = 0.882$), outcome expectancy ($r = 0.888$), and anxiety ($r = 0.791$) were all significantly correlated ($\rho \leq 0.01$) suggesting that respondents rated their ED score and EDP factor score consistently (Carberry, Ohland, & Lee, 2009).

Construct validity was addressed by identifying an appropriate theoretical framework. The self-efficacy theory suggests that individuals who have high self-efficacy about their capabilities put forth more effort to achieve a goal. A correlation matrix was performed to determine the impact of the variables on one another. Motivation and expectancy for success were positively correlated to self-efficacy while anxiety had a negative correlation to self-efficacy. Suggesting that anxiety is typically associated with individuals who have a low self-efficacy, motivation and expectancy for success are typically associated with individuals who have a high self-efficacy.

Examination of Engineering Design in Curriculum Content and Assessment Practices in Secondary Technology Education (EEDCCAPSTE) Survey

The EEDCCAPSTE developed by Kelley (2008), was designed specifically for measuring teachers' perceived ability to implement engineering design into their curriculum and how often they do so (see Figure 3). The EEDCCAPSTE is a compilation of other surveys (Asunda & Hill, 2007; Childress & Rhodes, 2008; Smith, 2006; Wicklein & Gattie, 2007); therefore, the validity and reliability of the survey was assessed several times. The identified learning outcomes and assessment strategies were compiled into a list and presented to a panel of experienced engineering education faculty for further verification. Open-ended questions accompanied each section of the instrument's seven subset categories, as well as at the end of the assessment strategies section. The panel was asked to identify any missing learning outcomes or assessment strategies he/she deemed important for implementation of engineering design content in high schools. The list of learning outcomes and assessment strategies was then administered to 11 technology education teachers who were members of the International Technology and Engineering Educator Association (ITEA) in a pilot study. Participants were asked to complete the questionnaire and identify any items that were confusing or caused difficulty to respond and explain his/her interpretation of the seven subset categories. Participants rated their level of agreement regarding the content and assessment strategies he/she employed compared with content and assessment strategies identified by experienced engineers and engineering faculty. After participants completed the survey and an item analysis, five items were removed resulting in 73 learning outcomes (nine questions) across 7 constructs (i.e., engineering design, engineering analysis, application of engineering design, engineering communication, design thinking, engineering and human values, and engineering science). Respondents indicated their frequency of use in a 6-point Likert scale. A rating of zero indicated that the respondent never implements this component of engineering design; a rating of five indicates that the participant implements this component of engineering design daily.

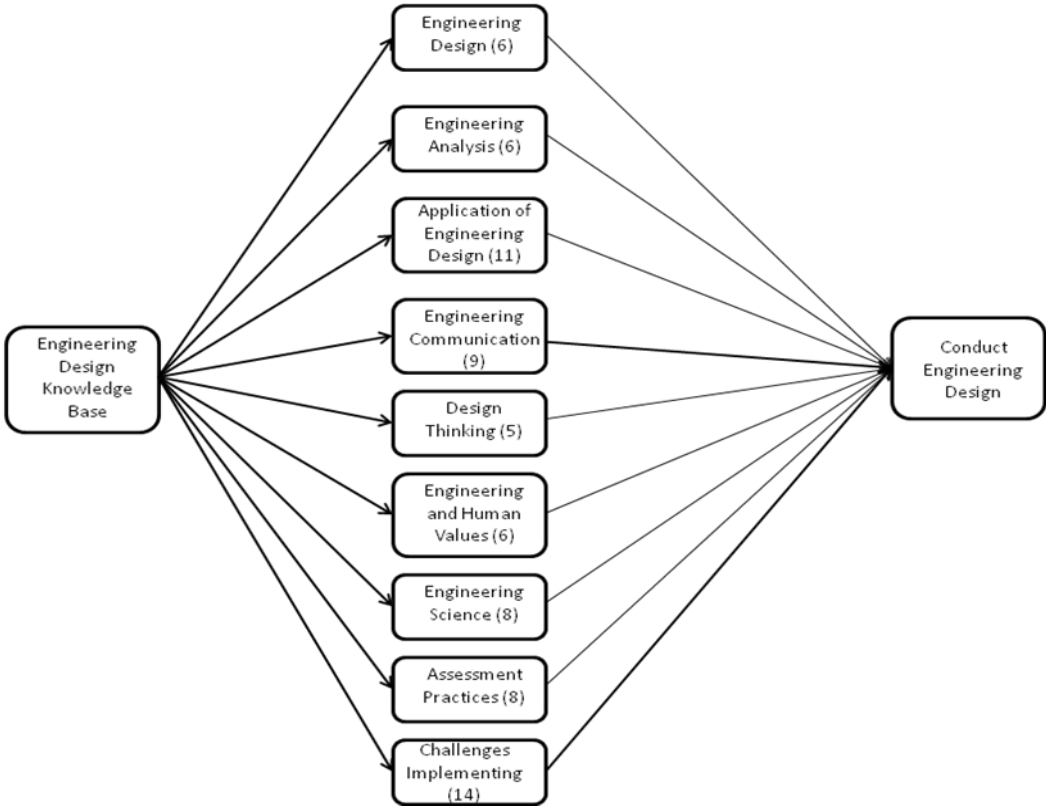

Figure 3: Subscales of engineering design knowledge base

Tests of reliability were performed for the total and for each of the seven subscales. Internal consistency of the Kelley (2008) survey was determined through computation of an Alpha coefficient, which was calculated using a split sample technique. The total scale Alpha for the sample was .982.

Kelley surveyed 226 ITEA high school technology education teachers who were members of ITEA. Kelley (2008) evaluated the validity and reliability for scores on of the instrument through frequency distributions, correlation matrices, statistics available from reliability programs, and face validity. The frequency distributions provided a visual of the frequency of responses for each question. The correlation matrices were used to consider the effectiveness of each item. The instrument was designed in which several items measured the same construct, so the correlation matrix provided insight on how the items were related to one another. If certain items were outliers then they were examined more closely using *alpha item if deleted,* which allows the researcher to delete an item from the set to determine whether that item is helping or hurting the internal consistency. This helped the researcher develop an instrument that was concise, yet reliable, by deleting the items that harmed the internal consistency.

Data Collection

A research proposal outlining the details of this study was submitted to the Southern University Institutional Review Board (IRB) for permission to conduct the study. After consent was received, the survey cover letter received from the IRB was mailed to participants along with the survey. Participants were informed that all responses would be held in strict confidence and only the group results will be published. The participants' names were not revealed in the study and the participant's identity were not associated with their responses. Only the researcher involved in this study had access to the data. Identification information of participants was not retained on any data or forms used in the study.

The local school district was contacted and meetings were scheduled with the appropriate school administrator(s) to obtain their approval to conduct the study. After receiving approval from the school districts, each of the middle and high school principals were contacted to solicit their approval to conduct the study within their respective schools. An email cover letter was carefully drafted that included a statement of confidentiality of the respondent, a thorough description of the study, a need for the participants assistance, and the relevance of the study for the field of technology education and to the school districts (Appendix). The cover letter also informed participants about how confidentiality would be maintained by using identification numbers on the questionnaires for follow-up purposes. The cover letter was sent electronically through e-mail for teachers in the sample who had an active email address listed on the school website. The electronically delivered consent letter contained specific instructions on how to fill-out the on-line questionnaire.

The researcher sent out the surveys to the entire sample of 200 secondary STEM educators. To safeguard the confidentiality of respondents the following procedures were followed:

1. Only number codes were used to link the respondent to the questionnaire.
2. Name-to-code linkage information was stored separately from the questionnaires.
3. All identifying information about respondents was destroyed upon conclusion of e-mail follow-ups, to ensure that all responses had been entered into the statistical database.
4. All names and addresses of survey respondents were omitted from computer files used for analysis.

5. Statistical tabulations were presented by broad enough categories so that individual respondents could not be identified.

After waiting four days past the specified date of return, which was three weeks after the initial mailing, the researcher contacted non-respondents by sending a follow-up email containing the URL for the on-line survey link. This has been a proven method by other researchers to achieve compliance from non-respondents (Gall, Gall, & Borg, 2007).

Data Analysis Procedures

Self-reported information pertaining to engineering design self-concepts were collected and included in the online multiple-choice instrument. Results were analyzed using the Statistical Package for the Social Sciences (SPSS) Version 12 to calculate sample frequencies and means. The data for the study was analyzed using Cronbach's alpha and computed for each subscale to determine the internal consistency of each subscale. A principal component analysis was used to reduce the number of variables and to classify variables.

Data collected from the EDSE survey was analyzed to produce four engineering design process (EDP) factor scores – self-efficacy, motivation, expectancy for success, and anxiety. EDP factor scores were used to analyze how the engineering design self-concepts of STEM educators varied in terms of the demographic variables.

CHAPTER 4: RESULTS

The purpose of this study was to examine the need for examining the degree to which technology and non-technology educators are implementing elements of engineering design in the curriculum and their self-efficacy in relation to engineering design. Two instruments were used for this study. The Examination of Engineering Design in Curriculum Content and Assessment Practices in Secondary Technology Education (EEDCCAPSTE) Survey was constructed from current research in the field of technology education that had identified curricular goals, engineering design outcomes for technology education at the secondary level, and appropriate assessment practices. The Engineering Design Self-Efficacy (EDSE) Survey was constructed from current research in the field of technology related to engineering design self-efficacy (Carberry, Ohland, Lee, 2009). Secondary STEM educators were presented with a set of questions with a Likert scale response format to rate their level of agreement regarding their content, teaching practices, assessment practices, and self-efficacy in relation to engineering design. Participants were asked to respond to the instrument items regarding their teaching and assessment practices by indicating frequency of use and time per typical use for each instrument item, and self concepts towards engineering design tasks. Descriptive results are set forth first, followed by analysis of the research questions. The latent structures of scales used in the study are also examined.

Summary of Responses

An incentive of winning one $100 gift card was used to help generate a high response rate. Providing this incentive had a significant effect on the amount of time respondents took to complete the survey and the number of survey items respondents completed.

An e-mail cover letter was drafted using Southern University A & M College Internal Review Board procedure that included: (a) thorough description of the study, (b) purpose of the study, (c) eligibility of participants, (d) risks and discomforts for participating in the study, (e) benefits for participating in the study, (f) alternative procedures to conduct the study, (g) confidentiality of the participant, (h) conditions and possible penalties for withdrawing or terminating from the study early. The survey link was posted on the researcher's Wiki page and emailed to participants with a message inviting them to access the on-line survey. The survey was administered using "SurveyMonkey", online software at www.surveymonkey.com. SurveyMonkey is an online service for creating, distributing, and analyzing surveys.

At the end of the first week the survey was activated, a total of seven respondents completed the survey for a 1.6% rate of return. Although the researcher provided an incentive of one $100 gift card, the initial response to the survey was poor. Additional efforts were made by offering a $300 gift card to the school with the most respondents to complete the survey. The survey was emailed three additional times and school administrations contacted to yield an additional 21.2% rate of return. A final total of 100 STEM educators completed the on-line survey. Survey responses were collected in

SurveyMonkey and the data was analyzed using the Statistical Package for Social Sciences (SPSS) software.

Demographic Factors

The sample consisted of 100 educators who taught at a school that offered at least one technology or engineering course. The biographical demographic section of the survey revealed that 49% of the respondents taught at a middle/high school and 51% taught at a high school from 19 schools within a local school district. The majority of the respondents were female (64%) and the other 36% was male. The ages of the respondents ranged from 28 to 63. Thirty-one percent of the respondents were on a block schedule to organize the school day and the other 69% was on a traditional teaching schedule with classes meeting five days a week for approximately 50 min each class period. Table 9 and figures 4 and 5 present data on the demographic variables. Table 9 shows that 75% of the schools were in an urban setting, 21% of the schools were in a suburban/exurban setting, and 4% were in a rural area. Seventy-three percent of the schools in this study had a school size of 500 – 1500 students and 56% of them were in an urban setting. Sixty-nine percent of the schools in this study were on a traditional schedule, where 53% of them were in the urban setting. A complete summary is located in Table 10.

Table 9

School setting results by school size and type of schedule

		SchoolSize			Type of Schedule	
		Large (greater than 1500 students)	Medium (500 - 1500 students)	Small (less than 500 students)	Block	Traditional
SchoolSetting	Rural	0	0	4	0	4
	Suburban/Exurban	3	17	1	9	12
	Urban	4	56	15	22	53

Sixty-four of the respondents were above the age of 40 year, and 27 of them were between the ages of 50 and 56 (Figure 4). Nineteen respondents had 20 years or more of teaching experience. Of the 19 respondents, 12 of them had between 20 and 26 years of experience and seven of those respondents were math educators (Table 10). All seven math educators were between the ages of 40 and 46. Figure 5 shows a high percentage of respondents had five years or less of teaching experience in at least one of the courses they taught. Table 10 includes data for educators who taught in a single and multiple content areas with varied experience in each of those areas. Eighty-nine educators were over the age of 40, and forty of those educators had five years or less teaching experience. A detailed summary of the respondent's teaching experience by age and years of teaching is located in Table 10. The respondent's teaching experience based on content area and age was compared because prior research reports a difference in engineering design self-efficacy on these same demographic variables.

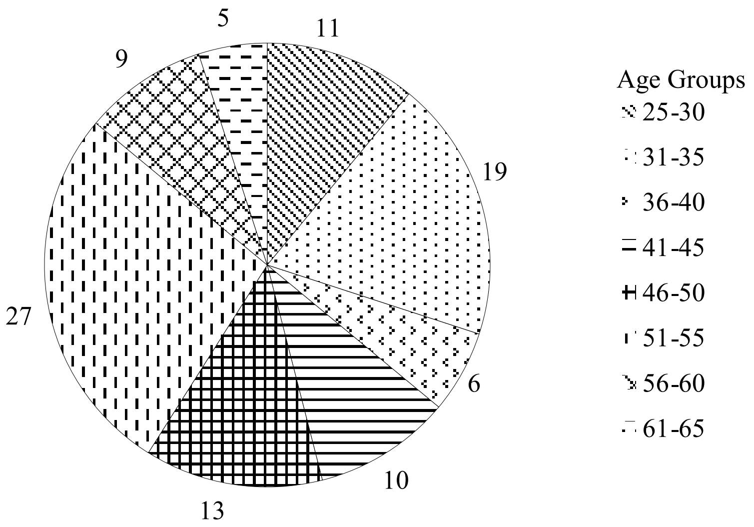

Figure 4: Number of educators by age groups

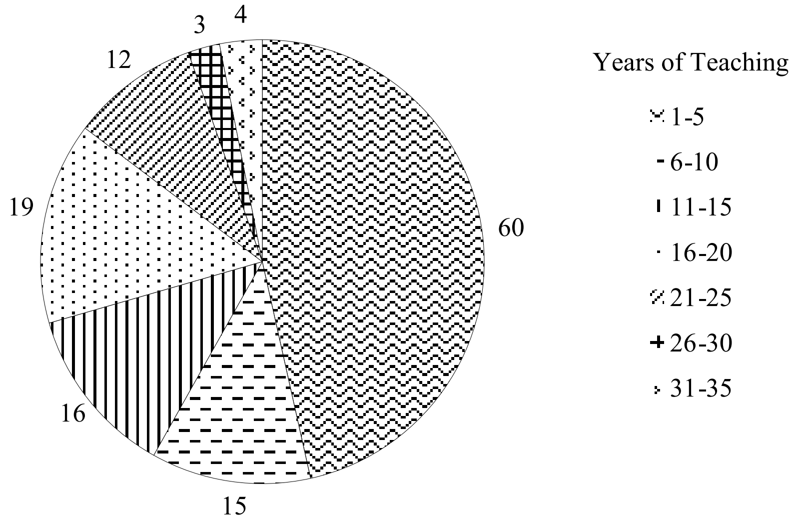

Figure 5: Number of Educators by Years of Teaching

Table 10

Detailed Summary of Educator's Teaching Experience by Content and Age

	Years of Teaching																											
	1-5				6-10				11-15				16-20				21-25				26-30				31-35			
Age	S	T	E	M	S	T	E	M	S	T	E	M	S	T	E	M	S	T	E	M	S	T	E	M	S	T	E	M
25-30	5	4			2																							
31-35	6				3	5			5																			
36-40		3		2					2	2			1															
41-45	1			1								2								7								
46-50	6	4	2	4									5								2							
51-55	12	2		1			2	2				2	3			7												
56-60		3		1													3		2						1			
61-65			3			1				3			3									1						3
Total	30	16	5	9	5	6	2	2	7	5	0	4	12	0	0	7	3	0	2	7	2	1	0	0	1	0	0	3

Note: S = Science; T = Technology; E = Engineering; M = Mathematics

Forty-five percent of the respondents only taught in the science content area (Figure 6). Fifteen respondents taught science and at least one other course. Five respondents taught in each of the STEM areas. All of the respondents who taught multiple courses were at least 40 years old.

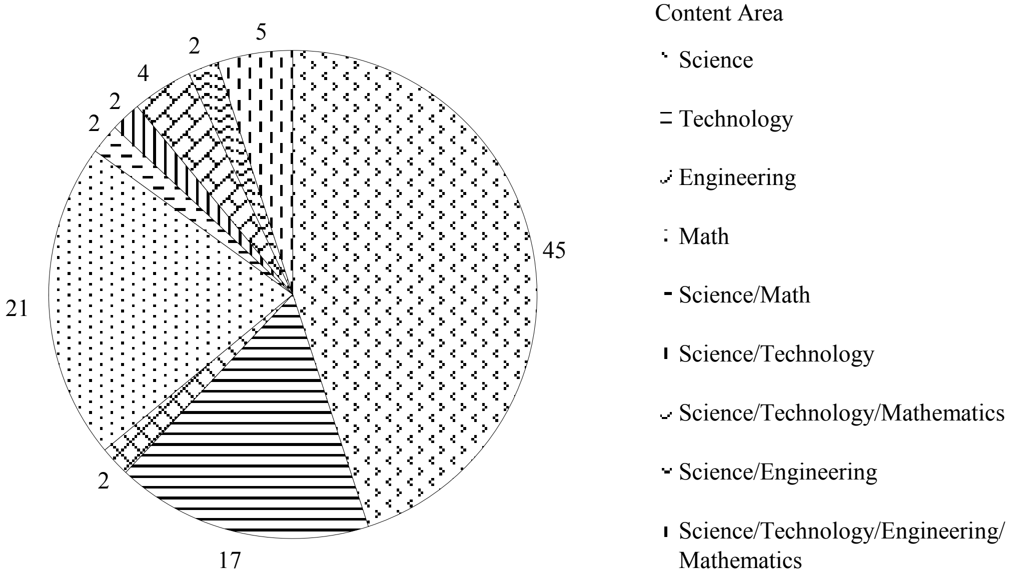

Figure 6: Number of educators by content area

The educators who responded to this survey were not only experienced but were also highly educated with 49% obtaining their undergraduate degree in science, technology, or mathematics and 22% obtaining their undergraduate degree in education (Figure 7). The number of degrees obtained by respondents was also higher in these fields compared to other fields (Table 11). Ninety-two percent of the respondents had at least a Bachelor's Degree (Figure 8). Fifty-three percent of respondents had a Master's Degree and 39% had a Bachelor of Science or Bachelor of Arts Degree. A detailed summary of the respondent’s highest degree earned by undergrad major and content area is located in Table 11.

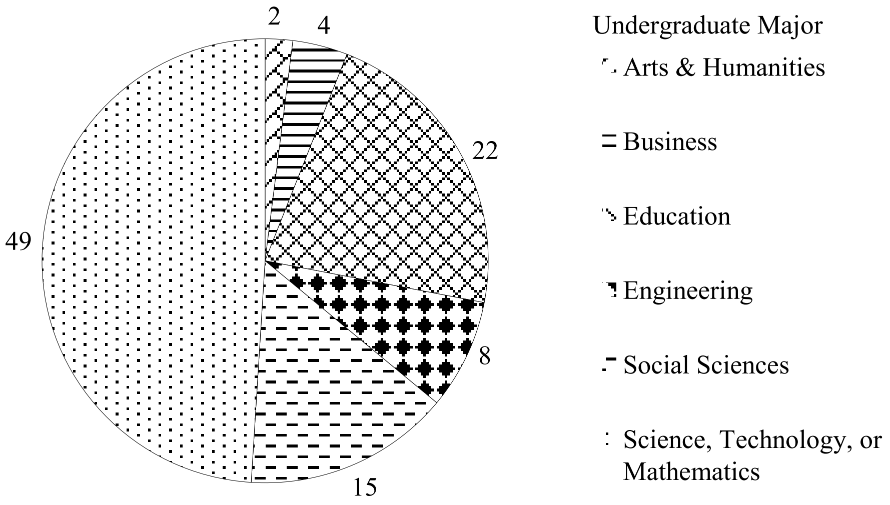

Figure 7: Number of Educators by Undergraduate Major

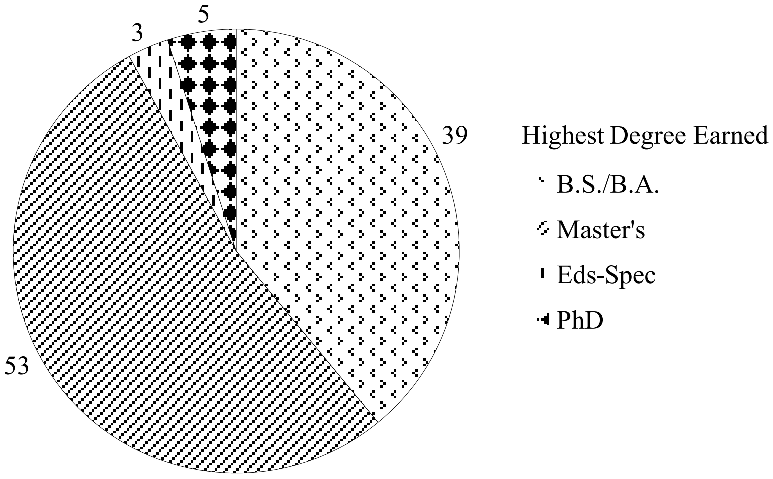

Figure 8: Number of Educators by Highest Degree Earned

Table 11

Summary of Highest Degree Earned by Undergrad Major and Content

		Highest Degree			
Undergrad Major	Content	B.S./B.A.	Eds-Specialist	Masters	PhD
Arts and Humanities	Science				
	Technology			2	
	Engineering				
	Math				
Business	Science				
	Technology			3	
	Engineering				
	Math	1			
Education	Science	6		6	
	Technology	2	3	3	
	Engineering	2		3	
	Math	2		10	
Engineering	Science			6	
	Technology				
	Engineering			2	
	Math	2			
Social Sciences	Science	6		2	
	Technology			2	
	Engineering				
	Math			7	

“Table 11 (continued)”

		Highest Degree			
Undergrad Major	Content	B.S./B.A.	Eds-Specialist	Masters	PhD
STM	Science	17		12	5
	Technology	7		6	
	Engineering			2	
	Math	4		6	

Of the 100 educators surveyed, 80 of them had a teacher certificate. Table 12 shows the certification status of educators by content area and highest degree obtained, including educators that taught in multiple content areas. The twenty respondents who were not certified consisted of 9 educators in science, 8 educators in technology, and 3 educators in mathematics. Thirty-six of the 80 educators were certified in science and 18 were certified in math. The 15 participants who taught multiple courses were certified educators, 11 of which had earned a Master’s degree.

Table 12

Summary of Certification by Content Area and Content

		Highest Degree			
Certification	Content	B.S./B.A.	Eds-Specialist	Masters	PhD
No	Science	8		1	
	Technology	5		3	
	Engineering				
	Math	3			
Yes	Science	17		14	5
	Technology		3	6	
	Engineering			2	
	Math	2		16	
	Science/Technology			2	
	Science/Engineering			2	
	Science/Math			2	
	STM	2		2	
	STEM	2		3	

Note: STM = Science/Technology/Mathematics

Of the 100 educators surveyed, 64 of them were above the age of 40. Table 13 shows the highest degree earned by age group. Twenty-seven of the 64 respondents were between the ages of 50 and 56. This age group also had the highest number of degrees earned: 13 B.S./B.A., 14 Master's degrees, and 13 Eds-Specialist degrees. The next largest age group, '31-35', earned 19 degrees: 16 B.S./B.A. and 3 Master's degrees. The only age group to have earned PhD's was the '46-50' age group.

Table 13

Summary of Highest Degree Earned by Age Group

		Highest Degree			
Age	Total	B.S./B.A.	Eds-Specialist	Masters	PhD
25-30	11	2	9		
31-35	19	16	3		
36-40	6		6		
41-45	10		10		
46-50	13	8			5
51-55	27	13	14	3	
56-60	9		6		
61-65	5		5		

EEDCCAPSTE Survey Results

Factor analysis on the EEDCCAPSTE was done using varimax rotation with Kaiser normalization to compare the number of subscales resulting among this sample as oppose to Kelley (2008). The Principal component analysis in this study shows the same nine factor coefficients (Table 14). The instrument had an overall Cronbach's α reliability of 0.971.

Table 14

Engineering Design Knowledge Base Rotated Component Matrix

Items	Component								
	1	2	3	4	5	6	7	8	9
Engr Design Process Freq				.447					
Engr Design Creativity Freq				.699					
EDApproaches2DesignFreq				.749					
EDPotentialCareerOptionFreq				.598					
EDGoalsBadDesignFreq				.517					
EDAbility2DesignFreq				.555					
EAKnowledgeSciMathFreq	.623								
EAApplyEngrSciFreq	.556								
EAMeasuringEquipFreq	.794								
EAPhysMathModelsFreq	.788								
EAOptimizationFreq	.563								
EAModelsSimulationsFreq	.777								
APDApplyKnowledgeFreq			.675						
APDIdentifyProblemsFreq			.577						
APDNoPerfectDesignFreq			.692						
APDReverseEngrFreq			.789						
APDOrganizeManageFreq			.637						
APDDesignProductTestFreq			.909						
APDApplyResearchFreq			.863						

“Table 14 (continued)”

Items	Component								
	1	2	3	4	5	6	7	8	9
APDDevelopSkillsFreq			.673						
APDDemonstrateAbilityFreq			.582						
APDDevelopBasicStudentSkillsFreq			.544						
APDUnderstandDesignFreq			.523						
ECOrallyFreq					.525				
ECWritingFreq					.632				
ECTechnicalDrawingsFreq					.591				
EC3DFreq					.677				
ECPortfolioFreq					.557				
ECCADFreq					.556				
ECDimensioningFreq					.733				
ECManufacturingToleranceFreq					.636				
ECCompAppsFreq					.658				
DTThinkCriticallyFreq							.542		
DTSynthesizesFreq							.626		
DTSystemsThinkingFreq							.582		
DTBrainstormingFreq							.657		
DTOpenEndedFreq							.724		
EHVEthicsFreq		.875							
EHVEconomicalSocialFreq		.811							
EHVCreateOtherProblemsFreq		.793							

“Table 14 (continued)”

Items	Component								
	1	2	3	4	5	6	7	8	9
EHVCostSafetyAppearanceFreq		.786							
EHVHumanValueLimitationsFreq		.817							
EHVBasicErgonomicsFreq		.863							
ESApplyMathSciFreq								.821	
ESApplyBasicMechanicsFreq								.821	
ESApplyStaticsFreq								.859	
ESApplyDynamicsFreq								.871	
ESUseAlgebraFreq								.835	
ESUseGeometryFreq								.813	
ESUseTrigonometryFreq								.833	
ESMaterialProcessFreq								.823	
APSupportEvidenceFreq						.565			
APProvideEvidenceFreq						.831			
APDesignCriteriaFreq						.756			
APIdeaGenerationFreq						.549			
APRecordDesignInfoFreq						.759			
APMathematicalModelsFreq						.684			
APPrototypeModelFreq						.805			
APDesignTeamFreq						.780			
CIEDIntegrateAppLevel									.812
CIEDMathSci									.794
CIEDEngrFundamentals									.689
CIEDAppTextbooks									.893
CIEDLabEquipment									.897

“Table 14 (continued)”

Items	Component								
	1	2	3	4	5	6	7	8	9
CIEDAcquiringFundingTools									.891
CIEDAcquiringFundingMat									.840
CIEDNetworking									.941
CIEDMathSciFaculty									.757
CIEDSchoolAdmin									.689
CIEDPromoteEngr									.851
CIEDCommunitySupport									.862
CIEDParentSupport									.679

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.
a Rotation converged in 11 iterations.

Mean Ranks

One goal of this research was to accurately describe the degree to which STEM educators were implementing elements of engineering design in the curriculum. Each independent variable was classified and ranked by the total mean score. The mean ranking helps identify how participants felt about the questions in each variable. A five-point Likert scale response was used that corresponded with how often (frequency) they were teaching the engineering design content, and for how long (time) in each item.

Table 15 shows the results of the *Engineering Design* category. The first category of the engineering design content presented in the instrument was E*ngineering Design*. Respondents indicated their level of teaching practice as it related to six general engineering design concepts. Mean scores measured by frequency of use in *Engineering Design* section ranged from 1.37 to 1.42. Mean scores for time per typical use in the *Engineering Design* section ranged from 1.19 to 2.32. The factor that participants agreed upon the most was "recognize engineering as a potential career option". Second was, "recognize that there are many approaches to design and not just one design process". The item receiving the least support was "understand engineering design is an iterative process". The mean scores measured by frequency of use ranged from 1.48 to 1.59 for females and 1.17 to 2.33 for males. Females agreed the most on "recognize that there are many approaches to design and not just one design process". Males agreed the most on "recognize engineering as a potential career option". Males and females agreed the least on "understand engineering design is an iterative process". Total results can be reviewed in Table 15.

Table 15

Engineering Design Results

	Overall				Female				Male			
Engineering Design Content	*Mf*	SD*f*	M Time	SD Time	*Mf*	SD*f*	M Time	SD Time	*Mf*	SD*f*	M Time	SD Time
understand engineering design is an iterative process	1.37	1.548	1.19	1.433	1.48	1.403	1.20	1.211	1.17	1.781	1.17	1.781
understand creativity is an important characteristic for engineers to apply in design	2.16	1.704	2.02	1.676	2.31	1.592	2.05	1.463	1.89	1.953	1.97	2.021
recognize that there are many approaches to design and not just one design process	2.31	1.516	2.21	1.539	2.59	1.318	2.19	1.258	1.81	1.721	2.25	1.962
recognize engineering as a potential career option	2.42	1.707	2.17	1.602	2.47	1.490	2.20	1.311	2.33	2.056	2.11	2.039
are able to identify good and bad design	2.07	1.458	2.32	1.675	2.16	1.461	1.97	1.469	1.92	1.461	2.94	1.851
believe in his/her ability to design a solution to a technological problem	2.15	1.641	2.04	1.614	2.16	1.556	2.03	1.532	2.14	1.807	2.06	1.772
Total Group Mean	2.08		1.99		2.20		1.94		1.88		2.08	

Table 16 shows the results of the *Engineering Analysis* category, the second category presented in the instrument. Respondents indicated their level of teaching practice as it related to student learning outcomes and the analysis phase of the engineering design process. Overall mean scores measured by frequency of use in *Engineering Analysis* section ranged from 1.96 to 3.29. Mean scores for time per typical use in the *Engineering Analysis* section ranged from 1.99 to 2.97. The factor that participants agreed upon the most was "understand that knowledge of science and mathematics is critical to engineering". Second was, "use physical and/or mathematical models to estimate the probability of events". The item receiving the least support was "apply engineering science principles when designing solutions". The mean scores measured by frequency of use ranged from 1.89 to 3.56 for females and 2.03 to 2.81 for males. Females and males agreed the most on "understand that knowledge of science and mathematics is critical to engineering". Females agreed the least on "apply engineering science principles when designing solutions". Males agreed the least on "use physical and/or mathematical models to estimate the probability of events". Total results can be reviewed in Table 16.

Table 16

Engineering Analysis Results

	Overall				Female				Male			
Engineering Analysis Content	M*f*	SD*f*	M Time	SD Time	M*f*	SD*f*	M Time	SD Time	M*f*	SD*f*	M Time	SD Time
understand that knowledge of science and mathematics is critical to engineering	3.29	1.552	2.97	1.611	3.56	1.308	2.83	1.386	2.81	1.833	3.22	1.944
apply engineering science principles when designing solutions	1.96	1.711	1.99	1.592	1.89	1.861	1.75	1.458	2.08	1.422	2.42	1.746
use measuring equipment to gather data for troubleshooting, experimentation, and analysis	2.49	1.812	2.55	1.623	2.67	1.928	2.61	1.497	2.17	1.558	2.44	1.843
use physical and/or mathematical models to estimate the probability of events	2.66	1.701	2.54	1.592	3.02	1.628	2.59	1.354	2.03	1.665	2.44	1.963
use optimization techniques to determine optimum solutions to problems	2.32	1.576	2.03	1.501	2.38	1.464	1.86	1.246	2.22	1.775	2.33	1.852
use models or simulations to study processes	2.58	1.634	2.60	1.524	2.75	1.671	2.45	1.425	2.28	1.542	2.86	1.676
Total Group Mean	2.55		2.45		2.71		2.35		2.27		2.62	

Table 17 shows the results of the *Engineering Application* category, the third category presented in the instrument. Respondents indicated their level of teaching practice as it related to student learning outcomes and the application of the engineering design process. Overall mean scores measured by frequency of use in *Engineering Application* section ranged from 1.39 to 2.38. Mean scores for time per typical use in the *Engineering Analysis* section ranged from 1.51 to 2.53. The factor that participants agreed upon the most was “develop basic students’ skills in the use of tools”. Second was, “demonstrate the ability to handle open-ended/ill-defined problems”. The item receiving the least support was “apply knowledge for manufacturing products to the engineering design”. The mean scores measured by frequency of use ranged from 1.33 to 2.36 for females and 1.17 to 2.56 for males. Females and males agreed the most on “understand that knowledge of science and mathematics is critical to engineering”. Females agreed the least on “apply engineering science principles when designing solutions”. Males agreed the least on “use physical and/or mathematical models to estimate the probability of events”. Total results can be reviewed in Table 17.

Table 17

Application of Engineering Design Results

	Overall				Female				Male			
Application of Engineering Design Content	M*f*	SD*f*	M Time	SD Time	M*f*	SD*f*	M Time	SD Time	M*f*	SD*f*	M Time	SD Time
apply knowledge for manufacturing products to the engineering design	1.39	1.595	1.51	1.547	1.52	1.480	1.52	1.458	1.17	1.781	1.50	1.715
identify problems that could be solved through engineering design	1.71	1.610	1.81	1.698	1.58	1.478	1.69	1.489	1.94	1.820	2.03	2.021
understand no perfect design solution exists	1.95	1.760	1.81	1.716	1.86	1.708	1.73	1.546	2.11	1.864	1.94	1.999
conduct reverse engineering to analyze product design	1.54	1.553	1.72	1.664	1.33	1.491	1.42	1.489	1.92	1.610	2.25	1.842
organize and manage design process for optimal use of materials, processes, time, and expertise	1.47	1.501	1.68	1.746	1.34	1.394	1.44	1.521	1.69	1.670	2.11	2.039
design, produce, and test prototypes	1.76	1.778	1.78	1.878	1.57	1.688	1.37	1.579	2.08	1.903	2.50	2.158
apply research to designing products, processes, and materials	1.93	1.827	1.90	1.834	1.61	1.705	1.80	1.765	2.50	1.920	2.08	1.962
develop skills to use, manage, and assess technology	2.14	1.538	2.32	1.626	2.06	1.602	2.06	1.602	2.28	1.427	2.78	1.588
demonstrate the ability to handle open-ended/ill-defined problems	2.19	1.509	2.09	1.564	1.98	1.453	1.91	1.318	2.56	1.557	2.42	1.903
develop basic students' skills in the use of tools	2.38	1.632	2.53	1.611	2.36	1.703	2.41	1.519	2.42	1.519	2.75	1.763
understand design often requires tradeoffs	1.82	1.766	1.72	1.865	1.88	1.704	1.59	1.650	1.72	1.892	1.94	2.203
Total Group Mean	1.87		1.90		1.74		1.72		2.04		2.21	

Table 18 shows the results of the *Engineering Communication* category, the fourth category presented in the instrument. Respondents indicated their level of teaching practice as it related to student learning outcomes within engineering design and communicating design solution. Overall mean scores measured by frequency of use in *Engineering Communication* section ranged from 1.24 to 3.12. Mean scores for time per typical use in the *Engineering Communication* section ranged from 1.34 to 3.12. The factor that participants agreed upon the most was “use basic computer applications such as word processors, spreadsheets, and presentation software”. Second was, “communicate design ideas orally, through presentations, and graphics”. The item receiving the least support was “apply rules of manufacturing tolerance”. The mean scores measured by frequency of use ranged from 1.20 to 3.17 for females and 1.03 to 3.03 for males. Females and males agreed the most on “understand that knowledge of science and mathematics is critical to engineering”. Females agreed the least on “apply engineering science principles when designing solutions”. Males agreed the least on “use physical and/or mathematical models to estimate the probability of events”. Total results can be reviewed in Table 18.

Table 18

Engineering Communication Results

	Overall				Female				Male			
Engineering Communication Content	M*f*	SD*f*	M Time	SD Time	M*f*	SD*f*	M Time	SD Time	M*f*	SD*f*	M Time	SD Time
communicate design ideas orally, through presentations, and graphics	2.48	1.726	2.32	1.814	2.63	1.821	2.44	1.735	2.22	1.533	2.11	1.953
communicate through writing technical reports	2.02	1.735	2.20	1.712	2.17	1.890	2.19	1.661	1.75	1.402	2.22	1.822
use technical drawings to construct or implement an object , structure, or process	2.12	1.860	2.36	1.925	2.12	2.020	2.03	1.799	2.11	1.563	2.94	2.028
visualize in three dimensions	2.05	1.731	2.12	1.838	2.27	1.702	1.80	1.565	1.67	1.740	2.69	2.149
develop and maintain an engineering design portfolio	1.48	1.691	1.78	1.894	1.34	1.711	1.48	1.755	1.72	1.649	2.31	2.040
use computer-aided design to construct technical drawings	1.34	1.683	1.69	1.900	1.45	1.632	1.58	1.688	1.14	1.775	1.89	2.240
apply the rules of dimensioning	1.27	1.620	1.34	1.707	1.41	1.550	1.33	1.584	1.03	1.732	1.36	1.930
apply rules of manufacturing tolerance	1.24	1.718	1.36	1.801	1.20	1.595	1.06	1.435	1.31	1.939	1.89	2.240
use basic computer applications such as word processors, spreadsheets, and presentation software	3.12	1.866	3.12	1.799	3.17	1.848	2.84	1.757	3.03	1.920	3.61	1.793
Total Group Mean	1.90		2.03		1.97		1.86		1.78		2.34	

Table 19 shows the results of the *Design Thinking Related to Engineering Design* category, the fifth category presented in the instrument. Respondents indicated their level of teaching practice as it related to student learning outcomes within engineering design and communicating design solution. Overall mean scores measured by frequency of use in *Design Thinking Related to Engineering Design* section ranged from 2.17 to 3.24. Mean scores for time per typical use in the *Design Thinking Related to Engineering Design* section ranged from 2.2 to 3.18. This category received the highest group mean score (2.67) for frequency of use, indicating that most respondents teach some basic level of design thinking related to engineering design in their courses. The factor that participants agreed upon the most was “think critically”. Second was, “apply brainstorming and innovative concept generation”. The item receiving the least support was “apply SYSTEMS THINKING-understanding and considering the multiple facets of a design solution result in positive and negative impacts”. The mean scores measured by frequency of use ranged from 2.25 to 3.37 for females and 2.25 to 3.36 for males. Females agreed the most on “think critically”. Males agreed the most on “apply brainstorming and innovative concept generation”. Females and males agreed the least on “apply SYSTEMS THINKING-understanding and considering the multiple facets of a design solution result in positive and negative impacts”. Total results can be reviewed in Table 19.

Table 19

Design Thinking Related to Engineering Design Results

Design Thinking Related to Engineering Design Content	Overall				Female				Male			
	M*f*	SD*f*	M Time	SD Time	M*f*	SD*f*	M Time	SD Time	M*f*	SD*f*	M Time	SD Time
think critically	3.24	1.688	3.18	1.708	3.37	1.714	3.09	1.716	3.00	1.639	3.33	1.707
synthesizes simple parts into complex systems	2.31	1.692	2.55	1.866	2.34	1.819	2.30	1.779	2.25	1.461	3.00	1.957
apply SYSTEMS THINKING- understanding and considering the multiple facets of a design solution result in positive and negative impacts	2.17	1.664	2.20	1.735	2.25	1.746	2.06	1.754	2.03	1.521	2.44	1.698
apply brainstorming and innovative concept generation	2.90	1.648	2.88	1.783	2.64	1.694	2.42	1.789	3.36	1.477	3.69	1.470
have the ability to approach open-ended/ ill defined problems	2.72	1.621	2.84	1.629	2.59	1.669	2.58	1.595	2.94	1.530	3.28	1.614
Total Group Mean	2.67		2.73		2.64		2.49		2.72		3.15	

Table 20 shows the results of the *Engineering and Human Values* category, the sixth category presented in the instrument. Respondents indicated their level of teaching practice as it related to student learning outcomes within engineering design and communicating design solution. Overall mean scores measured by frequency of use in *Engineering and Human Values* section ranged from 1.77 to 2.39. Mean scores for time per typical use in the *Engineering and Human Values* section ranged from 1.77 to 2.44. The factor that participants agreed upon the most was “understand that the solution to one problem may create other problems”. Second was, “take human values and limitations into account when designing and solving problems”. The item receiving the least support was “understand how engineers put ethics into practice”. The mean scores measured by frequency of use ranged from 1.84 to 2.34 for females and 1.64 to 2.47 for males. Females and males agreed the most on “understand that the solution to one problem may create other problems”. Females and males agreed the least on “understand how engineers put ethics into practice”. Total results can be reviewed in Table 20.

Table 20

Engineering and Human Values Results

	Overall				Female				Male			
Engineering and Human Values Content	M*f*	SD*f*	M Time	SD Time	M*f*	SD*f*	M Time	SD Time	M*f*	SD*f*	M Time	SD Time
understand how engineers put ethics into practice	1.77	1.752	1.84	1.774	1.84	1.757	1.67	1.614	1.64	1.759	2.14	2.016
are aware of social, economical, and environmental impacts on design solutions	2.09	1.787	2.12	1.860	2.16	1.793	1.92	1.674	1.97	1.797	2.47	2.131
understand that the solution to one problem may create other problems	2.39	1.651	2.44	1.783	2.34	1.586	2.19	1.632	2.47	1.781	2.89	1.968
consider cost, safety, appearance, and consequences of design failures	2.12	1.765	2.18	1.904	2.13	1.750	1.94	1.745	2.11	1.817	2.61	2.115
take human values and limitations into account when designing and solving problems	2.13	1.643	2.30	1.726	2.11	1.624	2.05	1.547	2.17	1.699	2.75	1.948
apply knowledge of basic ergonomics to engineering design process	1.90	1.744	1.77	1.757	1.95	1.759	1.47	1.512	1.81	1.737	2.31	2.040
Total Group Mean	2.07		2.11		2.09		1.87		2.03		2.53	

Table 21 shows the results of the *Engineering Science* category, the seventh category presented in the instrument. Respondents indicated their level of teaching practice as it related to student learning outcomes within engineering design and communicating design solution. Overall mean scores measured by frequency of use in *Engineering Science* section ranged from 1.71 to 2.34. Mean scores for time per typical use in the *Engineering Science* section ranged from 1.74 to 2.41. The factor that participants agreed upon the most was “use of algebra to solve problems or predict results to design solutions”. Second was, “apply math and science to the engineering design process”. The item receiving the least support was “apply knowledge of dynamics to the engineering design process”. The mean scores measured by frequency of use ranged from 1.56 to 2.28 for females and 1.83 to 2.58 for males. Females agreed the most on “apply math and science to the engineering design process”. Males agreed the most on ”use of algebra to solve problems or predict results to design solutions”. Females agreed the least on “apply knowledge of dynamics to the engineering design process”. Males agreed the least on “use trigonometry to solve problems or predict results to design solutions”. Total results can be reviewed in Table 21.

Table 21

Engineering Science Results

	Overall				Female				Male			
Engineering Science Content	M*f*	SD*f*	M Time	SD Time	M*f*	SD*f*	M Time	SD Time	M*f*	SD*f*	M Time	SD Time
apply math and science to the engineering design process	2.32	1.814	2.41	1.881	2.28	1.713	2.23	1.669	2.39	2.004	2.72	2.199
apply knowledge of basic mechanics to the engineering process	2.11	1.938	2.18	1.997	2.00	1.911	1.87	1.821	2.31	1.997	2.72	2.199
apply knowledge of basic statics and strengths of materials to engineering design process	1.87	1.862	2.02	1.974	1.86	1.661	1.77	1.630	1.89	2.201	2.47	2.432
apply knowledge of dynamics to the engineering design process	1.71	1.871	1.74	1.915	1.56	1.670	1.45	1.613	1.97	2.184	2.25	2.298
use of algebra to solve problems or predict results to design solutions	2.34	1.821	2.37	1.884	2.20	1.836	2.02	1.759	2.58	1.795	3.00	1.957
use geometry to solve problems or predict results to design solutions	2.12	1.866	2.15	1.935	2.06	1.754	1.92	1.684	2.22	2.072	2.56	2.286
use trigonometry to solve problems or predict results to design solutions	1.74	1.878	1.76	1.949	1.69	1.816	1.48	1.681	1.83	2.007	2.25	2.298
apply knowledge of material process to engineering design process	1.78	1.947	1.79	2.012	1.63	1.864	1.41	1.716	2.06	2.083	2.47	2.324
Total Group Mean	2.00		2.05		1.91		1.77		2.16		2.56	

Summary EEDCCAPSTE Teaching Practices

Table 22 has a complete listing of categories based upon group mean scores measured by frequency of use. The *Design Thinking Related to Engineering Design* received the highest overall group mean score (2.67) for frequency of use. The second highest overall group mean score for frequency of use was the teaching of *Engineering Analysis* with a group mean of 2.55. The third highest overall group mean score for frequency of use was the teaching of *Engineering Design* with a group mean of 2.08. The highest female group mean score for frequency of use was the teaching of *Engineering Analysis* with a group mean of 2.71. The highest overall male group mean score for frequency of use was the teaching of *Engineering Design* with a group mean of 2.72. Total results can be reviewed in Table 22.

Table 22

Engineering Design Category Group Mean (Frequency)

Engineering Design Content Category	Total Group *Mf*	Total Female M*f*	Total Male M*f*
Design Thinking Related to Engineering Design	2.67	2.64	2.72
Engineering Analysis	2.55	2.71	2.27
Engineering Design	2.08	1.91	2.16
Engineering and Human Values	2.07	2.09	2.03
Engineering Science	2.00	1.97	1.78
Engineering Communications	1.90	2.20	1.88
Application of Engineering Design	1.87	1.74	2.04

Table 23 has a complete listing of categories based upon group mean scores measured by time per typical use. The *Design Thinking Related to Engineering Design* received the highest overall group mean score (2.73) for time per typical use. The second highest overall group mean score for time per typical use was the teaching of *Engineering Analysis* with a group mean of 2.45. The third highest overall group mean score for time per typical use was the teaching of *Engineering and Human Values* with a group mean of 2.11. The highest female and male groups mean score for time per typical use was the teaching of *Design Thinking Related to Engineering Design*, with a group mean of 2.49 and 3.15 respectively. Total results can be reviewed in Table 23.

Table 23

Engineering Design Category Group Mean (Time per Typical Use)

Engineering Design Content Category	Total Group *Mf*	Total Female M*f*	Total Male M*f*
Design Thinking Related to Engineering Design	2.73	2.49	3.15
Engineering Analysis	2.45	2.35	2.62
Engineering and Human Values	2.11	1.77	2.56
Engineering Science	2.05	1.87	2.53
Engineering Communications	2.03	1.86	2.34
Engineering Design	1.99	1.94	2.08
Application of Engineering Design	1.90	1.72	2.21

The survey item “understand the knowledge of science and mathematics is critical to engineering” had the highest response for *frequency of use* with a total mean score of 3.29. The second highest survey item, “think critically”, received a total mean score of 3.24. The third highest survey item, “use basic computer applications such as word processors, spreadsheets, and presentation software”, received a total mean score of 3.12.

The survey item “apply rules of manufacturing tolerance” had the lowest response for *frequency of use* with a total mean score of 1.28.

The survey item “think critically” had the highest response for *time per typical use* with a total mean score of 3.18. The second highest survey item, “use basic computer applications such as word processors, spreadsheets, and presentation software”, received a total mean score of 3.12. The third highest survey item, “apply brainstorming and innovative concept generation”, received a total mean score of 2.88. The survey item “understand engineering design is an iterative process” had the lowest response for *time per typical use* with a total mean score of 1.19. Results from the teaching practices of respondents indicate low scoring survey items as content items that are not heavily emphasized or taught at all in technology education or engineering-related courses. The reliability of the instrument results were measured using Cronbach’s internal consistency coefficient alpha. The results revealed a Cronbach Alpha of 0.971.

Composite Score: Total Hours per Content Category

A composite score was determined to identify the total hours of teaching time dedicated to the seven content categories for engineering design (Mayer, 1999; Mullens & Gayler, 1999; Supovitz & Turner, 2000). The composite score was computed using the conversion chart presented to respondents in the survey and is also shown in Table 24. The computed composite score allows the researcher to determine the total instructional time an educator devotes to a specific content or teaching strategy. It was computed by multiplying how often the educator was teaching engineering design content (frequency) by the time spent per class period (time) to generate a final composite score. In many cases the group mean scores fell between two whole Likert scale units.

The whole number of the group mean score is converted into units in days or minutes according to the conversions in Table 24. The decimal part of the group mean was multiplied by the difference between the two Likert scale units, either units in days or minutes. The decimal conversion is then added to the whole number conversion.

Table 24

Frequency Table

	How Often? (Frequency)			**How Many Minutes? (Time)**		
Likert	**Wording**	Traditional (meets 5 days a week)	Block	**Wording**	Traditional (50 minutes per period)	Block (90 minutes per period)
0	**Never**	0	0	**None**	0 min.	0 min.
1	**A few times a year**	5 days	5 days	**A few minutes per period**	5 min.	9 min.
2	**1 or 2 times a month**	14 days (1.5 * 9.1)	7 days (1.5 * 4.6)	**Less than half the period**	15 min.	30 min.
3	**1 or 2 times a week**	55 days (1.5 * 36.8)	28 days (1.5 * 18.4)	**About half**	25 min.	45 min.
4	**Nearly everyday**	129 days (3.5 * 36.8)	64 days (3.5 * 18.4)	**More than half**	37.5 min.	67.5 min.
5	**Daily**	184 days	92 days	**Almost all period**	50 min.	90 min.

Figures 9 and 10 represent the total number of hours in a given school year for each of the seven engineering design categories for block scheduling and traditional scheduling. The information was represented in two separate figures because the total instructional time varies depending on whether a school is organized by a block schedule or traditional schedule.

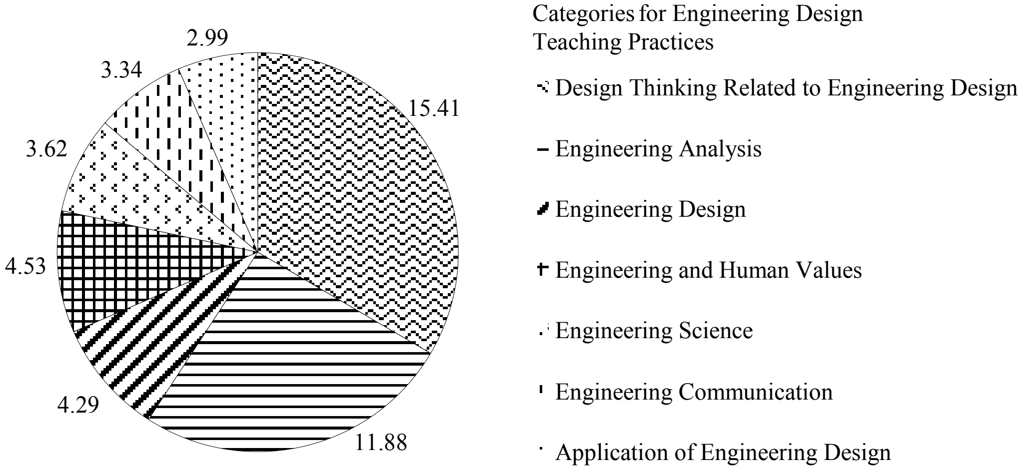

Figure 9: Composite score for traditional schedule

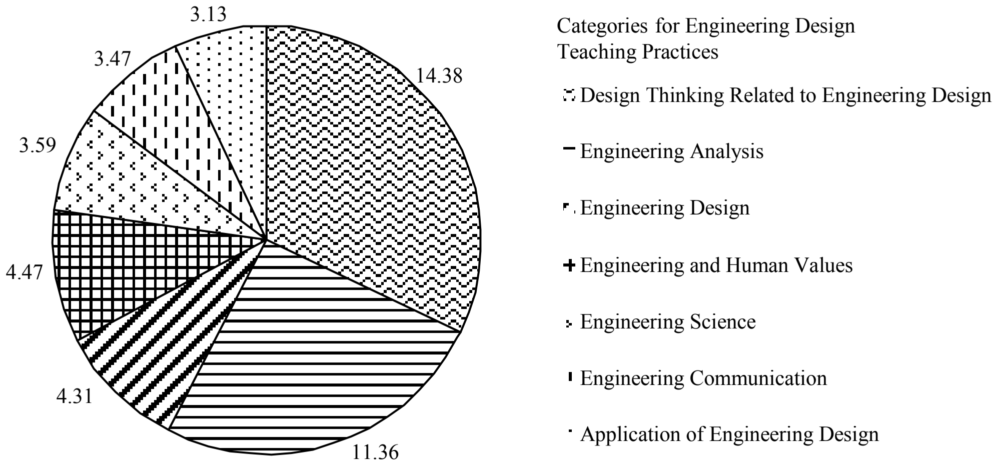

Figure 10: Composite score for block schedule

Table 25 displays the difference between the composite scores for total instructional hours between block scheduling and traditional scheduling. The total hour differences varied from the largest difference of 1.25 hours for the *Engineering and Human Values* category to as little as 0.02 of an hour for *Engineering Design* category. The differences between a traditional schedule and a block schedule were very minimal considering the total hours of instruction for a traditional schedule was 46.1 and 46.26 hours of instruction for a block schedule.

Table 25

Comparison of Difference of Total Hours between Traditional and Block Schedule for Engineering Design Content

	Overall			Female			Male		
Engineering Design Content Category	Total Hours Traditional Schedule	Total Hours Block Schedule	Difference	Total Hours Traditional Schedule	Total Hours Block Schedule	Difference	Total Hours Traditional Schedule	Total Hours Block Schedule	Difference
Application of Engineering Design	2.99	3.13	0.36	2.37	2.60	0.23	4.46	4.33	0.13
Engineering Communications	3.34	3.47	0.13	3.11	3.13	0.02	3.69	3.84	0.15
Engineering Science	3.62	3.59	0.03	2.79	2.86	0.07	7.06	6.63	0.43
Engineering and Human Values	4.53	4.47	1.25	4.04	4.04	0.00	5.15	4.83	0.33
Engineering Design	4.29	4.31	0.02	5.33	5.36	0.04	3.40	3.52	0.11
Engineering Analysis	11.88	11.36	0.52	13.29	12.87	0.42	8.86	8.30	0.56
Design Thinking Related to Engineering Design	15.41	14.38	1.03	13.35	2.60	0.62	19.49	17.83	1.66
Total	46.1	46.26	0.16	44.28	43.60	1.40	52.11	49.27	3.36

Assessment Practices for Engineering Design Projects

Table 26 shows the results of the *Assessment Practices for Engineering Design Projects* category. Respondents indicated their level of assessment practices as it related to engineering design projects. Overall mean scores measured by frequency of use in *Assessment Practices for Engineering Design Projects* section ranged from 1.55 to 2.38. Mean scores for time per typical use in the *Assessment Practices for Engineering Design Projects* section ranged from 1.67 to 2.37. The factor that participants agreed upon the most was “provide evidence of idea generation strategies (e.g. brainstorming, teamwork, et.”. Second was, “use support evidence/external research (research notes, illustrations, etc.)”. The item receiving the least support was “work on a design team worked as a functional interdisciplinary unit”. The mean scores measured by frequency of use ranged from 1.34 to 2.06 for females and 1.89 to 2.94 for males. Females and males agreed the most on “provide evidence of idea generation strategies (e.g. brainstorming, teamwork, etc.)”. Females agreed the least on “work on a design team, worked as a functional inter-disciplinary unit”. Males agreed the least on “develop a prototype model of the final design solution”. Total results can be reviewed in Table 26.

Table 26

Assessment Practices for Engineering Design Projects Results

Assessment Practices for Engineering Design Projects Content	Overall				Female				Male			
	M*f*	SD*f*	M Time	SD Time	M*f*	SD*f*	M Time	SD Time	M*f*	SD*f*	M Time	SD Time
use support evidence / external research (research notes, illustrations, etc)	2.31	1.733	2.37	1.762	1.98	1.839	1.89	1.738	2.89	1.369	3.22	1.476
provide evidence of formulating design criteria and constraints prior to designing solutions	1.86	1.826	1.94	1.841	1.63	1.839	1.56	1.651	2.28	1.750	2.61	1.990
use design criteria such as budget, constraints, criteria, safety, and functionality	1.74	1.744	1.92	1.851	1.59	1.823	1.59	1.752	2.00	1.586	2.50	1.905
provide evidence of idea generation strategies (e.g. brainstorming, teamwork, etc.)	2.38	1.797	2.55	1.872	2.06	1.798	2.00	1.737	2.94	1.672	3.53	1.715
properly record design information in an engineer's notebook	1.72	1.897	1.89	1.974	1.53	1.902	1.56	1.816	2.06	1.866	2.47	2.131
use mathematical models to optimize, describe, and/or predict results	2.10	1.714	2.19	1.762	1.84	1.784	1.75	1.652	2.56	1.501	2.97	1.699
develop a prototype model of the final design solution	1.68	1.869	1.86	1.990	1.56	1.798	1.61	1.778	1.89	1.997	2.31	2.278
work on a design team worked as a functional inter-disciplinary unit	1.55	1.648	1.67	1.804	1.34	1.616	1.34	1.625	1.92	1.663	2.25	1.977
Total Group Mean	1.92		2.05		1.69		1.66		2.32		2.73	

The composite score for assessment practices was computed in the same manner as teaching practices for engineering design. Figures 11 and 12 represent the total number of hours in a given school year for each of the assessment practices of engineering design projects for block scheduling and traditional scheduling.

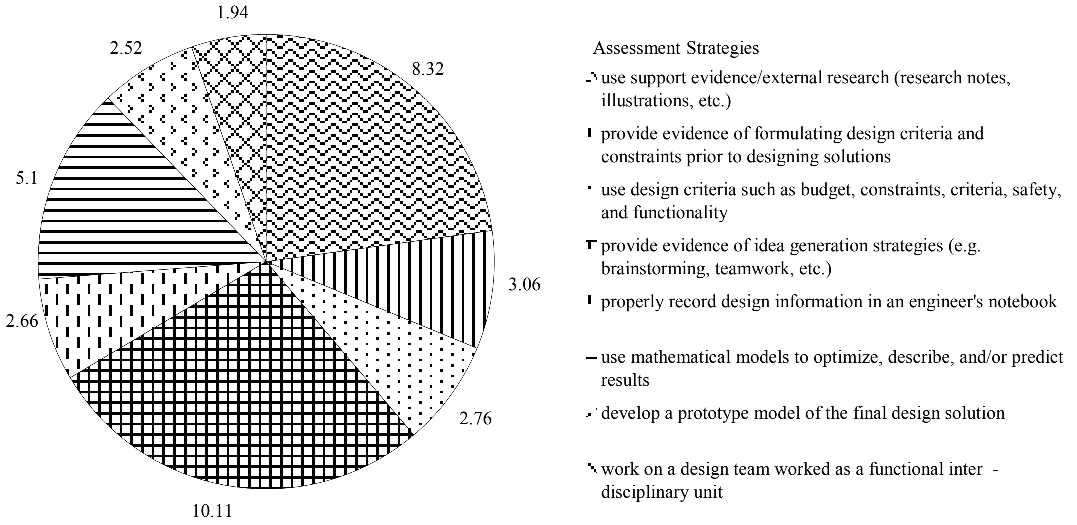

Figure 11: Composite score for Assessment Strategies for Traditional Schedule

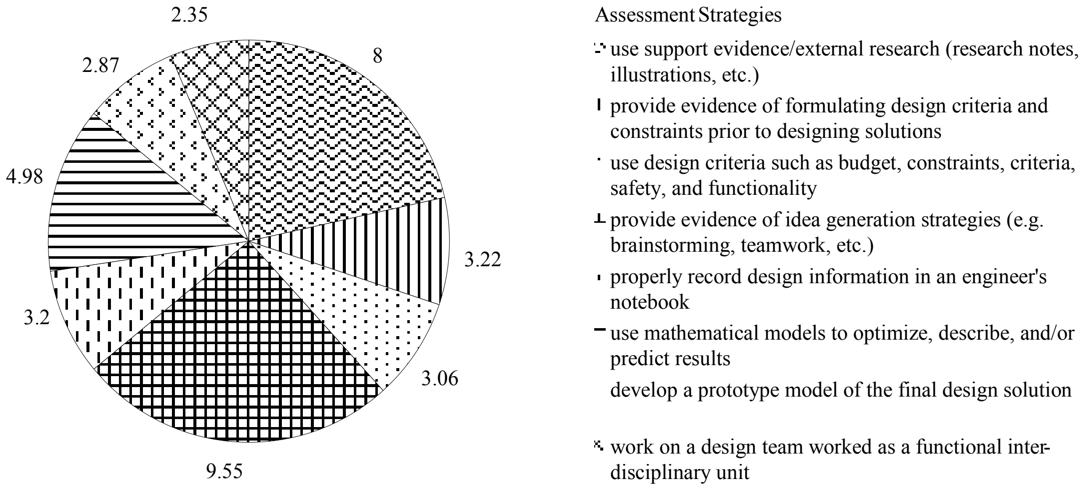

Figure 12: Composite score for assessment strategies for block schedule

Table 27 displays the difference between the composite scores for each of the assessment strategies between block scheduling and traditional scheduling. The total hour differences varied from the largest difference of 0.56 hours for the "provide evidence of idea generation strategies (e.g. brainstorming, teamwork, etc.) category to as little as 0.12 of an hour for " use mathematical models to optimize, describe, and/or predict results". The differences between a traditional schedule and a block schedule were very minimal considering the total hours of instruction for a traditional schedule was 36.47 and 46.26 hours of instruction for a block schedule.

Table 27

Comparison of differences of total hours between traditional and block schedule for assessment practices

	Overall			Female			Male		
Engineering Design Assessment Strategies	Total Hours Traditional Schedule	Total Hours Block Schedule	Difference	Total Hours Traditional Schedule	Total Hours Block Schedule	Difference	Total Hours Traditional Schedule	Total Hours Block Schedule	Difference
use support evidence / external research (research notes, illustrations, etc)	8.32	8.00	0.32	3.20	3.21	0.01	15.12	21.39	6.27
provide evidence of formulating design criteria and constraints prior to designing solutions	3.06	3.22	0.16	1.89	2.17	0.28	6.99	8.40	1.41
use design criteria such as budget, constraints, criteria, safety, and functionality	2.76	3.06	0.3	1.87	2.20	0.33	4.67	4.38	0.29
provide evidence of idea generation strategies (e.g. brainstorming, teamwork, etc.)	10.11	9.55	0.56	3.82	4.13	0.32	17.04	25.37	8.33
properly record design information in an engineer's notebook	2.66	3.20	0.54	1.73	2.10	0.37	5.01	5.10	0.09
use mathematical models to optimize, describe, and/or predict results	5.10	4.98	0.12	2.62	2.76	0.14	10.60	13.93	3.32
develop a prototype model of the final design solution	2.52	2.87	0.35	1.86	2.22	0.38	3.92	3.92	0.01
work on a design team worked as a functional inter-disciplinary unit	1.94	2.35	0.41	1.13	1.53	0.4	3.87	3.85	0.03
Total Group Mean	36.47	37.23	0.76	18.10	20.32	2.22	67.23	86.33	19.1

Table 28 shows the results of the *Teacher Challenges Infusing Engineering Design* category, the ninth category presented in the instrument. In this section respondents did not consider the frequency or time per typical use of implementing strategies. Respondents indicated their level of experience with fourteen selected teacher challenges using a five-point Likert scale (0 = Never, 1 = Rarely, 2 = Sometimes, 3 = Very Often, and 5 = Always). The challenge that participants agreed upon the most was "integrating the appropriate levels of math and science into instructional content". Second was, "obtaining support from math and science faculty". The item considered to be the least challenging was "acquiring funding to purchase materials to teach engineering design networking with practicing engineers for consultation". The item considered to be the most challenging for females and males was "integrating the appropriate levels of math and science into instructional content". The item considered to be the least challenging for females was "acquiring funding to purchase tools and equipment to teach engineering design". The item considered to be the least challenging for males was "obtaining parent support to implement engineering". "Total results can be reviewed in Table 28.

Table 28

Teacher Challenges Infusing Engineering Design Results

Teacher Challenges Infusing Engineering Design Content	Overall		Female		Male	
	Mf	SD	*Mf*	SD	*Mf*	SD
integrating the appropriate levels of math and science into instructional content	2.48	1.275	2.36	1.302	2.69	1.215
locating and learning the appropriate levels of math and science to teach engineering design	1.96	1.428	1.70	1.388	2.42	1.402
locating and learning knowledge of engineering fundamentals (statics, fluid mechanics, dynamics)	1.80	1.470	1.50	1.333	2.33	1.568
locating appropriate textbooks to teach engineering design	1.62	1.509	1.03	1.195	2.67	1.454
locating the appropriate laboratory equipment to teach engineering design	1.69	1.454	1.30	1.422	2.39	1.248
locating the appropriate laboratory layout and space to teach engineering design	1.56	1.452	1.27	1.417	2.08	1.381
acquiring funding to purchase tools and equipment to teach engineering design	1.36	1.501	0.95	1.302	2.08	1.574
acquiring funding to purchase materials to teach engineering design	1.35	1.591	0.94	1.457	2.08	1.574
networking with practicing engineers for consultation	1.51	1.446	1.03	1.272	2.36	1.355
obtaining support from math and science faculty	2.05	1.466	1.81	1.542	2.47	1.230
obtaining support from school administration and school counselors	1.84	1.398	1.80	1.449	1.92	1.317
obtaining support to promote engineering design course by school administration	1.42	1.401	1.09	1.40	2.00	1.219
obtaining community support to implement engineering design courses	1.64	1.567	1.23	1.54	2.36	1.355
obtaining parent support to implement engineering design course	1.37	1.412	1.13	1.374	1.81	1.390
Total Group Mean	1.69		1.37		2.26	

EDSE Survey Results

The EDSE Survey references an individual's self-conception toward conducting engineering design and the eight-step process proposed by the Massachusetts Department of Engineering (DoE) Science and Technology/Engineering Curriculum Framework (Massachusetts DoE, 2001/2006). The survey measures these nine steps for four task-specific self-concepts. A task-specific self-concept is any variable concerning the understanding an individual has of him or herself for a specific task. Understanding of self leads to desire, or lack thereof, to complete a specific task. According to self-efficacy theory, an individual's level of self-efficacy is influenced by other self-concepts such as motivation, expectancy of success, and anxiety in completing that task. The four task-specific self-concepts measured in the survey were self-efficacy, motivation, expectancy of success, and anxiety.

Table 29 displays the nine-item scale developed for each task-specific self-concept. The first item in Table 29 represents the respondent's ED score and the other eight items represent the eight steps of the engineering design process: identify a design need, research a design need, develop a design solution, select the best possible design, construct a prototype, evaluate and test a design, communicate a design, and redesign.

Table 29

Generic scale used to represent the engineering design domain

Rate your degree of (FILL IN TASK-SPECIFIC SELF-CONCEPT OF INTEREST) to perform the following tasks by recording a number from 0 to 100 (0 = low; 50 = moderate; 100 = high)

	0	10	20	30	40	50	60	70	80	90	100
Conduct engineering design	○	○	○	○	○	○	○	○	○	○	○
Identify a design need	○	○	○	○	○	○	○	○	○	○	○
Research a design need	○	○	○	○	○	○	○	○	○	○	○
Develop design solutions	○	○	○	○	○	○	○	○	○	○	○
Select the best possible design	○	○	○	○	○	○	○	○	○	○	○
Construct a prototype	○	○	○	○	○	○	○	○	○	○	○
Evaluate and test a design	○	○	○	○	○	○	○	○	○	○	○
Communicate a design	○	○	○	○	○	○	○	○	○	○	○
Redesign	○	○	○	○	○	○	○	○	○	○	○

The inter-item reliability of each of the engineering design process (EDP) steps for each of the task-specific self-concepts was analyzed separately using Cronbach's internal consistency coefficient alpha. The instrument had an overall Cronbach's α reliability of 0.965. The Cronbach's alpha values for self-efficacy (0.988), motivation (0.995), expectancy of success (0.991), and anxiety (0.987) show a high reliability among the eight steps for each task-specific self-concept. A random subset of the respondents were tested to ensure that the reliability of the instrument was not affected by gender. Table 30 displays the Cronbach's alpha values for the females, males, and overall subset. The high reliability among the gender and non-gender analysis for each of the EDP steps for each of the task-specific self-concepts shows overall agreement of the respondents across the eight steps for each task-specific self-concept.

Table 30

Gender-specific reliability analysis of the four task-specific self-concepts

Task-specific self-concepts	Female (n = 21)	Male (n = 12)	Overall (n = 33)
Self-Efficacy	0.981	0.979	0.982
Motivation	0.989	0.999	0.994
Expectancy of success	0.997	0.981	0.993
Anxiety	0.995	0.979	0.988

The high inter-item reliabilities indicate that a factor analysis was necessary to determine the following: (1) number of factors present among the EDP steps for each of the task-specific self-concepts, and (2) number of factors present for each individual EDP step across the four task-specific self-concepts. Factor analysis in both cases was done using varimax rotation with Kaiser normalization and factors were selected where the eigenvalues were greater than one. Factor analysis for the EDP steps for each of the task-specific self-concepts revealed one factor with an eigenvalue greater than one. The EDP factor (self-concept) score is an average of the eight individual EDP steps resulting in EDP Self-Efficacy, EDP Motivation, EDP Success, and EDP Anxiety. A second factor analysis was done to ensure that the same EDP step was present across the four task-specific self-concepts. The factor analysis of each individual EDP step revealed one factor across the four task-specific self-concepts.

Pearson correlations were calculated between the ED score (respondent's self-conception toward conducting engineering design) and the EDP factor scores. The strong positive correlations for self-efficacy (0.770), motivation (0.962), expectancy of success (0.924), and anxiety (0.809) were significant at the $p < 0.01$ level. The purpose of calculating the correlations was to determine whether the eight steps defined by the Massachusetts Department of Education accurately represent engineering design. Each step of the engineering design process had a strong positive correlation to each of the engineering design constructs at the significance level of $p < 0.01$.

This study hypothesized that individuals with high levels of engineering experience would have overall high levels of self-efficacy and individuals with low levels of engineering experience would have overall low levels of self-efficacy. Respondents were divided into three groups based on level of engineering design self-efficacy. The three groups were high self-efficacy, intermediate self-efficacy, and low self-efficacy. The following groups resulted:

> *High self-efficacy (n =37)* – respondents who majored in engineering, teach technology or engineering courses, or have certification in vocational education.
>
> *Intermediate self-efficacy (n =44)* – respondents who did not major in engineering or technology but have a science background, teach science, or have a science certification.

Low self-efficacy (n =19) – respondents with little to no engineering experience. The mean ED factor scores were compared for the three groups.

A one-way ANOVA comparing the respondent's self-conception toward conducting engineering design for each of the task-specific self-concepts was compared for the three groups. A significant difference was found among the three groups for all four task-specific self-concepts ($F_{self\text{-}efficacy}(2,97) = 52.619$, $p < 0.001$; $F_{motivation}(2,97) = 52.247$, $p < 0.001$; $F_{success}(2,97) = 74.207$; $F_{anxiety}(2,97) = 28.649$, $p < 0.001$). Tukey's HSD was used to determine the nature of the differences between the groups. This analysis revealed that the mean scores for self-efficacy, motivation, expectancy of success, and anxiety (Table 31) were significantly different at the $p < 0.01$ level among all three groups with the following exceptions: the Intermediate Self-Efficacy and Low Self-Efficacy groups were statistically significant at the $p < 0.05$ level for all four task-specific self-concepts.

Table 31

Mean ED scores with standard deviations for experience analysis

	Self-Efficacy		Motivation		Expectancy of success		Anxiety	
Group	M	SD	M	SD	M	SD	M	SD
High	78.38	23.28	75.95	21.92	74.86	21.94	19.73	19.07
Intermediate	43.64	16.58	41.59	16.13	38.41	12.56	42.5	22.32
Low	23.68	22.66	24.74	21.95	21.05	16.63	64.74	24.58

A one-way ANOVA comparing the respondent's self-conception toward the eight individual engineering design steps for each of the task-specific self-concepts was compared for the three groups. A significant difference was found among the three groups for all four task-specific self-concepts ($F_{self\text{-}efficacy}(2,97) = 58.740$, $p < 0.001$; $F_{motivation}(2,97) = 35.851$, $p < 0.001$; $F_{success}(2,97) = 45.418$; $F_{anxiety}(2,97) = 25.204$, $p < 0.001$). Tukey's HSD was used to determine the nature of the differences between the groups. This analysis revealed that the mean scores for self-efficacy, motivation, expectancy of success, and anxiety (Table 32) were significantly different at the $p < 0.01$ level among all three groups with the following exception: the Intermediate Self-Efficacy and Low Self-Efficacy groups were not statistically significant for motivation ($p = 0.054$).

Table 32

Mean EDP scores with standard deviations for experience analysis

	Self-Efficacy		Motivation		Expectancy of success		Anxiety	
Group	M	SD	M	SD	M	SD	M	SD
High	82.60	15.83	80.57	21.36	80.98	19.30	22.26	17.24
Intermediate	48.64	17.78	46.70	19.72	46.25	17.15	47.67	26.55
Low	29.41	25.68	32.04	30.69	32.43	28.20	67.5	27.12

Pearson correlations were computed to investigate the relationships between self-efficacy and the remaining task-specific self-concepts in this study. Motivation, expectancy of success, and anxiety were all statistically significant with self-efficacy at the $p < 0.01$ level. This result confirms the self-efficacy theory predictions that an individual's level of self-efficacy is influenced by other self-concepts such as motivation, expectancy of success, and anxiety in completing that task. Motivation (0.832) and expectancy of success (0.878) were positively correlated and anxiety (-0.480) was negatively correlated to self-efficacy. This suggests that individuals with low self-efficacy toward engineering design could not be motivated or successful in engineering. Also, the negative correlation of anxiety to self-efficacy does not necessarily suggest that anxiety is eliminated from respondent's with a high self-efficacy.

Research Questions

Research Question One

1. To what extent do motivation, expectancy for success, and anxiety influence engineering design self-efficacy of secondary STEM educators?

To answer this research question, stepwise regression model was developed. Two variables were found to be significant in explaining engineering design self-efficacy among participants in the study. The two variables were found to contribute 78.2% of variance in EDSE: motivation and success. Such a finding suggests that those participants who have a higher engineering design self-efficacy have a higher motivation and success to conduct activities. The regression was done by entering all of the background variables in a forward stepwise manner. This process yielded two models indicating two significant variables.

In model one EDSuccess was the most significant predictor variable ($F(1,98) = 329.992$, $p < 0.05$). The beta weight was $\beta = 0.878$, $p < 0.05$. The adjusted R^2 value was 0.769 (see Table 33). In model two the variable EDMotivation was added to EDSuccess, yielding $F(2,97) = 179.023$, $p < 0.05$. The adjusted R^2 value improved to 0.782. A detailed summary of both models is shown in Table 34.

Table 33

Engineering design self-efficacy model summary

Model	R	R Square	Adjusted R Square	F	Sig.
1	0.878	0.771	0.769	329.992	.000(a)
2	0.887	0.787	0.782	179.023	.000(b)

a Predictors: (Constant), EDSuccess
b Predictors: (Constant), EDSuccess, EDMotivation
c Dependent Variable: EDSelfEfficacy

Table 34

Engineering design self-efficacy model showing combination of each variable

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	6.956	2.884		2.412	.018
	EDSuccess	.941	.052	.878	18.166	.000
2	(Constant)	4.926	2.897		1.700	.092
	EDSuccess	.693	.105	.646	6.572	.000
	EDMotivation	.276	.103	.264	2.682	.009

a Dependent Variable: EDSelfEfficacy

Research Question Two

2. To what extent do self-efficacy, motivation, expectancy for success, and anxiety influence the knowledge base of STEM educators?

To answer the second research question one-way Multivariate Analysis of Variance (MANOVA) was performed. The MANOVA was done to determine the association between the engineering design task-specific self-concepts and engineering design knowledge base. Similar to research question one a forward stepwise approach was taken. The Wilks' Lambda statistic was used to demonstrate the amount of variance accounted for in the dependent variable by the independent variable; the smaller the value, the larger the distance between the groups being analyzed. The results for question two indicated that EDConfidence ($F(44,55) = 11.486$, $p < .05$), EDMotivation ($F(44,55) = 16.466$, $p < .05$), EDSuccess ($F(26,73) = 2.663$, $p < .05$), and EDAnxiety ($F(80,19) = 9.155$, $p < .05$) were all significant ($p < .05$), so it can be concluded that the engineering design task-specific concepts had a significant effect on the engineering design knowledge base. However, the interactions of the independent variables did not have a significant effect on the engineering design knowledge base. A detailed summary is shown in Table 35.

Table 36 provides more detail as to the effect of the engineering design task-specific self-concepts on each component of engineering design knowledge base of STEM educators. EDConfidence, EDMotivation, EDSuccess, and EDAnxiety accounted for 89.8% of the variance on EDFreq, 95.2% of the variance on EAFreq, 94.1% of the variance on AEDFreq, 94.7% of the variance on ECFreq, 93.8% of the variance on DTFreq, 84.3% of the variance on EHVFreq, 95.4% of the variance on ESFreq, 95.4% of the variance on APFreq, and 84.5% of the variance on CIED. EDConfidence had a significant effect on EDFreq ($F(4,95) = 3.018$, $p < .05$), AEDFreq ($F(4,95) = 3.818$, $p < .05$), ECFreq ($F(4,95) = 4.45$, $p < .05$), ESFreq ($F(4,95) = 3.147$, $p < .05$), and APFreq ($F(4,95) = 7.223$, $p < .05$). EDMotivation had a significant effect on AEDFreq ($F(4,95) = 2.786$, $p < .05$), ECFreq ($F(4,95) = 4.888$, $p < .05$), DTFreq ($F(4,95) = 5.851$, $p < .05$), ESFreq ($F(4,95) = 3.729$, $p < .05$) and APFreq ($F(4,95) = 5.984$, $p < .05$). EDSuccess had a significant effect on AEDFreq ($F(2,97) = 3.513$, $p < .05$), and ESFreq ($F(2,97) = 3.963$, $p < .05$). EDAnxiety had a significant effect on EDFreq ($F(8,91) = 4.515$, $p < .05$), EAFreq ($F(8,91) = 5.736$, $p < .05$), AEDFreq ($F(8,91) = 5.060$, $p < .05$), ECFreq

($F(8,91) = 4.810$, $p < .05$), DTFreq ($F(8,91) =5.207$, $p < .05$), EHVFreq ($F(8,91) = 2.527$, $p < .05$), ESFreq ($F(8,91) = 4.693$, $p < .05$) and APFreq ($F(8,91) = 6.151$, $p < .05$).

Table XXXV

Multivariate Test (General Interpretation)

Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	.997	694.935(a)	9.000	21.000	.000
	Wilks' Lambda	.003	694.935(a)	9.000	21.000	.000
	Hotelling's Trace	297.829	694.935(a)	9.000	21.000	.000
	Roy's Largest Root	297.829	694.935(a)	9.000	21.000	.000
EDConfidence	Pillai's Trace	2.819	3.591	45.000	125.000	.000
	Wilks' Lambda	.000	11.486	45.000	97.041	.000
	Hotelling's Trace	173.471	74.785	45.000	97.000	.000
	Roy's Largest Root	166.211	461.698(b)	9.000	25.000	.000
EDMotivation	Pillai's Trace	3.003	4.178	45.000	125.000	.000
	Wilks' Lambda	.000	16.466	45.000	97.041	.000
	Hotelling's Trace	245.888	106.005	45.000	97.000	.000
	Roy's Largest Root	232.347	645.409(b)	9.000	25.000	.000
EDSuccess	Pillai's Trace	2.539	14.065	27.000	69.000	.000
	Wilks' Lambda	.001	23.663	27.000	61.973	.000
	Hotelling's Trace	60.967	44.408	27.000	59.000	.000
	Roy's Largest Root	53.225	136.019(b)	9.000	23.000	.000
EDAnxiety	Pillai's Trace	3.983	2.559	81.000	261.000	.000
	Wilks' Lambda	.000	9.155	81.000	144.682	.000
	Hotelling's Trace	286.791	68.059	81.000	173.000	.000
	Roy's Largest Root	266.259	857.946(b)	9.000	29.000	.000

a Exact statistic
b The statistic is an upper bound on F that yields a lower bound on the significance level.
c Design: Intercept+EDConfidence+EDMotivation+EDSuccess+EDAnxiety

Table 36

Tests of Between Subjects-Effects Test (General Interpretation)

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	EDFreq	149.623(a)	67	2.233	3.801	.000
	EAFreq	172.257(b)	67	2.571	8.523	.000
	AEDFreq	177.184(c)	67	2.645	6.859	.000
	ECFreq	168.821(d)	67	2.520	7.805	.000
	DTFreq	169.366(e)	67	2.528	6.573	.000
	EHVFreq	220.578(f)	67	3.292	2.317	.007
	ESFreq	278.481(g)	67	4.156	8.893	.000
	APFreq	227.112(h)	67	3.390	9.019	.000
	CIED	121.332(i)	67	1.811	2.353	.006
Intercept	EDFreq	243.616	1	243.616	414.645	.000
	EAFreq	381.195	1	381.195	1263.675	.000
	AEDFreq	183.216	1	183.216	475.196	.000
	ECFreq	219.788	1	219.788	680.767	.000
	DTFreq	371.864	1	371.864	966.892	.000
	EHVFreq	205.959	1	205.959	144.958	.000
	ESFreq	208.211	1	208.211	445.499	.000
	APFreq	180.799	1	180.799	481.061	.000
	CIED	138.535	1	138.535	180.025	.000
EDConfidence	EDFreq	8.866	5	1.773	3.018	.026
	EAFreq	3.838	5	.768	2.545	.050
	AEDFreq	7.361	5	1.472	3.818	.009
	ECFreq	7.183	5	1.437	4.450	.004
	DTFreq	4.527	5	.905	2.354	.066
	EHVFreq	11.241	5	2.248	1.582	.196
	ESFreq	7.354	5	1.471	3.147	.022
	APFreq	13.573	5	2.715	7.223	.000
	CIED	5.196	5	1.039	1.350	.272
EDMotivation	EDFreq	6.511	5	1.302	2.216	.080
	EAFreq	3.939	5	.788	2.611	.046
	AEDFreq	5.371	5	1.074	2.786	.036
	ECFreq	7.890	5	1.578	4.888	.002
	DTFreq	11.251	5	2.250	5.851	.001
	EHVFreq	8.783	5	1.757	1.236	.318
	ESFreq	8.714	5	1.743	3.729	.010
	APFreq	11.245	5	2.249	5.984	.001
	CIED	1.535	5	.307	.399	.845
EDSuccess	EDFreq	2.046	3	.682	1.161	.342
	EAFreq	.022	3	.007	.024	.995
	AEDFreq	4.063	3	1.354	3.513	.028
	ECFreq	1.840	3	.613	1.900	.152
	DTFreq	2.603	3	.868	2.256	.103
	EHVFreq	4.641	3	1.547	1.089	.369

"Table 36 (continued)"

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
	ESFreq	5.557	3	1.852	3.963	.018
	APFreq	2.071	3	.690	1.837	.162
	CIED	5.438	3	1.813	2.355	.092
EDAnxiety	EDFreq	23.875	9	2.653	4.515	.001
	EAFreq	15.573	9	1.730	5.736	.000
	AEDFreq	17.560	9	1.951	5.060	.000
	ECFreq	13.977	9	1.553	4.810	.001
	DTFreq	18.023	9	2.003	5.207	.000
	EHVFreq	32.313	9	3.590	2.527	.028
	ESFreq	19.740	9	2.193	4.693	.001
	APFreq	20.805	9	2.312	6.151	.000
	CIED	7.178	9	.798	1.036	.436
Error	EDFreq	17.038	29	.588		
	EAFreq	8.748	29	.302		
	AEDFreq	11.181	29	.386		
	ECFreq	9.363	29	.323		
	DTFreq	11.153	29	.385		
	EHVFreq	41.204	29	1.421		
	ESFreq	13.554	29	.467		
	APFreq	10.899	29	.376		
	CIED	22.316	29	.770		
Total	EDFreq	583.167	97			
	EAFreq	794.778	97			
	AEDFreq	525.769	97			
	ECFreq	525.531	97			
	DTFreq	837.280	97			
	EHVFreq	685.222	97			
	ESFreq	703.891	97			
	APFreq	611.156	97			
	CIED	434.122	97			
Corrected Total	EDFreq	166.662	96			
	EAFreq	181.005	96			
	AEDFreq	188.366	96			
	ECFreq	178.184	96			
	DTFreq	180.520	96			
	EHVFreq	261.781	96			
	ESFreq	292.035	96			
	APFreq	238.011	96			
	CIED	143.648	96			

a R Squared = .898 (Adjusted R Squared = .662)
b R Squared = .952 (Adjusted R Squared = .840)
c R Squared = .941 (Adjusted R Squared = .804)
d R Squared = .947 (Adjusted R Squared = .826)
e R Squared = .938 (Adjusted R Squared = .795)
f R Squared = .843 (Adjusted R Squared = .479)
g R Squared = .954 (Adjusted R Squared = .846)
h R Squared = .954 (Adjusted R Squared = .848)
i R Squared = .845 (Adjusted R Squared = .486)

Research Question Three

3. To what extent do the demographic variables (college major, highest degree, certification area, gender, and years of teaching) influence the engineering design self-efficacy of STEM educators?

The results of the univariate analysis for question three indicated that five demographic variables were significant in explaining engineering design self-efficacy among participants in the study. The five variables were found to contribute 33.5% of variance in EDSE: years of teaching technology, years of teaching engineering, years of teaching math, certification in vocational education, and certification in computer literacy. Such a finding suggests that those participants who have a higher engineering design self-efficacy is influenced by years of teaching technology, engineering, or math, and certification in vocational education or computer literacy.

In model one YrsTeachingTech was the most significant predictor variable ($F(1,96) = 12.814$, $p < 0.05$). The beta weight was $\beta = 0.343$, $p < 0.05$. The adjusted R^2 value was 0.109 (see Table 37). In model two the variable YrsTeachingEngr was added to YrsTeachingTech, yielding $F(2,95) = 13.110$, $p < 0.05$. The adjusted R^2 value improved to 0.200. In model three the variable YrsTeachingMath was added yielding $F(3,94) = 13.125$, $p < 0.05$. The adjusted R^2 value improved to 0.273. In model four the variable VocEdCert was added yielding $F(4,93) = 11.916$, $p < 0.05$. The adjusted R^2 value improved to 0.310. In the final model the variable CompLitCert was added yielding $F(5,92) = 10.756$, $p < 0.05$. The adjusted R^2 value improved to 0.335. A detailed summary of the five models is shown in Table 38.

Table 37

Engineering design self-efficacy model showing combination of each demographic variable

Model	R	R Square	Adjusted R Square	F	Sig.
1	0.343	0.118	0.109	12.814	.001(a)
2	0.465	0.216	0.200	13.110	.000(b)
3	0.543	0.295	0.273	13.125	.000(c)
4	0.582	0.339	0.310	11.916	.000(d)
5	0.607	0.369	0.335	10.756	.000(e)

a Predictors: (Constant), YrsTeachingTech
b Predictors: (Constant), YrsTeachingTech, YrsTeachingEngr
c Predictors: (Constant), YrsTeachingTech, YrsTeachingEngr, YrsTeachingMath
d Predictors: (Constant), YrsTeachingTech, YrsTeachingEngr, YrsTeachingMath, VocEdCert
e Predictors: (Constant), YrsTeachingTech, YrsTeachingEngr, YrsTeachingMath, VocEdCert, CompLitCert
f Dependent Variable: EDConfidence

Table 38

Engineering design self-efficacy model showing combination of each demographic variable

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	48.361	3.075		15.728	.000
	YrsTeachingTech	2.271	.634	.343	3.580	.001
2	(Constant)	46.350	2.971		15.602	.000
	YrsTeachingTech	2.400	.602	.363	3.986	.000
	YrsTeachingEngr	2.647	.766	.315	3.456	.001
3	(Constant)	50.602	3.121		16.215	.000
	YrsTeachingTech	2.537	.576	.383	4.406	.000
	YrsTeachingEngr	2.499	.732	.297	3.415	.001
	YrsTeachingMath	-.922	.284	-.282	-3.244	.002
4	(Constant)	49.818	3.055		16.306	.000
	YrsTeachingTech	2.517	.561	.380	4.489	.000
	YrsTeachingEngr	9.315	2.842	1.107	3.277	.001
	YrsTeachingMath	-.956	.277	-.292	-3.448	.001
	VocEdCert	-173.378	69.988	-.837	-2.477	.015
5	(Constant)	50.015	3.003		16.657	.000
	YrsTeachingTech	2.789	.566	.421	4.929	.000
	YrsTeachingEngr	8.940	2.798	1.062	3.196	.002
	YrsTeachingMath	-.806	.281	-.247	-2.866	.005
	VocEdCert	-164.581	68.878	-.795	-2.389	.019
	CompLitCert	-22.593	10.793	-.185	-2.093	.039

a Dependent Variable: EDConfidence

Research Question Four

4. To what extent do the demographic variables (college major, highest degree, certification area, gender, and years of teaching) influence the knowledge base of STEM educators?

The results of the one-way Multivariate Analysis of Variance (MANOVA) for question four indicated that three demographic variables were significant in explaining the knowledge base of STEM educators: undergraduate major, highest degree obtained, and age. There was not a statistical significant difference in the instructional time devoted to teaching in the following areas:

- Engineering design between participants who majored in business and social science, business and science, science and social science, and education and arts and humanities.
- Engineering analysis between participants who majored in education and technology, education and arts and humanities, technology and engineering, technology and arts and humanities, and engineering and arts and humanities.
- Application of engineering design between participants who majored in science and arts and humanities, and technology and engineering.
- Engineering communications between participants who majored in education and business, and technology and engineering.
- Design thinking related to engineering design between participants who majored in education and science, education and arts and humanities, science and arts and

humanities, technology and engineering, and social science and arts and humanities.

- Engineering and human values between participants who majored in education and engineering, business and arts and humanities, science and social science, and engineering and education.
- Engineering science between participants who majored in education and social science.
- Assessment strategies between participants who majored in business and math and science and engineering.
- Challenges in infusing engineering design between participants who majored in education and arts and humanities, science and engineering, technology and social science, technology and arts and humanities, engineering and arts and humanities, and social science and arts and humanities.

Table 39 provides detail as to the effect of the demographic variables on each component of engineering design knowledge base of STEM educators. Undergraduate Major, highest degree obtained, and age accounted for 99.0% of the variance on EDFreq, 97.3% of the variance on EAFreq, 99.9% of the variance on AEDFreq, 99.5% of the variance on ECFreq, 97.8% of the variance on DTFreq, 99.2% of the variance on EHVFreq, 99.8% of the variance on ESFreq, 99.9% of the variance on APFreq, and 98.1% of the variance on CIED. Undergraduate major had a significant effect on EDFreq ($F(4, 95) = 153.73$, $p < .05$), EAFreq ($F(4, 95) = 71.676$, $p < .05$), AEDFreq ($F(4, 95) = 1362.519$, $p < .05$), ECFreq ($F(4, 95) = 358.171$, $p < .05$), DTFreq ($F(4, 95) =135.479$, $p < .05$), EHVFreq ($F(4, 95) = 221.754$, $p < .05$), ESFreq ($F(4, 95) = 937.087$, $p < .05$), APFreq ($F(4, 95) = 2498.565$, $p < .05$), and CIED ($F(4, 95) = 33.046$, $p < .05$). Highest degree had a significant effect on EDFreq ($F(1,98) = 34.146$, $p < .05$), EAFreq ($F(1,98) = 149.192$, $p < .05$), AEDFreq ($F(1,98) = 351.476$, $p < .05$), ECFreq ($F(1,98) = 87.869$, $p < .05$), DTFreq ($F(1,98) =17.357$, $p < .05$), EHVFreq ($F(1,98) = 108.974$, $p < .05$), ESFreq ($F(1,98) = 941.143$, $p < .05$), APFreq ($F(1,98) = 1536.619$, $p < .05$) and CIED ($F(1,98) = 144.276$, $p < .05$). Age had a significant effect on EDFreq ($F(10,89) = 198.854$, $p < .05$), EAFreq ($F(10,89) = 40.276$, $p < .05$), AEDFreq ($F(10,89) = 1524.288$, $p < .05$), ECFreq ($F(10,89) = 274.38$, $p < .05$), DTFreq ($F(10,89) = 98.891$, $p < .05$), EHVFreq ($F(10,89) = 303.118$, $p < .05$), ESFreq ($F(10,89) = 1024.679$, $p < .05$), APFreq ($F(10,89) = 3027.088$, $p < .05$), and CIED ($F(10,89) = 44.348$, $p < .05$).

Table 39

Tests of between-subjects effects test (General Interpretation)

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	EDFreq	164.691(a)	33	4.991	186.385	.000
	EAFreq	173.295(b)	33	5.251	66.736	.000
	AEDFreq	184.161(c)	33	5.581	1373.026	.000
	ECFreq	172.777(d)	33	5.236	336.842	.000
	DTFreq	175.581(e)	33	5.321	83.477	.000
	EHVFreq	250.715(f)	33	7.597	217.239	.000
	ESFreq	278.672(g)	33	8.445	1098.924	.000
	APFreq	231.168(h)	33	7.005	2532.208	.000
	CIED	137.921(i)	33	4.179	94.424	.000
Intercept	EDFreq	191.716	1	191.716	7160.005	.000
	EAFreq	248.319	1	248.319	3155.725	.000
	AEDFreq	145.354	1	145.354	35761.822	.000
	ECFreq	141.155	1	141.155	9081.324	.000
	DTFreq	306.685	1	306.685	4811.680	.000
	EHVFreq	115.865	1	115.865	3313.015	.000
	ESFreq	165.991	1	165.991	21600.975	.000
	APFreq	143.511	1	143.511	51876.459	.000
	CIED	105.506	1	105.506	2383.647	.000
HighestDegree	EDFreq	.914	1	.914	34.146	.000
	EAFreq	11.740	1	11.740	149.192	.000
	AEDFreq	1.429	1	1.429	351.476	.000
	ECFreq	1.366	1	1.366	87.869	.000
	DTFreq	1.106	1	1.106	17.357	.000
	EHVFreq	3.811	1	3.811	108.974	.000
	ESFreq	7.232	1	7.232	941.143	.000
	APFreq	4.251	1	4.251	1536.619	.000
	CIED	6.386	1	6.386	144.276	.000
Age	EDFreq	58.570	11	5.325	198.854	.000
	EAFreq	34.862	11	3.169	40.276	.000
	AEDFreq	68.150	11	6.195	1524.288	.000
	ECFreq	46.913	11	4.265	274.380	.000
	DTFreq	69.334	11	6.303	98.891	.000
	EHVFreq	116.609	11	10.601	303.118	.000
	ESFreq	86.615	11	7.874	1024.679	.000
	APFreq	92.115	11	8.374	3027.088	.000
	CIED	21.593	11	1.963	44.348	.000
UndergradMajorGroup	EDFreq	20.581	5	4.116	153.730	.000
	EAFreq	28.200	5	5.640	71.676	.000
	AEDFreq	27.690	5	5.538	1362.519	.000
	ECFreq	27.836	5	5.567	358.171	.000
	DTFreq	43.176	5	8.635	135.479	.000
	EHVFreq	38.777	5	7.755	221.754	.000

"Table 39 (continued)"

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
	ESFreq	36.005	5	7.201	937.087	.000
	APFreq	34.560	5	6.912	2498.565	.000
	CIED	7.313	5	1.463	33.046	.000
Error	EDFreq	1.633	61	.027		
	EAFreq	4.800	61	.079		
	AEDFreq	.248	61	.004		
	ECFreq	.948	61	.016		
	DTFreq	3.888	61	.064		
	EHVFreq	2.133	61	.035		
	ESFreq	.469	61	.008		
	APFreq	.169	61	.003		
	CIED	2.700	61	.044		
Total	EDFreq	576.917	95			
	EAFreq	791.167	95			
	AEDFreq	519.289	95			
	ECFreq	524.531	95			
	DTFreq	826.880	95			
	EHVFreq	653.111	95			
	ESFreq	678.891	95			
	APFreq	595.016	95			
	CIED	430.934	95			
Corrected Total	EDFreq	166.325	94			
	EAFreq	178.095	94			
	AEDFreq	184.409	94			
	ECFreq	173.725	94			
	DTFreq	179.469	94			
	EHVFreq	252.848	94			
	ESFreq	279.140	94			
	APFreq	231.337	94			
	CIED	140.621	94			

a R Squared = .990 (Adjusted R Squared = .985)
b R Squared = .973 (Adjusted R Squared = .958)
c R Squared = .999 (Adjusted R Squared = .998)
d R Squared = .995 (Adjusted R Squared = .992)
e R Squared = .978 (Adjusted R Squared = .967)
f R Squared = .992 (Adjusted R Squared = .987)
g R Squared = .998 (Adjusted R Squared = .997)
h R Squared = .999 (Adjusted R Squared = .999)
i R Squared = .981 (Adjusted R Squared = .970)

Summary

The results of the EEDCCAPSTE and EDSE surveys have been presented in this chapter. The sample, design of research instruments, data analysis, and findings of the research were presented in detail. The results of the study revealed the level of engineering design knowledge of participants, as well as the level of self-efficacy. Chapter V will discuss the relationship between engineering design knowledge base and self-efficacy in further detail.

CHAPTER V: SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

This chapter consists of a review of the rationale and conceptual framework of the study, a review of the statement of purpose and research question, followed by a review of the methodology used in the study. The review is followed by a discussion of the findings and the implications on how these results may be applied to practice and future research within the field of technology education and the STEM community.

Summary of the Study

Slightly over 400,000 students enrolled in U.S. engineering programs in 2003 and again in 2004 (BLS, 2009). In 2008 there was a need of 150,931 engineers but only 74,170 students graduated from U.S. engineering programs. A 10.1% increase in enrollment has been projected from 2008 to 2018 but retention has become increasingly critical since the number of students graduating from 4- or 5-yr engineering programs is significantly lower than the number of student enrolling in these programs. Due to these facts, researchers have investigated secondary STEM educators as a factor contributing to the attrition rate in collegial engineering programs. There have been a number of new programs that propose teaching engineering concepts or engineering design in technology education as a vehicle to address the standards for technological literacy. However, it was unclear as to the degree to which technology educators are implementing engineering design content into their curriculum. Therefore, research was needed to determine the knowledge base and self-efficacy STEM educators have in implementing engineering design content into their classrooms.

Conceptual Framework

The success of implementing or maintaining an engineering design focus in technology education is not only dependent on the programs ability to articulate that engineering design can generate a type of thinking that can be applied to many occupations, but the teachers self-efficacy as well. The conceptual framework for this study consisted of knowledge obtained from several studies (Asunda & Hill, 2007; Carberry, Ohland, & Lee, 2009; Childress & Rhodes, 2008; Gattie & Wicklein, 2007; Kelley, 2008; Smith, 2006). Three of the studies (Asunda & Hill, 2007; Childress & Rhodes, 2008; Smith, 2006) defined the content that should be taught in high school technology education classes, the outcomes for students completing a course in engineering design, and appropriate strategies for assessing engineering design activities. However, the results did not inform the field of technology education about the current status of implementing engineering design into technology education classrooms. Although Gattie & Wicklein (2007) identified a list of challenges commonly facing technology educators, questions still remained regarding how much time educators spent implementing engineering design into technology education classrooms. Kelley (2008) did inform the field of technology education regarding the frequency and how much time within a period educators spent implementing engineering design into technology education classrooms. However, Kelley (2008) did not inform the field of technology education on how the implementation of engineering design into technology education classrooms was connected to their engineering design self-efficacy. Carberry, Ohland, and Lee (2009) defined the elements to measure students' self-efficacy regarding engineering design, but did not make a connection to the engineering design outcomes for technology education. Results of this study added to the knowledge base and self-efficacy required to help implement engineering design into STEM classrooms, informed the field of technology education on what is currently happening in STEM classrooms, and informed the field of technology education on how self-efficacy in regards to engineering design impacts an individual's engineering design knowledge base.

Purpose and Research Questions

The purpose of this study was to gain knowledge regarding the degree to which STEM educators are implementing elements of engineering design and their level of self-efficacy in implementing engineering design in their curriculum. A total of 100 teachers from 16 secondary schools in a southern Louisiana school district responded to the survey that was used in this study. Factor analysis, pearsons correlation, step-wise regression analysis, one-way ANOVA, and one-way MANOVA tests were used to answer the research questions. The survey instruments gathered data about the degree to which engineering design concepts were incorporated into the curriculum content, assessment practices employed by secondary STEM educators, challenges to implementing engineering design concepts, and measurement of participants self-concepts toward engineering design tasks.

The study sought to answer the following questions:

1. To what extent do motivation, expectancy for success, and anxiety influence engineering design self-efficacy of secondary STEM educators?
2. To what extent do self-efficacy, motivation, expectancy for success, and anxiety influence the knowledge base of STEM educators?

3. To what extent do the demographic variables (college major, highest degree, certification area, gender, and years of teaching) influence the engineering design self-efficacy of STEM educators?
4. To what extent do the demographic variables (college major, highest degree, certification area, gender, and years of teaching) influence the knowledge base of STEM educators?

Methodology

This study investigated the relationship between engineering design self-efficacy, knowledge base, and demographic variables of STEM educators. Although programs have been developed that have implemented engineering content into the curriculum as a vehicle to teach the standards for technological literacy, little was known about the current status of this implementation in curriculum content. This study sought to describe the current engineering design content, assessment practices, and self-efficacy in completing engineering tasks.

Sample

Surveys were sent to 200 educators in a local southern Louisiana school district. One hundred responses were received, a 50.0% return. The sample consisted of secondary STEM educators, regardless of whether they indicated they were teaching engineering design in their classroom. Initially the rate of return was 1.6%. An incentive for a $100 gift card to a random respondent, and a $300 gift card to the school with the most respondents was provided by the researcher.

Measures

The first main section (questions 2 through 10) of the survey gathered data about the degree to which engineering design concepts were incorporated into curriculum content, assessment practices, and challenges in implementing. Seven categories were identified to address the engineering design concepts: (a) engineering design, (b) engineering analysis, (c) application of engineering design, (d) engineering communication, (e) design thinking related to engineering design, (f) engineering and human values, and (g) engineering science (Appendix). Respondents were required to respond to each curriculum category twice, once for the *frequency of use* and once for *typical time per use.* A six-point Likert scale was used with 0 representing never and 5 indicating daily for *frequency of use,* and almost all period for *time per typical use.* A table was provided with the survey detailing the breakdown of the Likert scale as it related to *frequency of use* and *time per typical use* (Table 24). This section also gathered data about the assessment practices (question 9 on the survey) used by STEM educators to evaluate engineering design activities. Respondents rated their level of agreement on eight individual instrument items in this section of the survey. The same six-point Likert scale was used as in the previous section. The last question of this section (question 10 on survey) of the survey gathered data about the identified teacher challenges related to implementing engineering design. Respondents rated their level of agreement on fourteen individual instrument items in this section of the survey. The following five-point Likert scale was used: Never = 0, Rarely = 1, Sometimes = 2, Very Often = 3, and Always = 4.

The second section (questions 11 – 14) of the survey gathered data about the degree of self-efficacy, motivation, expectancy of success, and anxiety related to conducting the engineering design process as well as each step of the engineering-design process. Respondents rated themselves on these task-specific self-concepts on a 10-point scale, where 0 = cannot do at all, 50 = moderately can do, and 100 = highly certain can do.

The final section of the survey instrument collected general demographic information of each participant. A total of twelve questions about participants teaching grade level, years of experience, courses taught, gender, age, highest college degree obtained, universities attended, undergraduate major, certification status, certification area, school setting, school size, and email address.

Limitations

The final results of this study yielded a total of 100 respondents; therefore, the results of this study cannot be generalized to the entire population. Although there are other studies that investigated the knowledge base and self-efficacy of STEM educators, there were a very limited number of studies that investigated the engineering design knowledge base and self-efficacy. In addition, in previous studies they were investigated in isolation of each other. This study was the first to have investigated the relationship between engineering design knowledge base and self-efficacy as defined here.

Summary of Results

Of the demographic variables in this study only eight were significant. For the third research question the participant's years of teaching technology, engineering, and math, and certification area (vocational education and computer literacy only) influenced engineering design self-efficacy. For the fourth research question the engineering design knowledge base of the participant's was influenced by their age, undergraduate major, and highest degree obtained. The fact that the remaining demographic variables were not significant within this study is not definitive proof that they are not contributors to the dependent variables in other circumstances. The variables that were not shown to add any value to the research questions were certification status, certification areas other than vocational education and computer literacy, and gender.

Engineering Design Curriculum Content

Humans are often asked to consider what they value most by identifying where the majority of their time is spent. Having educators identify how much time is spent on an instructional or assessment practice allowed educators to consider where the majority of their time is spent. For many STEM educators, the highest scoring group mean by category of engineering design curriculum measure by *time per typical use* was *Design Thinking Related to Engineering Design* with a group mean score of 2.73. Kelley (2008) found a similar group mean for this category, but *Engineering Communication* was the highest scoring group mean by category. This may not be a surprising result for many STEM educators because several individual items in this category relate to critical thinking, a skill necessary in all career fields. The highest mean score individual item measured by *time per typical use* was *think critically*. Another critical thinking related item was *have the ability to approach open-ended/ill-defined problems* with a mean score of 2.84, which was the third highest mean score individual item overall measured by *time per typical use.* This mean score indicated STEM educator responses fell between *1 or 2 times a month* and *1 or 2 times a week* (frequency) and between *less than half the period* and *about half the class period* (time). For STEM educators, the high mean score of this category is logical because emphasizing critical thinking skills is encouraged in all fields, especially the STEM fields in order to be successful. One conclusion that can be drawn from the results is that STEM educators are emphasizing engineering design by emphasizing critical thinking in instruction.

Another result of this study of particular interest for the field of technology education is that the second highest mean score item measure by *time per typical use* was *use basic computer applications such as word processors, spreadsheets, and presentation software* with a mean of 3.12. It appears that the field of technology education is emphasizing the use of electronic communication of engineering design in instruction. This may be surprising to educators that math educators are using these tools to communicate engineering design. The fourth highest mean score item measure by *time per typical use* was *develop basic students' skills in the use of tools* with a mean of 2.54. This item was the second highest mean score item in the study conducted by Kelly and Todd (2008). This mean score indicated STEM educator responses fell between *less than half the period* to *about half the class period* (time). The mean score for *frequency of use* for this item was 2.38. This mean score indicated STEM educator responses fell between *1 or 2 times a month* and *1 or 2 times a week* (frequency); which means that the field of technology is gradually moving away from its industrial arts roots. It is important that

STEM educators provide learning opportunities to develop basic tool skills. However, there must be a proper balance between instruction and tool skill development. Further research is necessary to identify which skills are being developed, what tools are being used in technology education programs, and if the learning opportunities related to these tools enhance the learning of engineering design.

The lowest group mean score categories based on composite scores for total instructional time were *Application of Engineering Design* (2.99 hours for traditional schedule; 3.13 hours for block schedule), *Engineering Communications* (3.34 hours for traditional schedule; 3.47 hours for block schedule), *Engineering Science* (3.62 hours for traditional schedule; 3.59 hours for block schedule), *Engineering Design* (4.29 hours for traditional schedule; 4.31 hours for block schedule), and *Engineering and Human Values* (4.53 hours for traditional schedule; 4.47 hours for block schedule) (Figures 9 and 10). Kelley (2008) found *Engineering and Human Values, Engineering Science, and Engineering Analysis* as the lowest group mean score categories. These low group mean scores indicate that the engineering design process is not being properly infused into the technology education classroom. Identifying the lowest mean scoring item in each category aids in understanding why these categories are low scoring. Individual items with low scoring mean including the items for *time per typical use* were *understand engineering design is an iterative process* (mean of 1.19), *apply the rules of dimensioning* (mean of 1.34), *apply knowledge for manufacturing products to the engineering design* (mean of 1.51), *apply knowledge of dynamics to the engineering design process* (mean of 1.74), and *apply knowledge of ergonomics to engineering design process* (mean of 1.77). In the study conducted by Gattie and Wicklein (2007) 90% of the technology educators indicated they were teaching engineering design. However, only 45.4% of their instructional content was related to engineering design. Gattie and Wicklein also found that teachers felt they needed to have the appropriate levels of math and science to teach engineering design and the fundamental knowledge of engineering science. The results of this study suggested that STEM educators are not emphasizing all the curriculum content in each category and do not have the necessary knowledge or self-efficacy to do so.

The lack of emphasis on engineering communication indicates STEM educators do not place much emphasis on computer-aided-design (CAD). This may be due to the fact that CAD is a very time-consuming technology topic and STEM educators may not have had the time to master the software and feel confident in teaching it.

The lack of emphasis placed on engineering science, engineering design, and application of engineering design in secondary technology programs may be the design process itself. Table 3 presented the differences between the engineering design process (Eide et. Al., 2001) compared with the technology design process as it appears in the Standards for Technological Literacy (ITEA, 2000). The major differences between the two processes are the absence of the analysis and optimization, and the emphasis of building a model or prototype in the technological design process. The key stages absent from the technological design process lead to a lack of instructional emphasis in those areas of the engineering design process. These results can also cause an individual to wonder if STEM educators had access to curriculum materials or textbooks that presented an engineering design process with emphasis on analysis and optimization. Based on the above results STEM educators must make a conscious effort to properly infuse engineering analysis and optimization into the curriculum content in order to provide students with an opportunity to meet the expectation of technology education standards.

Standards 4 through 6 of the Standards for Technological Literacy (2000/2002) identify the need to teach about the social, economical, and environmental issues related to the use of technology. Hill (2006) presented an argument for teaching the social aspects of engineering design. However, the lack of emphasis on *Engineering and Human Values* indicate STEM educators are not strong advocates for the teaching of social, economical, and environmental impacts of technology on society.

Assessment Practices

The top three individual assessment items based upon *time per typical* use were *provided evidence of idea generation strategies (e.g. brainstorming, teamwork, etc.)* (mean of 2.55), *use support evidence / external research (research notes, illustrations, etc.)* (mean of 2.37), and *use mathematical models to optimize, describe, and / or predict results* (mean of 2.19). All of the items in this category had a mean score less than three. The lowest mean score items were *work on a design team as a functional interdisciplinary unit* (mean of 1.67), *develop a prototype model of the final design solution* (mean of 1.86), *properly record design information in an engineer's notebook* (mean of 1.89), *use design criteria such as budget, constraints, criteria, safety, and functionality* (mean of 1.92), and *provide evidence of formulating design criteria and constraints prior to designing solutions* (mean of 1.94). The highest assessment item for frequency of use in this study was the same as in the study conducted by Kelley (2008). The results of the assessment practices indicate STEM educators did not place much emphasis on working as a design team, developing a prototype, properly recording information, using design criteria to design solutions, or providing evidence of design criteria and constraints prior to designing solutions.

Challenges

STEM educators in this study indicated the most challenging when infusing engineering design was *integrating the appropriate levels of math and science into instructional content* (mean of 2.48). The third highest mean score item was similar in context *locating and learning the appropriate levels of math and science to teach engineering design* (mean of 1.96). In the study conducted by Kelley (2008) these same items had the highest and fourth highest mean scores, respectively. The second highest mean score item was *obtaining support from math and science faculty* (mean of 2.08). The fourth highest mean score item was *obtaining support from school administration and school counselors* (mean on 1.84). Oftentimes finding the proper funding is a challenge for educators. However, the least challenging for STEM educators was *acquiring funding to purchase materials to teach engineering design* (mean of 1.35) and *acquiring funding to purchase tools and equipment to teach engineering design* (mean of 1.36). The later was the third highest mean scoring individual item in the study conducted by Kelley (2008). These results indicate that STEM educators did not struggle as much to locate appropriate tools and equipment to teach engineering design in curriculum content.

Engineering Design Self-Efficacy

The results of this study indicate the engineering design process steps used in this study can represent engineering design when measuring task-specific self-concepts such as self-efficacy, motivation, expectancy for success, and anxiety. The results indicate engineering design self-efficacy was highly dependent on their engineering experiences. Engineering experiences in this study included majoring in engineering, teaching technology or engineering courses, or certification in vocational education. This was evident in the significant differences in the task-specific self-concepts among the high, intermediate, and low engineering experience groups. According to Bandura's theory on self-efficacy, individuals can build self-efficacy from engineering experiences. Without experiences, participants lack mastery experiences, vicarious experiences, social persuasion, and physiological states (Bandura, 1977, 1986). This was also evident from the results to research question one. Further analysis revealed engineering design self-efficacy was stronger for individuals who had more experience teaching engineering. Experience in teaching technology and math, and certification in vocational education and computer literacy also had an effect on an individual's engineering design self-efficacy.

Bandura's theory also states that self-efficacy is related to other self-concepts such as motivation, expectancy for success, and anxiety. Motivation and expectancy for success had a strong positive correlation with self-efficacy. Anxiety had a negative moderate correlation with self-efficacy. These results confirm the theoretical connections in the study.

Implications for Professional Development

Recent studies have discussed the efforts made to provide professional development to teachers who were attempting to infuse engineering content into the curriculum (Asunda, 2007; Cunningham, Knight, & Kelley, 2007; Hailey, et. al.). As more states revise their curricula for technology education to infuse engineering content it is more likely professional development programs will be developed to properly equip teachers with the knowledge to teach engineering concepts. The results of this study keep local and state leaders informed about the teaching practices, assessment strategies, and identified challenges of current STEM educators working to infuse engineering design into the curriculum. This information will prove useful to leaders seeking to develop professional development for these STEM educators.

These results have described the amount of instructional and classroom time STEM educators devote to various engineering design concepts. In doing so, areas of deficiency have been highlighted in certain engineering design content. In addition, these results also described the degree to which STEM educators implement assessment strategies into the classroom. The results also identified the challenges teachers had when infusing engineering design into STEM curricula. Finally, the results have described the level of self-efficacy STEM educators had towards engineering design. Information obtained from this research can help designers of professional development create workshops, curriculum, conferences, interactive videoconferences, satellite broadcasts, seminars, university and community education courses, web-based instruction, training of trainers, and support materials that will properly equip STEM educators with the knowledge and confidence to properly infuse engineering design into the classroom.

Conclusions

Although these results cannot be generalized to the entire population, valuable information was presented for the field of technology education. There have been several studies that suggested the best approach for infusing engineering into technology education is by establishing engineering design as a focus (Custer, Daugherty, & Meyer, 2009; Dearing and Daugherty, 2004; Fales, Kuetemeyer, Y& Brusic, 1998; Hailey et al., 2005; Lewis, 2005; Wicklein, 2006; Wright, 2002). There have also been several studies that suggested the best assessment practices for secondary engineering design programs (Asunda & Hill, 2007; Childress & Rhodes, 2008; Smith, 2006). Gattie and Wicklein (2007) presented the benefits of infusing engineering design into technology education by understanding the perceptions and attitudes of technology teachers, technology teacher educators, and other leaders in technology education. Kelley (2008) extended the results of the prior study by using the results to identify the current status of technology education regarding the engineering design curriculum content, assessment strategies, and challenges technology teachers have in implementing engineering design. Carberry, Ohland, and Lee (2009) was the only study conducted to investigate engineering design self-efficacy as it related to the engineering design process.

This study sought to extend the results of those prior studies by using those results to describe the relationship between self-concepts (self-efficacy, motivation, expectancy of success, and anxiety) and the degree to which STEM educators implemented engineering design curricula, assessment strategies, and the challenges teachers face when infusing engineering design into the curriculum. It is important that local and state leaders not only be aware of the current status of technology education, but how educators self-efficacy relates to the issues and needs regarding the implementation of engineering design in the curriculum. The potential benefits presented by Gattie and Wicklein (2007) can be achieved if leaders keep abreast of the current status of technology education to provide technology education teachers the academic training, support, and educational resources necessary to infuse engineering design into the curriculum.

Recall the purpose of technology education is to develop technological literacy in all students. Education as a whole is to prepare students to become efficient workers in a global society. Therefore, technology education programs serve two purposes. The results of this study also address the issue of students being prepared to work in a global economy. BLS (2009) reported a 10.1% increase in the demand for engineers from 2008 to 2018, but many engineering jobs remain unfilled. The National Academy of Engineering (2004) and the National Science Foundation (2007) described the skills necessary for an undergraduate student completing an engineering program. Technology education programs can do both: address the needs of a global workforce and develop technological literate students. Some of the results of this study indicate that STEM educators are already providing learning opportunities for secondary students to develop job related skills. Some of the highest mean score items in this study addressed these needs including *think critically* (second highest mean score item measured by frequency) and *use basic computer applications such as word processors, spreadsheets, and presentation software.* These skills are necessary for a global worker, and are well supported by STEM educators based on the results. *Engineering and Human Values* was the fourth highest category group mean, but the category contains items related to making ethical decisions regarding engineering problems and the awareness of social, economical, and environmental impacts on design solutions. Although this category is not the lowest, the mean score for frequency of these items is less than *1 or 2 times a week.* Since the items in this category address the skills necessary for a global work, it is also an area of improvement for technology education curriculum content. The results of the engineering design self-efficacy can assist school leaders in identifying educators that need additional professional development learning opportunities. Understanding how self-efficacy affects a teacher's learning, teaching practice and assessment strategies will aid in determining how effective the teacher is in the classroom.

Recommendations

This research study has provided insight into the current local status of technology education regarding engineering design curriculum content, assessment strategies, and challenges facing secondary STEM educators working to infuse engineering design into their classes and the connection to engineering design self-efficacy. This study allows educators to see what is taking place in the classroom but also the areas of deficiencies in implementing engineering design. This is the first study investigating the relationship between engineering design knowledge base and engineering design self-efficacy. Therefore, more research needs to be conducted to inform the field of technology education regarding these constructs. The following recommendations are suggested for further research to inform the field of technology education:

a. Conduct similar research using participants from other districts, locally and nationally, to compare the results with this study. This would yield a larger sample size and allow the research to statistically generalize to the entire population of STEM educators.

b. Conduct similar research using *Project Lead the Way* curriculum as the grouping variable, and compare the results with this study. This would yield valuable information regarding the self-concepts, student outcomes, assessment strategies, challenges, and any deficiencies in the curriculum.

c. Conduct qualitative and quantitative research to determine the professional development opportunities educators received that are appropriate for teaching engineering design at the secondary level in order to properly infuse engineering design into the curriculum.
d. Conduct similar research using other engineering design process models. There is not a consensus on one engineering design process model and this would yield valuable information regarding the validity in measuring task-specific self-concepts.
e. Conduct qualitative and quantitative research to determine the student's engineering design self-efficacy in relation to the teacher's engineering design knowledge base and self-efficacy.
f. Conduct qualitative and quantitative research to determine how the teacher's engineering design knowledge base and self-efficacy relate to cognitive learning outcomes in the student.

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APPENDIX

Engineering Design Knowledge Base and Self Efficacy

1. Welcome

Thank you for participating in this brief survey.

This survey will inquire about your experiences as a science, technology, engineering, or mathematics teacher and the extent to which engineering is incorporated into your instruction. We very much appreciate your feedback, and especially your honesty, in responding.

Your responses are completely anonymous, and will be examined and reported in aggregate form only. That is, on personally identifiable information will be collected, and your responses will never be individually examined.

Upon answering all questions, you will be asked to enter your email address for a chance to win a $100.00 VISA gift card.

Engineering Design Knowledge Base and Self Efficacy Survey

2. Engineering Design Knowledge Base

This survey is being used to determine your teaching practices, assessment practices, and self-efficacy as they relate to teaching engineering design in secondary technology education. Please complete all items on this survey until you reach the final thank you page, indicating you have completed the survey. Your participation is vital to the improvement of technology education, and your honest and professional opinion is highly valued. Be assured that your responses will be held in strict confidence. Thank you in advance for your prompt return on the survey; completion of the survey by the due date makes you eligible for a random drawing for one (1) $100.00 VISA GIFT CARD. The survey contains a table defining the Likert scale for your reference. This table will be used for questions about your teaching practices as they relate to curriculum content and assessment practices. You can either print out the survey or turn off the pop-up blocker so an additional web browser window can display the table for your reference throughout the survey. The online questionnaire displays best on Internet Explorer.

If you need assistance or have questions while taking the survey, please contact:

Kanika Vessel
kanikavessel@engr.subr.edu
(225)806-1281

***1. What best describes your high school day schedule?**

○ Traditional schedule (meets daily 5 days a week)
○ Block schedule (AB Block or 4x4 Block)

Assumptions: Traditional schedule meets 5 days a weekn 50 minutes per period, 184 day school year. Typical A/B and 4x4 block scheduling meets for 92 days for 90 minutes.

How Often? (Frequency)				How Many Minutes? (Time)		
Likert	**Wording**	Traditional (meets 5 days a week)	Block	**Wording**	Traditional (50 minutes per period)	Block (90 minutes per period)
0	**Never**	0	0	**None**	0 min.	0 min.
1	**A few times a year**	5 days	5 days	**A few minutes per period**	5 min.	9 min.
2	**1 or 2 times a month**	14 days (1.5 * 9.1)	7 days (1.5 * 4.6)	**Less than half the period**	15 min.	30 min.
3	**1 or 2 times a week**	55 days (1.5 * 36.8)	28 days (1.5 * 18.4)	**About half**	25 min.	45 min.
4	**Nearly everyday**	129 days (3.5 * 36.8)	64 days (3.5 * 18.4)	**More than half**	37.5 min.	67.5 min.
5	**Daily**	184 days	92 days	**Almost all period**	50 min.	90 min.

Engineering Design Knowledge Base and Self Efficacy Survey

***2. Engineering Design**

The following items consist of student learning outcomes. Please carefully read each outcome as they relate to ENGINEERING DESIGN. Please respond to the choice that best reflects your teaching practice as it relates to frequency (column 1) and time per typical use (column 2). The table above is provided for your reference to define the Likert scale based upon your schedule (Traditional or Block). Please note these units are approximations, select the number that best reflects your instructional practices.

Throughout my courses, I provide instruction addressing these objectives:

	Frequency of Use						Time per Typical Use					
	0	1	2	3	4	5	0	1	2	3	4	5
understand engineering designs is an iterative process	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
understand creativity is an important characteristic for engineers to apply in design	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
recognize that there are many approaches to design and not just one design process	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
recognize engineering as a potential career option	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
are able to identify goals and bad design	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
believe in his/her ability to design a solution to a technological problem	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Engineering Design Knowledge Base and Self Efficacy Survey

***3. Engineering Analysis**

The following items consist of student learning outcomes. Please carefully read each outcome as they relate to ENGINEERING ANALYSIS. Please respond to the choice that best reflects your teaching practice as it relates to frequency (column 1) and time per typical use (column 2). The table above is provided for your reference to define the Likert scale based upon your schedule (Traditional or Block). Please note these units are approximations, select the number that best reflects your instructional practices.

Throughout my courses, I provide instruction addressing these objectives:

	Frequency of Use						Time per Typical Use					
	0	1	2	3	4	5	0	1	2	3	4	5
understand that knowledge of science and mathematics is critical to engineering	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
apply engineering science principles when designing	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
use measuring equipment to gather data for troubleshooting, experimentation, and analysis	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
use physical and/or mathematical models to estimate the probability of events	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
use optimization techniques to determine optimum solutions to problems	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
use models or simulations to study processes	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Engineering Design Knowledge Base and Self Efficacy Survey

*4. Application of Engineering Design

The following items consist of student learning outcomes. Please carefully read each outcome as they relate to APPLICATION OF ENGINEERING DESIGN. Please respond to the choice that best reflects your teaching practice as it relates to frequency (column 1) and time per typical use (column 2). The table above is provided for your reference to define the Likert scale based upon your schedule (Traditional or Block). Please note these units are approximations, select the number that best reflects your instructional practices.

Throughout my courses, I provide instruction addressing these objectives:

	Frequency of Use						Time per Typical Use					
	0	1	2	3	4	5	0	1	2	3	4	5
apply knowledge for manufacturing products to the engineering design	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
identify problems that could e solved through engineering design	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
understand no perfect design solution exists	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
conduct reverse engineering to analyze product design	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
organize and manage design process for optimal use of materials, processes, time, and expertise	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
design, product, and test prototypes	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
apply research to designing products, processes, and materials	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
develop skills to use, manage, and assess technology	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
demonstrate the ability to handle open-ended/ill-defined problems	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
develop basic students' skills in the use of tools	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
understand design often requires tradeoffs	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

*5. Engineering Communication

The following items consist of student learning outcomes. Please carefully read each outcome as they relate to ENGINEERING COMMUNICATION. Please respond to the choice that best reflects your teaching practice as it relates to frequency (column 1) and time per typical use (column 2). The table above is provided for your reference to define the Likert scale based upon your schedule (Traditional or Block). Please note these units are approximations, select the number that best reflects your instructional practices.

Throughout my courses, I provide instruction addressing these objectives:

	Frequency of Use						Time per Typical Use					
	0	1	2	3	4	5	0	1	2	3	4	5
communicate design ideas orally, through presentations, and graphics	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
communicate through writing technical reports	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
use technical drawings to construct or implement an object, structure, or process	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
visualize in three dimensions	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
develop and maintain an engineering design portfolio	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
use computer-aided design to construct technical drawings	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
apply the rules of dimensioning	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
apply rules of manufacturing tolerance	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
use basic computer application such as word processors, spreadsheets, and presentation software	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Engineering Design Knowledge Base and Self Efficacy Survey

*6. Design Thinking as it Relates to Engineering Design

The following items consist of student learning outcomes. Please carefully read each outcome as they relate to DESIGN THINKING AS IT RELATES TO ENGINEERING DESIGN. Please respond to the choice that best reflects your teaching practice as it relates to frequency (column 1) and time per typical use (column 2). The table above is provided for your reference to define the Likert scale based upon your schedule (Traditional or Block). Please note these units are approximations, select the number that best reflects your instructional practices.

Throughout my courses, I provide instruction addressing these objectives:

	Frequency of Use						Time per Typical Use					
	0	1	2	3	4	5	0	1	2	3	4	5
think critically	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
synthesizes simple parts into complex systems	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
apply SYSTEMS THINKING-understanding and considering the multiple facets of a design solution result in positive and negative impacts	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
apply brainstorming and innovate concept generation	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
have the ability to approach open-ended/ill-defined problems	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

***7. Engineering and Human Values**

The following items consist of student learning outcomes. Please carefully read each outcome as they relate to ENGINEERING AND HUMAN VALUES. Please respond to the choice that best reflects your teaching practice as it relates to frequency (column 1) and time per typical use (column 2). The table above is provided for your reference to define the Likert scale based upon your schedule (Traditional or Block). Please note these units are approximations, select the number that best reflects your instructional practices.

Throughout my courses, I provide instruction addressing these objectives:

	Frequency of Use						Time per Typical Use					
	0	1	2	3	4	5	0	1	2	3	4	5
Understand how engineers put ethics into practice	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Are aware of social, economical, and environmental impacts on design solutions	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Understand that the solution to one problem may create other problems	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Consider cost, safety, appearance, and consequence of design failure	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Take human values and limitation into account when designing and solving problems	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Apply knowledge of basic ergonomics to engineering design process	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

***8. Engineering Science**

The following items consist of student learning outcomes. Please carefully read each outcome as they relate to ENGINEERING SCIENCE. Please respond to the choice that best reflects your teaching practice as it relates to frequency (column 1) and time per typical use (column 2). The table above is provided for your reference to define the Likert scale based upon your schedule (Traditional or Block). Please note these units are approximations, select the number that best reflects your instructional practices.

Throughout my courses, I provide instruction addressing these objectives:

	Frequency of Use						Time per Typical Use					
	0	1	2	3	4	5	0	1	2	3	4	5
apply math and science to the engineering design process	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
apply knowledge of basic mechanics to the engineering process	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
apply knowledge of basic statics and strengths of materials to engineering design process	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
apply knowledge of dynamics to the engineering design process	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
use of algebra to solve problems or predict results to design solutions	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
use geometry to solve problems or predict results to design solutions	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
use trigonometry to solve problems or predict results to design solutions	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
apply knowledge of material process to engineering design process	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Engineering Design Knowledge Base and Self Efficacy Survey

*9. Assessment Practices for Evaluating Engineering Design Activities

The following items consist of student learning outcomes. Please carefully read each outcome as they relate to ASSESSMENT PRACTICES FOR EVALUATING ENGINEERING DESIGN ACTIVITIES. Please respond to the choice that best reflects your teaching practice as it relates to frequency (column 1) and time per typical use (column 2). The table above is provided for your reference to define the Likert scale based upon your schedule (Traditional or Block). Please note these units are approximations, select the number that best reflects your instructional practices.

Throughout my courses upon completion of assignments, I assess students abilities to:

	Frequency of Use						Time per Typical Use					
	0	1	2	3	4	5	0	1	2	3	4	5
use support evidence/external research (research notes, illustrations, etc.)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
provide evidence of formulating design criteria and constraints prior to designing solutions	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
use design criteria such as budget, constraints, criteria, safety, and functionality	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
provide evidence of idea generation strategies (e.g. brainstorming, teamwork, etc.)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
properly record design information in an engineer's notebook	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
use mathematical models to optimize, describe, and/or predict results	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
develop a prototype model of the final design solution	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
work on a design as a functional interdisciplinary unit	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

*10. Challenges Implementing Engineering Design

The following items are selected challenges that teachers may face when seeking to implement technology education curriculum changes to infuse engineering design into technology education curriculum. Please rate your level of agreement based upon your experiences.

Throughout my courses, I provide instruction addressing these objectives:

	Never	Rarely	Sometimes	Very Often	Always
Integrating the appropriate levels of math and science into instructional content	☐	☐	☐	☐	☐
Locating and learning the appropriate levels of math and science to teach engineering design	☐	☐	☐	☐	☐
Locating and learning knowledge of engineering fundamentals (statics, fluid, mechanics, dynamics)	☐	☐	☐	☐	☐
Locating appropriate textbooks to teach engineering design	☐	☐	☐	☐	☐
Locating the appropriate laboratory equipment to teach engineering design	☐	☐	☐	☐	☐
Locating the appropriate laboratory layout and space to teach engineering design	☐	☐	☐	☐	☐
Acquiring funding to purchase tools and equipment to teach engineering design	☐	☐	☐	☐	☐
Acquiring funding to purchase materials to teach engineering design	☐	☐	☐	☐	☐
Networking with practicing engineers for consultation	☐	☐	☐	☐	☐
Obtaining support from math and science faculty	☐	☐	☐	☐	☐
Obtaining support from school administration and school counselors	☐	☐	☐	☐	☐
Obtaining support to promote engineering design course by school administration	☐	☐	☐	☐	☐
Obtaining community support to implement engineering design courses	☐	☐	☐	☐	☐
Obtaining parent supports to implement engineering design course	☐	☐	☐	☐	☐

Engineering Design Knowledge Base and Self Efficacy Survey

3. Engineering Design Self-Efficacy

***11. Rate your degree of confidence (i.e. belief in your current ability) to perform the following tasks by recording a number from 0 to 100.**

(0 = cannot do at all; 50 = moderately can do; 100 = highly certain can do)

Throughout my courses upon completion of assignments, I assess students abilities to:

	0	10	20	30	40	50	60	70	80	90	100
conduct engineering design	○	○	○	○	○	○	○	○	○	○	○
identify a design need	○	○	○	○	○	○	○	○	○	○	○
research a design need	○	○	○	○	○	○	○	○	○	○	○
develop design solutions	○	○	○	○	○	○	○	○	○	○	○
select the best possible design	○	○	○	○	○	○	○	○	○	○	○
construct a prototype	○	○	○	○	○	○	○	○	○	○	○
evaluate and test a design	○	○	○	○	○	○	○	○	○	○	○
communicate a design	○	○	○	○	○	○	○	○	○	○	○
redesign	○	○	○	○	○	○	○	○	○	○	○

***12. Rate how motivated you would be to perform the following tasks by recording a number from 0 to 100.**

(0 = not motivated; 50 = moderately motivated; 100 = highly motivated)

	0	10	20	30	40	50	60	70	80	90	100
conduct engineering design	○	○	○	○	○	○	○	○	○	○	○
identify a design need	○	○	○	○	○	○	○	○	○	○	○
research a design need	○	○	○	○	○	○	○	○	○	○	○
develop design solutions	○	○	○	○	○	○	○	○	○	○	○
select the best possible design	○	○	○	○	○	○	○	○	○	○	○
construct a prototype	○	○	○	○	○	○	○	○	○	○	○
evaluate and test a design	○	○	○	○	○	○	○	○	○	○	○
communicate a design	○	○	○	○	○	○	○	○	○	○	○
redesign	○	○	○	○	○	○	○	○	○	○	○

Engineering Design Knowledge Base and Self Efficacy Survey

3. Engineering Design Self-Efficacy

***13. Rate how successful you would be in performing the following tasks by recording a number from 0 to 100.**

(0 = cannot expect success at all; 50 = moderately expect success; 100 = highly certain of success)

Throughout my courses upon completion of assignments, I assess students abilities to:

	0	10	20	30	40	50	60	70	80	90	100
conduct engineering design	○	○	○	○	○	○	○	○	○	○	○
identify a design need	○	○	○	○	○	○	○	○	○	○	○
research a design need	○	○	○	○	○	○	○	○	○	○	○
develop design solutions	○	○	○	○	○	○	○	○	○	○	○
select the best possible design	○	○	○	○	○	○	○	○	○	○	○
construct a prototype	○	○	○	○	○	○	○	○	○	○	○
evaluate and test a design	○	○	○	○	○	○	○	○	○	○	○
communicate a design	○	○	○	○	○	○	○	○	○	○	○
redesign	○	○	○	○	○	○	○	○	○	○	○

***14. Rate your degree of anxiety (how apprehensive you would be) in performing the following tasks by recording a number from 0 to 100.**

(0 = not anxious at all; 50 = moderately anxious; 100 = highly anxious)

	0	10	20	30	40	50	60	70	80	90	100
conduct engineering design	○	○	○	○	○	○	○	○	○	○	○
identify a design need	○	○	○	○	○	○	○	○	○	○	○
research a design need	○	○	○	○	○	○	○	○	○	○	○
develop design solutions	○	○	○	○	○	○	○	○	○	○	○
select the best possible design	○	○	○	○	○	○	○	○	○	○	○
construct a prototype	○	○	○	○	○	○	○	○	○	○	○
evaluate and test a design	○	○	○	○	○	○	○	○	○	○	○
communicate a design	○	○	○	○	○	○	○	○	○	○	○
redesign	○	○	○	○	○	○	○	○	○	○	○

Engineering Design Knowledge Base and Self Efficacy Survey

4. Demographic Information

***15. Check or complete the appropriate demographic criteria below.**

	Middle/High School Teacher	High School Teacher	Other
Which best describes your current position?	○	○	○

***16. Years of Experience as a STEM education teacher at the start of the 2010 – 2011 school year**

Science

Technology

Engineering

Mathematics

***17. Please list the courses you teach**

***18. Gender**

○ Female
○ Male

***19. What was your age at your last birthday?**

Age

***20. Highest College Degree attained (Check only highest)**

○ B.S./B.A.
○ Masters
○ Eds-Specialist
○ EdD
○PhD

***21. What universities did you attend?**

Undergraduate University Attended

Graduate University Attended

Engineering Design Knowledge Base and Self Efficacy Survey

4. Demographic Information

***22. Major at undergraduate university (choose one):**

○ Arts and Humanities (art, language, pre-law, etc.)
○ Social Sciences (psychology, political science, sociology, history, etc.)
○ Education
○ Business
○ Engineering
○ Science, Technology, or Math
○ Not Applicable
○ Other

Other (please specify):

☐

***23. Are you a certified teacher?**

○ Yes
○ No

***24. School Setting?**

○ Rural (less than 40 persons per square mile or 40 or more acres per household unit)
○ Suburban/Exurban (40 to 999 persons per square mile or 5 to 39 acres per housing unit)
○ Urban (1,000+ persons per square mile or 1/3 to 1.5 acres per housing unit)

***25. What best describes your school size?**

○ Small (less than 500 students)
○ Medium (500 – 1,500 students)
○ Large (greater than 1,500 students)

***26. To be included for a chance to win a $100.00 VISA GIFT CARD and/or $300.00 school donation, please list your WORK email address. Email addresses will not be linked to survey results, published in research findings, or given to a third party. In order to qualify all questions must have been answered in the survy.**

VITA

VITA

NAME: Kanika Nicole Vessel

DEGREE AND DATE TO BE CONFERRED: Ph.D., 2011

EDUCATION

Date	Degree	Institution
Expected Graduation: Fall, 2011	Ph.D.	Southern University and A & M College Science and Mathematics Education
2002	M.S.	Louisiana State University and A & M College Mechanical Engineering
1999	B.S.	Southern University and A & M College Mechanical Engineering

PROFESSIONAL POSITIONS IN HIGHER EDUCATION:

Dates	Institution	Position
2004	Southern University	Instructor

PROFESSIONAL POSITIONS OTHER THAN IN HIGHER EDUCATION

Dates	Institution	Position
2011-	Houston Independent School District	Secondary Math Team Leader
2010-2011	Houston Independent School District	Secondary Math Instructional Specialist
2009-2010	The New Teacher Project	Secondary Math Content Leader

"VITA (continued)"

Dates	Institution	Position
2008-2010	East Baton Rouge Parish Scotlandville Magnet High School	Engineering Department Chair
2005-2010	East Baton Rouge Parish Scotlandville Magnet High School	Engineering Teacher
2004-2010	East Baton Rouge Parish Scotlandville Magnet High School	Mathematics Teacher

PUBLICATIONS

Vessel, K.N. (2008). Enhancing Academic Preparedness of Undergraduate Students through Secondary Engineering Programs. Southern University and A & M College. Paper presented at The Mid-South Educational Research Association Conference.

Vessel, K. N., Ram, Y.M., Pang, S.S., Nichols, R., and Negulescu, I. (2003). "The Sensitivity of the Natural Frequencies of a Vibrating System to Perturbations. Proc. Tenth Annual International Conference on Composites/Nano Engineering (ICCE/10) (Ed.: D. Hui), pp. 745-746, New Orleans, Louisiana, July 20-26, 2003.

Vessel, K. N., Ram, Y.M., and Pang, S.S. (2006). On the Sensitivity of Repeated Eigenvalues to Perturbations. AIAA Journal, *44,* p. 317-322.

Vessel, K. N. (2002). Parametric and Sensitivity Analysis of a Vibratory Automobile Model. (Master's Thesis). Baton Rouge, LA: Louisiana State University and A & M College at Baton Rouge.

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Author ____ Kanika Nicole Vessel___

Date _______November 21, 2011_____