EXAMINATION OF ENGINEERING DESIGN IN CURRICULUM CONTENT AND ASSESSMENT PRACTICES OF SECONDARY TECHNOLOGY EDUCATION

by

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(Under the Direction of Robert C. Wicklein)

ABSTRACT

This descriptive study examined the current status of technology education teacher practices with respect to engineering design. Participants were drawn from the current International Technology Education Association (ITEA) high school teacher membership database. A survey instrument gathered data about the extent to which engineering design concepts are incorporated into the curriculum content, and assessment practices employed by secondary technology educators. Moreover, the survey identified challenges faced by technology educators when seeking to implement engineering design. Current curriculum content that addresses engineering design concepts consisted of the following seven subsets: (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. The instrument was developed from current research in technology education that has identified curricular goals, content recommended for teaching an engineering design focused program at the high school level, appropriate assessment practices for evaluating engineering design projects, and perceived challenges facing teachers implementing engineering design content (Asunda & Hill, 2007; Rhodes & Childress, 2006; Smith, 2006; Gattie & Wicklein, 2007). A composite score of total instructional hours was generated for each of the seven engineering design categories by combining the mean scores of frequency of use and time per typical use. These composite score results revealed that the categories engineering design, design thinking related to engineering design, and engineering communications were greatly emphasized in secondary technology education programs. The study results also indicated that engineering and human values, engineering science, and engineering analysis were the least emphasized categories in technology education curriculum content. The results of technology education teacher practices revealed that little emphasis has been place on assessing mathematical models to predict design results.

INDEX WORDS: Engineering design, Technology Education, Pre-Engineering, K-12 Engineering, Project Lead the Way

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“Whatever you do, work at it with all your heart, as working for the Lord, not for men”, Colossians 3:23. To my Lord and Savior Jesus Christ, I owe all that I am and all that I hope to be; with You all things are possible. You provide the purpose and meaning in life. You alone put the capital T in Truth.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1 INTRODUCTION

Historically, technology education has embraced multiple options for teaching students about technology. Throughout the history of technology education, curriculum emphasis has included manual arts, manual training, industrial arts, industrial technology, technology education, tech prep, and *Project Lead the Way* to name a few. A shift in focus of the field has occurred over the years from a skills-based approach and an industrial basis to a focus on design and problem-solving with a technological basis. Furthermore, technology education's scope has been extremely wide, including manufacturing, construction, communication, transportation, and biotechnology. This breadth of interests has limited secondary technology teachers' ability to present topics to students with any depth.

Technology education took a great leap forward in establishing a clear direction for the field with the publication of *Standards for Technological Literacy: Content for the Study of Technology* (ITEA, 2000), the professional development standards in *Advancing Excellence in Technological Literacy* (ITEA, 2003) and the call for technological literacy by the National Academy of Engineering and National Research Council in their document *Technically Speaking: Why all Americans Need to Know More About Technology* (NAE NRC, 2002). Each of these documents clearly established a need to teach technological literacy to all K-12 students. Although, none of these documents endorsed a specific method of delivering technological literacy, many in the field of technology education suggested engineering or engineering design as a curricular focus for technology education to achieve technological literacy (Daugherty, 2005, Lewis, 2004, Rogers, 2005, Wicklein, 2006). The National Academy of Science (NAE

NRC, 2002) supports the call for technology education teachers to approach technological literacy from an engineering rather than industrial perspective (Daugherty, 2005). From an engineering perspective, Douglas, Iversen, and Kalyandurg (2004) also identified a need for teaching engineering to public school students. This recommendation has been confirmed by research of the American Society for Engineering Education (ASEE). An ASEE on-line survey yielded a response from 522 K-12 educators; of those respondents 89.2 % agreed or strongly agreed that a basic understanding of engineering was important in understanding the world in which we live. Moreover, 77.4% of the respondents agreed or strongly agreed that implementing a secondary engineering curriculum would help in teaching other school subjects (Douglas et al., 2004).

The engineering education community and leaders in the field of technology education have identified the important role K-12 engineering education plays in the success of postsecondary engineering education (Douglas et al.; Hailey, Erekson, Becker, & Thomas, 2005), thus, providing support for the case that students should not be forced to wait until after high school to learn about engineering and that an early exposure to engineering will help students make informed decisions about engineering as a career path (Douglas et al.). Although technology education has been identified by some as a logical vehicle for delivering K-12 engineering education, it is unclear as to the current levels of engineering design and pre-engineering in high school technology programs. Furthermore, it is unclear as to the degree to which technology educators are currently implementing elements of engineering design in their curriculum.

Since publication of the *Standards for Technological Literacy* in 2000, there have been a number of new curricula designed to infuse engineering content into technology education courses such as *Project ProBase*, *Principles of Engineering*; *Project Lead the Way,* and *Introduction to Engineering* (Dearing & Daugherty, 2004.). Each of these programs proposed teaching engineering concepts or engineering design in technology education as a vehicle to address the standards for technological literacy. While teaching engineering content in secondary technology education programs is a popular trend, it is not a new approach. A course called *Principles of Engineering* has been taught in New York schools since the late 1980s (Lewis, 2005). Although there are new engineering design programs in development while others are decades old, it is unclear to what to degree technology educators are implementing engineering design content in their curriculum. Certainly, a study was needed to determine the extent to which these programs have been implemented into technology education classrooms and to what degree engineering design content is being presented.

Project Lead the Way (PLTW) is one pre-engineering program that has been implemented within a number of high school and middle school technology education programs in the United States. The *Project Lead the Way* program began development in the 1980s by Richard Blais at Shenendehowa Central School district in upstate New York (Blais & Adelson, 1998). Today, *Project Lead the Way* boasts serving over 1250 schools in 44 states and teaching over 160,000 students (Mcvearry, 2003). Despite wide use and position as a leader in secondary pre-engineering education, it is unclear what the actual teaching practices are in *Project Lead the Way* programs and the content being taught to high school students in these courses. A quick review of the curriculum guide for *Project Lead the Way* can provide some insight, however it remains unclear as to the degree technology teachers follow these guides or the effectiveness of the program on student learning. This uncertainty regarding the PLTW curriculum stems from the lack of public access to PLTW curriculum materials describing the degree to which engineering design content is delivered in this pre-engineering program. Likewise, there is little known about the type of challenges facing high school technology education teachers as they seek to implement curriculum with a focus on engineering concepts.

Many educators inside and outside technology education have viewed the move from industrial arts to technology education as a change in name only and is a factor in failing to establish a clear mission for the field (Wicklein, 2006). Research on this topic backs up this claim. Akmal, Oaks, and Barker (2002) conducted research seeking to assess the progress the field of technology education had made with respects to moving from industrial arts to technology education. A survey instrument solicited information from all technology education state supervisors; all but 4 of the 39 states that responded reported their state no longer used the program title 'industrial arts'. However, 34 states report that traditional industrial arts and technology education programs are currently operating simultaneously throughout their state, a fact that Clark (1989) suggested has stifled the movement to technology education. In a similar study, Sanders (2001) conducted research where he surveyed technology education teachers and found 40% of respondents identified their programs with vocational education. When compared with previous research on this subject, the data had not changed, indicating little progress had been made regarding the move to technology education in two decades (Dugger et al., 1980). In a similar vein, Hansen and Lovedahl (2004) ask an important question: "If instructional methodologies, content, clientele, and purpose are pragmatically the same before and after a name conversion, aren't the new technology education programs really vocational-technical education?"(p. 21). If many technology educators still remain focused on methods and instructional strategies more aligned with industrial arts, it would seem that the issues of implementing engineering design would be questionable within the technology education field.

Research was needed to determine the degree to which technology educators are implementing elements of engineering design in their curriculum.

Statement of Purpose

This descriptive study examined the degree to which technology educators are implementing elements of engineering design in their curriculum. Participants consisted of secondary technology educators who were members of the International Technology Education Association (ITEA) at the time of the study. The sample consisted of all high school technology teachers regardless of whether they indicated they were teaching engineering design in their classrooms. A survey instrument was used to gather data about the extent to which engineering design concepts were incorporated into the curriculum content, assessment practices employed by secondary technology educators, and challenges to implementing engineering design concepts in the secondary technology education curriculum. Current curriculum content that addresses engineering design concepts was determined using the following seven categories: (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. The instrument was developed from current research in technology education that had identified curricular goals, content recommended for teaching an engineering design focused program at the high school level, appropriate assessment practices for evaluating engineering design projects, and identified perceived challenges facing teachers implementing engineering design content (Asunda & Hill, 2007; Childress & Rhodes, 2008; Smith, 2006; Gattie & Wicklein, 2007).

Research Questions

The study answered the following questions:

1. To what degree does the current curriculum content of secondary technology education programs reflect engineering design concepts?
2. To what degree do current assessment practices of secondary technology educators reflect engineering design concepts?
3. What selected challenges are identified by secondary technology educators in teaching engineering design?

Conceptual Framework

Leaders in the field of technology education have suggested infusing engineering design into technology education (Lewis, 2004, Wicklein, 2006). It appears that the field has taken notice; at the 2007 International Technology Education Association conference held in San Antonio, over 40 presentations were related to engineering topics. Moreover, many new curriculum projects have been developed to teach engineering design or engineering related content in K-12 schools. These programs' titles include *Engineering by Design, Project Lead the Way*, *Project ProBase*, and *Principles of Engineering*, to name a few. Furthermore, many private vendors have created products, modules, and textbooks specifically to introduce engineering design into technology education programs. Even so, it is unclear as to what degree these programs are being implemented in secondary classrooms and if these programs have been properly designed to teach engineering design content that leads to technologically literate students. To understand the status of technology education at the time of this study with respect to engineering design as a curriculum focus, these issues must be addressed.

The recent trend to move to engineering design in technology education also caused researchers to investigate what outcomes should be a part of a program that integrates engineering design into high school technology education (Asunda & Hill, 2007; Childress & Rhodes, 2006; Gattie & Wicklein, 2007; Smith, 2006). These recent studies have obtained input from practicing engineers, engineering educators, mathematics educators, and technology teacher educators about the essential aspects and related academic concepts that are required to properly infuse engineering design into secondary technology education.

The conceptual framework for this study consisted of knowledge obtained from these four studies of engineering design as a focus for technology education. Although some professionals in the field of technology education have begun to agree that engineering design should be a curricular focus for technology education (Dearing & Daugherty, 2004, Wicklein & Gattie, 2007), debate continues with respect to what content should be taught in high school technology education classes. Furthermore, what are the outcomes for students completing a course in engineering design, and what strategies are appropriate for assessing engineering design activities? These research studies (Asunda & Hill, 2007; Childress & Rhodes, 2008; Smith, 2006; Gattie & Wicklein, 2007) have sought to answer these questions by polling experts in the field of engineering and technology education. Two of these studies have created a framework to define the ideal engineering design curriculum content with respect to the necessary learning outcomes for high school students (Childress & Rhodes, 2008; Smith, 2006). Specifically, a frame to define curriculum content that addresses engineering design concepts consisted of the following seven categories: (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. Results of Asunda and Hill's (2007) study created a frame to identify appropriate assessment strategies for secondary technology educators when assessing engineering design activities.

Finally, Gattie and Wicklein (2007) established a list of identified challenges commonly facing technology educators seeking to infuse engineering design into the curriculum. The results of each of these studies framed this research construct by providing criteria with which to define the degree that technology educators are implementing elements of engineering design in their curriculum.

Significance of Study

The results of this status study described the degree to which technology educators are implementing elements of engineering design in their curriculum. Past researchers of technology education curriculum regarding engineering design have studied the following areas: a better understanding of engineering design (Smith, 2006), descriptions of engineering design outcomes for technology education when the purpose is to generate technically literate individuals (Childress & Rhodes, 2008), and identification of features of the engineering design process within the context of technology education learning activities and identification of strategies to evaluate the infusion of engineering design into technology education activities (Asunda & Hill, 2007.). While these studies were fundamental to an understanding of engineering design and outcomes that lead to successful implementation of high school curriculum emphasizing engineering design, these studies do not inform the field about what was currently happening in technology education classrooms across the United States in relation to the infusion of engineering design at the time of this study. Moreover, although Gattie and Wicklein's (2007) study sought to better understand the status of technology education with respect to engineering design, questions remained about what teachers meant when they responded that they were teaching engineering design in high schools. This study helped clarify and extend the results of Gattie and Wicklein's study.

Results of this study added to the knowledge base required to help infuse engineering design into secondary technology education curriculum and to inform researchers and practitioners about what is currently happening in high school technology education classrooms with respect to the teaching of engineering design content. Results can be used to help inform curriculum developers about the degree to which technology educators are implementing elements of engineering design in their curriculum. Consequently, this knowledge can help when designing more appropriate curriculum and generate teacher strategies that are more effective at teaching problem solving, integrating of science, technology, engineering, and mathematics (STEM) subjects, and providing experiences that lead to technological literacy.

The National Center for Engineering and Technology Education (NCETE) stressed the importance of a status study of technology education. The fall 2006 NCETE meeting report stated, "We must develop a clear understanding of the landscape (status) of teaching and learning of engineering design in high schools and the associated research problems that we (NCETE) want to convey to the broader STEM community about the significance of our domain. We must understand the landscape so we can influence the landscape" (NCETE meeting report, Oct 11-14, 2006). Clearly, NCETE leadership determined that the best way to influence the field of technology education was to first be informed about what was currently happening in the classroom with respect to engineering design. Other goals for NCETE included developing a collaborative network of scholars who work to improve understanding of the process of learning and teaching of engineering design in technology education, developing a model for professional development with a focus on selecting engineering design concepts for technology education in high school, and to conducting research to identify learning outcomes for engineering design focused technology in high school, and describing instructional strategies that effectively develop engineering outcomes in high schools. To achieve these goals, NCETE must first be informed of the current status of technology education with regards to the teaching of engineering design content. Creating a professional development model for infusing technology education into technology education will require a clear understanding of the challenges facing educators who have sought to implement such programs. Proper development of an intervention to a problem must first start by "surveying the scene" to help identify the most critical issues to address. Carter Good and Douglas Scates (in Hopkins, 1976) described the significance of a status study "A survey of present conditions is an essential guide to one's thinking, whether in evaluating the course he is now following, or in embarking on a new venture. For any purpose, the starting point is important" (Hopkins, 1976, p. 135). Another significant contribution of this status study was that it informed the field of technology education of the scope of implementing elements of engineering design into technology education curriculum. At the time of this study, it was unclear as to how many high school technology teachers were teaching engineering design. Regardless of whether technology educators indicated that they were teaching courses focused on engineering design or other technology courses with a different curriculum focus, it was important to determine the degree to which engineering design was or was not implemented in existing curriculum. This study probed deeper into understanding what specifically was taking place in high schools with respect to engineering design.

CHAPTER 2 LITERATURE REVIEW

Defining Key Terms

The meaning of engineering design is not as straightforward as one may imagine. It is complex due to varying perspectives, which results in difficulty developing a clean and concise definition. One method to bring clarity of understanding to a compound term is to separate the terms and define them separately. In the case of *engineering* and *design*, each of these terms are also complex, and multiple definitions abound. Koen (2003) provides a foundational understanding of the origins of the term *engineer*. He writes:

> The term engineer comes directly from an old French word in the form of a verb—*s'ing'enier*… and thus we arrive at the interesting and certainly little known fact, that an engineer is… anyone who seeks in his mind, who sets his mental powers in action, in order to discover or devise some means of succeeding in a difficult task he may have to perform (p.8).

Although Koen believes that this is a little known fact about engineering, it certainly explains the holistic view of the term engineer. Engineering as an adjective is used to sell anything from toothpaste to cars. Recently, I read an article titled *Engineering a Poem: An Action Research Study*; beyond the title, the term engineering appears twice in the remainder of the article (Koch & Feingold, 2006). Engineering is a popular buzzword these days, used to appeal to the masses and elevate the content or product for sale, so overused and abused that misconceptions about the field of engineering are prevalent. Some suggest that one of the principle obstacles that must be overcome to successfully introduce the new discipline of engineering into the K-12 curriculum is teachers lack of knowledge about what engineering is and is not (Cunningham, Knight, Carlsen, & Kelly, 2007). Often science and engineering are used synonymously when the purpose of their methods are vastly different. Koen recalls a prime example in a speech made by President Reagan proposing a new generation of space weapons, later referred to as star wars. The purpose of this new defense system was to shield the United States from enemy missile attacks by using weapons positioned in space. President Reagan mistakenly called upon the scientific community instead of the engineering community to provide the way to achieve this new defense strategy. Koen points out that very little new scientific know-how would be required for such a system and that Reagan would have been better served to call upon engineers' advice.

Certainly, one of the best ways to define an occupation like engineering is to understand and describe what an engineer does. Lewis (2005) quotes Pahl and Beitz as saying that the main task of engineers is to "apply their scientific and engineering knowledge to the solution of technical problems, and then optimize those solutions within the requirements and constraints set by the material, technological, economic, legal, environmental and human-related considerations" (p. 41). Certainly, one can identify from these thoughts on engineering that this occupation requires the application of scientific knowledge to devise a plan that will solve a technical problem within a set of constraints and criteria that are often identified by the engineer. Moreover, engineering not only uses scientific knowledge but mathematical knowledge as well. Petroski (1996) writes;

> What distinguishes the engineer from the technician is largely the ability to formulate and carry out the detailed calculations of forces and deflections, concentrations and flows,

> voltages and currents, which are required to test a proposed design on paper with regard to failure criteria (p.89).

Petroski also stated that engineering is a social endeavor, and as such an engineer is bound to the multiple constraints and criteria that are imposed by the society. Identifying and addressing those constraints and criteria to develop a sustainable solution adds to the complexity of the task of the engineer. Shepard, Colby, Macatangay, & Sullivan (2004) make the point that engineering is influenced by politics, society, economics, and technology. Engineering is influenced by the past, continues to shape the present, and works to manipulate the future. Petroski writes:

> Engineering is inextricably involved with virtually all other aspects of society, as young engineers soon learn. No engineering problem is without its cultural, social, legal, economic, environmental, aesthetic, or ethical component, and any attempt outside the classroom to approach an engineering problem as a strictly technical one will be fraught with frustration (p.80).

Armed with the aforementioned description of engineering, a focus on the term *design* is now appropriate. Gilesecke, Mitchell, Spencer, Hill, Loving, Dygdon, and Novak (2000) expand on this definition: "Design is a process, a series of linked steps with stated objectives. It is a way of conceiving and creating new ideas and communicating those ideas to others in a way easily understood" (p. 422). Gilesecke et al. (2000) point out that there are different types of design such as aesthetic design and functional design. Middendorf & Engelmann (as cited in Lewis, 2005) argue that due to the very nature of design, the process of designing will differ depending on the type of product or system being created, the technology used in the design, the people in place to create and implement the design solution, the magnitude of the project, and so on. There are multiple factors involved in devising an engineering solution to a problem; how an engineer manages these factors determines the design process.

Teaching Engineering Design

Design is not only complex to define; it is equally difficult to teach. Moriarty (1994) believed that design requires an interdisciplinary approach and as such creates a course subject that is so complex to teach that many engineering schools across the country wait to teach a capstone design course until the engineering students' senior year. However, the Accreditation Board for Engineering and Technology (A.B.E.T.) has taken steps to integrate design throughout a student's design experience. The University of Georgia's Handbook on engineering design states:

> Design is the basic activity that differentiates engineering from science and is the one activity found in every field of engineering. However, the development of design skills are so critical to the engineering profession that A.B.E.T. has mandated that an accredited engineering program must incorporate one and one-half years of open-ended design experience in the curriculum" (UGA Handbook on Engineering Design, p. 3.).

Dym (1994) illustrated that design is a vital subject in engineering education; nevertheless, how and when design is taught generates great debate in the engineering education community and a consensus on design and design curriculum remains open for debate. Dym presented three general schools of thought on design:

> (a) Design is experimental in nature and creativity cannot be taught. This view warns against using a scientific approach to design and if done so it will likely result in generating an abstract and sterile science, thus, devoid of creativity and practical experience.

(b) Design is conversely generated from the views of engineering scientists, largely made up of analytical types possessing the opinion that there is no real context to teaching design. This belief is generated from a history of traditional design teachers unsuccessfully presenting the intellectual content of design education. This camp believed that there is no meaningful design curriculum unless it can be expressed mathematically.

(c) Design through a focus on scientific inquiry allowing for a broader view that encompasses the idea that design is a cognitive activity.

Dym proposed an integration of all three views on teaching design. He suggests using an experimental nature of design while considering that design is a cognitive activity.

Design is not only an important skill acknowledged by engineers but also by technology educators who stress the need to develop in K-12 students the ability to understand and perform design. Lewis (2005) argued that design is the single most important category in the Standards for Technological Literacy (ITEA, 2000), because design, as a subject and as a process as outlined in the Standards, falls within the domain of engineering. Lewis identified that of the twenty standards in the document, four directly address design. Moreover, Koen (2003) claimed that design is the essential core of engineering and what makes it a unique human activity. Another aspect of design that is worth exploring is the relationship between design and science. French (1998) pointed out that this relationship is misunderstood. He clarified the relationship by stating that science is the study of the natural world and its purpose is to bring understanding of the mysteries that lie within, while engineering design is focused on creating new things by using scientific knowledge.

Reviewing the above separate definitions of engineering and design, it is now appropriate to bring the world of engineering and the process of design together to define the term *engineering design*. Edie, Jenison, Mashaw, and Northup simply stated: “Engineering Design is a systematic process by which solutions to the needs of humankind are obtained” (2001, p. 79). A more detailed definition is:

> Engineering design is the creative process, which leads from the identification of a need to a device or system, which satisfies that need. It is the essential source of all new products. Design is an iterative process involving: a) many alternative approaches to satisfying the need (design concepts), b) multiple and often conflicting requirements and constraints (design criteria), and c) the use of various methods of evaluating and optimizing the alternative concepts (mathematical analysis, computer modeling and simulation, experimental prototyping and testing, and extrapolation from past experience) in order to arrive at the final configuration. (American Society of Mechanical Engineers, in Moriarty, 1994, p. 135)

Ullman (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).

The Standards for Technological Literacy 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). A later version of the Standards defines 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). A.B.E.T. has also 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 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).

Upon the review of these definitions, it is easy to see that engineering design is no easy term to define. There are many terms and concepts embedded within the various definitions of engineering design provided above, adding to the complexity of the definition, thus, allowing for multiple interpretations of what is meant by the term engineering design. For example, descriptions like basic science, mathematics, and engineering science leave a person to define the term basic in a subjective way. How basic is the math, science, and engineering sciences in engineering design? This example should serve to illustrate the point that even with this list of definitions of engineering design, the overall understanding of the term is often still open for interpretation.

Upon careful examination of the multitude of definitions, there are a number of key concepts embedded within these definitions that are common and thus create core elements of engineering design. Such as the term *systematic,* which is directly used in a number of the engineering design definitions (Dym et al., 2005; Edie et al.; ITEA, 2002) and is implied in other definitions (descriptions of engineers using a systematic approach to developing design solutions).

Another key term to describing engineering design is *iteration*. Although engineering design might use a systematic approach, the approach taken is not linear in nature but iterative (American Society of Mechanical Engineers in Moriarty, 1994; Dym, 1994; Gonnet, Henning, & Leone, 2007; Hill, 2006; Middendorf & Engelmann, 1998). The design process is an iterative loop so mixtures of questions are continually generated throughout the various stages of the design process, causing the engineer to return to various stages of design throughout the process (Dym et al., 2005).

Engineers do not create design solutions without any governing rules, regulations, or standards to maintain. No, engineers must function within defined *constraints* and *criteria* (American Society of Mechanical Engineers in Moriarty, 1994; Dym et al., 2005; Edie, et al. 2002; Wilson, 1965). Sheppard et al.(2004) described engineering work as being constraint-based problem solving.

Analysis through mathematics and scientific application is often cited as a key step in the engineering design process.

> Among the most important features of the design process are the formulation of a mathematical model, the analysis of the sensitivity of the system with respect to its elements, the analysis of the compatibility of the various components and subsystems, the

> determination of the stability of the system when subjected to various inputs, optimization of the design with respect to some pre-selected criterion, prediction of the performance of the system, and the evaluation and testing of the system by means of a mathematical model or prototype. (Wilson, 1965)

There are multiple definitions of engineering design that include the term analysis or imply the analysis process. (A.B.E.T.; Dym, 1994; American Society of Mechanical Engineers, 1986; Ullman, 2003)

Although these concepts identified above are key to understanding the term engineering design, the desired characteristics and abilities of an engineer as he or she takes on the role of designer are equally important. Dym et al. (2005) writes:

> There are many informative approaches to characterizing design thinking, some of which are now detailed. These characterizations highlight the skills often associated with good designers, namely the ability to: (a) Tolerate ambiguity that shows up in viewing design as inquiry or as an iterative loop of divergent-convergent thinking; (b) Maintain sight of the big picture by including system thinking and system design; (c) Handle uncertainty; (c) Make decisions; (d) Think as part of a team in a social process; and (e) Think and communicate in the several languages of design (p. 104).

A.B.E.T. defined the criteria for an engineer as having the abilities to:

> (a) apply the knowledge of mathematics, science, and engineering; (b) design and conduct experiments as well as analyze and interpret data; (c) design a system, component, or process to meet desired needs; (d) function on multidisciplinary teams; (e) identify, formulate, and solve engineering problems; (f) understand professional and ethical responsibility; (g) communicate effectively; (h) understand impact of engineering

> solutions in global and societal contexts; (i) engage in life long learning; (j) be aware of contemporary issues; (k) use the techniques, skills, and modern engineering tools necessary for engineering practice; and (l) manage a project. (Salinger, 2005, p. 3)

Robinson, Sparrow, Clegg, and Birdi (2004) conducted a study to determine the future competency profile for design engineers. The profile consisted of 42 competencies that were divided into the following six categories (in descending order of criticality): (a) personal attributes; (b) project management; (c) cognitive strategies; (d) cognitive abilities; (e) technical ability; (f) communication. Although it may appear that the results of this study suggests that technical ability is considered a lesser important competency for design engineers, the researchers suggested from the results of the study that technical ability and communication remains vital to engineering design. What separates good design engineers from great ones will be the level of personal attributes, management skills, and cognitive abilities and strategies. The researchers also pointed out that this is a new trend in desired qualities of engineers and thus teaching engineering will also need to reflect this change. Edie et al. (2001) suggested components in curriculum development to address such a change:

> The engineering design component of a curriculum must include most of the following features: development of student creativity, use of open-ended problems, development and use of modern design theory and methodology, formulation of design problem statements and specification, consideration of alternative solutions, feasibility consideration, production processes, concurrent engineering design, and detailed system description. Further, it is essential to include a variety of realistic constraints such as economic factors, safety, reliability, aesthetics, ethics, and social impact (pp. 79-80).

A.B.E.T. specifically outlines criteria that must be a part of an engineering design experience in an engineering program. The document stated:

> This design experience must be found throughout the curriculum and must culminate in a major project that requires the knowledge and skills acquired in earlier course work and incorporates engineering standards and realistic constraints that include the following considerations: economics, environmental, sustainability, manufacturability, ethical, health and safety, social, and political (UGA Handbook on Engineering Design, p. 3).

Just as with definitions for engineering design, multiple engineering design models exist. Moreover, just as obtaining consensus of one clear definition of the terms engineering, design, and engineering design is nearly impossible, so too is the inability from the field of engineering to reach a consensus on one engineering design model. The simplest of models of the engineering design process contain only three stages: *generation*, *evaluation*, and *communication*. Another simple model calls for steps that include *do research*, *create*, and *implement* (Dym & Little, 2002). Many other design models involve eight to ten stages of the design process such as Edie et al. (2001).

1. Identification of a need
2. Problem Definition
3. Search
4. Constraints
5. Criteria
6. Alternative solutions
7. Analysis
8. Decision

9. Specification

10. Communication (Edie et al., p. 5).

In review of examples of engineering design models, Maffin (1998) provided some insight into how some of the various design models differ. First, Maffin suggested that an engineer often uses several different design models dependent upon the type of project undertaken or problem encountered. He also pointed out that a distinguishing feature that differentiates the various design models is the design strategy implied in the process. Maffin has identified that the majority of engineering design models employ a *problem-focused* approach to the design process (Edie et al., 2002, Hubka & Eder, 1992). The focus of this approach to design starts with an analysis of the problem, followed by a systematic process of idea generation during which a number of possible solutions are generated. These ideas are further analyzed and refined until the best possible solution is generated. Conversely, a number of design models employ a *product-focused* approach to the design process (French, 1998), which first analyzes the product concept through the use of solution conjectures in order to generate design ideas and gain insight into and generation of a problem definition. This method supports the ideas that design solutions and problem identification can be generated concurrently. This method also employs the use of heuristics and any lack of scientific knowledge is supplemented by prior experience guided by general rules of thumb. Next, in the *product-focus* method, further analysis is applied and then process ends at the evaluation stage to refine and develop a final solution (Maffin, 1998).

An Engineering Design Model:

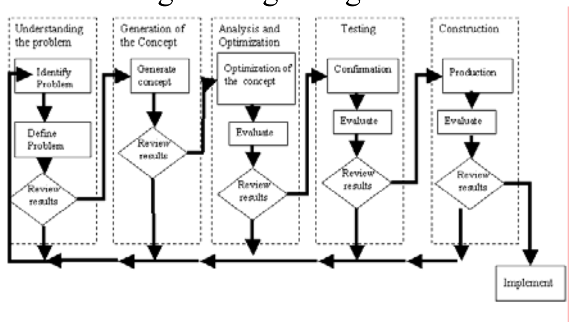


Figure 2.1. An Engineering Design Model

(Gattie, 2006, p. 4, University of Georgia Handbook on Engineering Design).

The *problem-focused* design method above centers around five engineering activities: (a) understanding the problem, (b) generation of the concept, (c) analysis and optimization, (d) testing, and (e) construction. The design process begins with an activity centered on the gathering of facts in order to better understand the needs expressed in a needs statement or statement of work. The desired result of this activity is a concise and coherent problem definition from which to work and should comprise of a new statement of work that better reflects the true problem, a set of criteria (both qualitative, set by the stakeholder, and quantitative, set by the designer) to assess the final design solution. Problem definition is often considered the most critical step (Dieter, 1991). The engineering problem definition created here is critical because the criteria defined within will be used to analyze, optimize, and predict the performance of the final design solution. It is important to note that although this is the first stage of the design process, it is appropriate and often necessary to return to this stage throughout the entire design process (see arrows in Figure 3.); once again the process is iterative so moving back and forth through the five activities is common. The next activity in this design model is *concept generation* where the design begins to interpret the problem statement into solution concepts. It is important to note, this activity requires a constant interaction between *understanding the problem*, and the next activity, *analysis and optimization,* for each concept generated. *Analysis* *and Optimization* requires refinement of conceptual solutions through multiple iterations moving from simple confirmation of the solution, addressing the problem definition, to the solution taking on more complex characteristics requiring further optimization. Mathematical models and engineering science principles are applied to the solution to assist in the analysis and optimization, and the smaller components of the solution are generated. Iterations continue through the first three activities of the design process until solution details are developed enough for mechanical drawings to be crafted. Testing requires the checking of the chosen solution to the original problem definition created by the stakeholder and engineer. This activity requires the confirmation or rejection of assumptions made in the prior stage of the process. Testing may encompass the use of simulations, prototyping, and or field-testing. The final activity involves *construction* of the final solution and is presented to the client or released to meet the need of society. In some cases, this activity requires a re-design of the design solution.

An Engineering Design Problem

Now that various definitions of engineering design have been discussed and some examples of engineering design models have been presented, a question may arise: 'what type of problem requires engineering? ' Koen (2003) provided an excellent example of an engineering problem when he cites the famous words of President John F. Kennedy:

> I believe that this nation should commit itself to achieve the goal, before this decade is out, of landing a man in the moon and returning him safely to the earth. No single space project in this period will be more impressive to mankind, or more important for the long-range exploration of space; and none so different or expensive to accomplish. (Koen, 2003, p24)

Koen used key elements from his definition to explain how this is an engineering problem. Koen defined the engineering method as "the strategy for causing the best change in a poorly understood situation within the available resources" (p. 7). President Kennedy's challenge was calling for the best change from an initial state where landing on the moon had never been done to a better state, successful space travel, moon landing, and safe return of the astronauts. Kennedy's challenge was complex, poorly understood at the time, and required the careful use of available resources. Koen suggested, when determining engineering problems, look for the key elements: *best*, *change*, *uncertainty*, and *resources.* Often engineering science is confused with engineering design. Certainly landing an astronaut on the moon and returning him or her safely back to earth requires engineering science, but engineering science alone cannot address all the issues of this engineering problem. Engineering design, in this case, was forced to work with such factors as safety of the astronauts, time constraints (remember this was a race of super powers), a limited budget, and limited resources and technology. These factors cannot be addressed by the simple application of engineering science.

In reflection of the information presented here in an effort to define engineering design, it is clear that the greatest hurdle for the field of technology education is not just to determine what engineering design is, but also how to teach engineering design authentically given the current conditions in technology education classrooms. Clearly technology education leadership must 'engineer' such a solution. Technology education leadership and curriculum developers must seek the most appropriate (*best*) ways to cause needed *change* in technology education classrooms in order to develop learning experiences that lead to technological literacy and prepares students to function as citizens and workers in a global society. Often the *resources* in technology education programs are limited and teachers are faced with many challenges beyond their control (Gattie & Wicklein, 2007). Moreover, there exists *uncertainty* for knowing what is currently being taught in technology education classrooms and determining what challenges those teachers implementing such a program face. Make no mistake about it; if you are looking for an engineering design problem, this is it.

Status Studies in Technology Education

Research needs for the field of technology education have been identified in a number of journal articles (Cajas, 2000, Foster, 1992; Lewis, 1999; Petrina, 1998; Zuga, 2000). Foster (1992) identified that program evaluation was the most frequent research topic area conducted by graduate students in the general field of industrial education, inclusive of technology education. Foster discovered that most research methods were surveys, and one quarter of those studies were status studies of the field. Petrina (1998) identified in a review of research in technology education that little time has been spent investigating the practice of teaching technology at the local, school-based level. This fact was confirmed by Lewis (1999) who indicated that although curriculum and program evaluation was a prime area of research investigation for technology education, little had been done up to that point to investigate the details of the status of change in the field from industrial arts to technology education. Lewis suggested that an investigation into what was taking place in practice at school districts was needed to better understand the changes that were taking place in technology education classrooms and the impacts it had on student learning. Lewis recommended conducting research that identified factors that cause certain teachers to change curriculum, while others held onto existing curriculum. Understanding what factors are involved in successfully making a change in curriculum and a description of the optimum conditions in which curriculum changes occur are research outcomes suggested by Lewis.

Since Lewis (1999) called for research in the area of the status of a movement in the field from industrial arts to technology education, a number of status studies have tackled the issue, some from an international perspective (Chinien, Oaks, & Boutin, 1995; Rasinen, 2003), a national perspective (Daugherty, 2005; Meade & Dugger, 2004; Newberry, 2001; Ndahi & Ritz, 2003, Oaks, 1991; Sanders, 2001), and a state level (Bussey, Dormody, & VanLeeuwen, 2000; Loveland, 2004).

Sanders' (2001) study used an existing instrument from Schmitt and Pelley (1966), later used in Dugger, Miller, Bame, Pinder, Gales, Young, & Dixon. (1980) study. The methodology and findings from both of these earlier studies provided a context and comparative data for this Sanders'study. His study attempted to describe the current programs of technology education at the time and compared these results with the findings of the Schmitt and Pelley study and the later Dugger et al. study. The research revealed that there has been an identified shift in thinking of the purpose of technology education from the study 1980 study. The new shift in thinking for technology education was demonstrated by respondent's top ranking of developing problem solving skills as the main purpose for teaching technology; previously the development of tools' skills held the top ranking. The second highest ranked purpose was identified as using technology to solve problems and meet human needs. Making informed educational and occupational choices was the third highest, ranked and understanding the application of math and science ranked fourth.

Also in 2000-2001 school year, Newberry conducted a descriptive study to determine the status of technology education in the United States. The study was sponsored by the International Technology Education Association's Technology for All American's Project (ITEA-TfAAP) in cooperation with the ITEA Council for State Supervisors. A survey instrument was sent out to all

U.S. state and territorial supervisors. The survey inquired into whether technology was a required subject in the state, if technology existed in each state's educational framework, and inquired about the number of technology teachers in each state. The results from the study showed that 57.7% of the respondents reported technology education was a part of the state framework of education, yet only 27% of the respondents reported technology education was required in some capacity. Another 30.8% reported that technology education was considered an elective in their state. The study found that 38,537 teachers were reported to be teaching technology education in middle and/or high schools. The results from this study revealed that a major movement was underway to establish technology education as an important subject in public schools. Likewise, school officials indicated that the publication of the National Standards for Technological Literacy (ITEA 2000/2002) was a pivotal document to help support this movement.

National surveys of the status of technology education have been conducted in the early 1990s to assess the progress the field of technology made with respects to moving from industrial arts to technology education. Oaks conducted a national survey in 1991 providing a progress report on the transition from industrial arts to technology education, and later Chinien, et al. (1995) conducted a study seeking a national census on technology education in Canada. More recently, Akmal, Oaks, and Barker (2002) expanded the Oaks and the Chinien, Oaks, and Bouten studies as well as the Newberry (2001) national study. Akmal, Oaks, and Barker used eleven of the most critical issues and trends in the field of technology education based on the literature to develop the following five major areas on which to focus their study: (a) The status technology education holds at the state level in schools; (b) The change in technology education program demographics during the last five years; (c) the degree to which extant curricular designs reflect current educational reform (the standards movement) and the evolution of technology education from industrial arts; (d) the current and future trends of technology educators supply and demand; (e) the diversity of school populations as reflected in technology education programs. Using the recommendations made from the Oaks (1991) study and the results from a research advisory group, the researchers selected state supervisors for the participants in this study. It was determined that "Supervisors have the primary responsibility for oversight of technology programs and that they were the single most qualified group to provide information requested in the survey instrument"(p.3). The results from this survey yielded 35 of the 39 states reporting that the field of technology education was held relatively high in status in the state offices of education, and that it was perceived by these state supervisors that technology education was a valued and recognized subject in their state. However, only 8 of the 39 states required technology education as a subject in their school curricula. Moreover, only 28 of the 39 supervisors reported that Career and Technical Education (CTE) initiatives such as Tech Prep, Career pathways, etc had a positive effect and 11 of the 39 state supervisors reported that these initiatives had no affect whatsoever in technology education receiving recognition. All but 4 of the 39 states reported that their state no longer used the program title "industrial arts". Although this is appearing to be a positive trend, 34 states report that traditional industrial arts and technology education programs are currently operating simultaneously throughout the state, a fact that Clark (1989) suggested has stifled the movement to technology education and caused many to view the changes in name only. An average was computed of those reporting industrial arts and technology education simultaneously, yielding a startling 48% still teaching industrial arts curriculum in their state. Thirty-one of the 39 state supervisors reported that their state was utilizing curriculum or plans for technology education, yet 17, or 44%, of those surveyed reported that the curriculum materials were aligned with the Standards for Technological

Literacy. Other areas of inquiry included: (a) teacher supply and demand for technology education programs, technology student organizations, diversity in technology education, and special education within technology education.

Dugger and Meade (2004) also conducted a status report on technology education in the United States. This research followed up the Newberry (2001) study to determine: (a) if technology education was in the state's framework of education?, (b) if technology education was a required subject in the state?, and (c) how many technology teachers were in each state?. Dugger and Meade also asked if the Standards for Technological Literacy were used in the state and if so how? They also asked if the document *Advancing Excellence in Technological Literacy: Student Assessment, Professional Development, and Program Standards* was used in the state, and, if so, how? These questions were pertinent to this study because the documents in question had been in publication for a few years, allowing time for implementation. The study had a 98% return rate. The results of the study indicated that 73.1% of the states include technology in the state framework compared with 57.7 % in the Newberry study. This study found that 23.1% of the respondents indicated that technology education was a required subject in their state; these results were down from the Newberry study (27%). Negative responses to this question were followed up with a phone interview which revealed that 28.8% of the participants who indicated that their state did not require technology did so to indicate that the decision was under local or district control. The follow-up interviews also revealed that 42.3% identified no state requirement for technology education existed in their state; therefore technology education was considered an elective choice. The research results indicated 35,909 teachers teaching technology education, with one state unreported. Seventy-eight percent (41 states) of respondents indicated that they use the Standards for Technological Literary (STL)

(ITEA, 2000/2002) either at the state level or in local school districts, and of those 53.8% report that the state based their own state standards and curriculum on the STL or realigned to STL. At the time of this study, the companion document to STL, *Advancing Excellence in Technological Literacy: Student Assessment, Professional Development, and Program Standards* (AETL) was just published in 2003, even so, 22 states (42.3%) indicated that they were using the document in some capacity.

Daugherty (2005) conducted a study examining the degree to which technology teacher education (TTE) programs supported the Standards for Technological Literacy and identify if there is a need/support for substantial change in technology teacher education. A total of 123 TTE teachers were surveyed with a 55.2% rate of return. Over 62% of respondents indicated that a major change was called for in the field. Most (over 80%) indicated that the program in place at their institution did not offer the ideal curriculum. These responders identified that change did not occur because of bureaucracy (19%), program in a state of revision, (13%) and another 13% indicated faculty disagreement or lack of a vision on curricular focus. Respondents indicated that a future change would differ from the current TTE programs by (a) more emphasis on content/ professional development standards (35%); (b) more emphasis on technological literacy, less on skill development (15%); (c) more emphasis on forming ties with other disciplines (13%); and (d) a change in focus to engineering and design (8%).

Respondents were asked what type of concepts should TTE programs prepare students to teach in technology education. The highest ranked item was teaching of the core concepts of technology. Teaching engineering design received was ranked 13th with a mean of 4.2 out of 5. What content base should be at the core of an ideal TTE program received a response of 28% for design, 22% for Engineering/Design, and 11% for technological literacy/standards. When asked about what competencies were current employers (school officials) demanding, traditional technical content (curriculum organizers) was ranked number one at 20%, standards-based technological literacy was number two at 12%, and classroom/laboratory management skills was 11%. The final question on the survey asked, if given a "clean slate" to starting over what would be the model to use for TTE. The top responses were technological literacy, design, and engineering and industrial curriculum organizers and technical skills each one accounting for 22% of the responses. Finally, integration with math, science, and the arts resulted in 14% as did the *Standards for Technological Literacy*.

The status of design in technology teacher education in the United States was researched by Warner and Morford (2004). The purpose of their descriptive study was to define the status of design in technology teacher education (TTE) programs in order to develop a database for later research on the effectiveness of various approaches to teach design in technology teacher education. Warner and Morford used two basic descriptors of design courses. Design courses were either described as *technique-based*, providing basic skills needed for the design trade such as focusing on technical drawing, computer aided drafting, and/or model making or *synergistic-based* where, courses combined technical skills with holistic thinking of the processes of design. Warner and Morford found that 431 courses in 57 programs focused on the study of design; of those, 373 were identified as technique-based courses compared with 58 synergistic courses. The average number of design courses per TTE program was reported at 7.6 courses. Survey results indicated that 38% of all the technique-based design courses were required for graduation, compared with 60% of the synergistic-based design courses.

Research on Technology Education with an Engineering Design Focus

Gattie and Wicklein (2007) conducted a national survey of technology educators in order to describe: (a) the current practices of technology education teachers in relation to utilizing engineering design practices within their classroom; (b) the value of an engineering design focus for technology education; and (c) instructional needs related to teaching engineering design. The results of this study indicated that over 90% of the in-service teachers identified that engineering design was an appropriate focus for technology education. The study also reported that 90% of the respondents indicated that they currently teach topics/courses that are related to engineering or engineering design. Respondents also indicated that 45.4% of their teaching instruction was related or connected to engineering or engineering design. Gattie and Wicklein's study also identified that 96.7% of in-service teachers surveyed indicated that engineering design was an ideal platform for integration with other school subjects, and 89.3% believed that engineering design as a focus would increase interest in math and science. Participants in the study indicated that engineering design focus elevated the field of technology education (92.7%) while improving instructional content (88.4%). However, the results of the study also indicated that these instructors face some challenges implementing such a curriculum. The top three instructional needs identified by the participants were (1) integrating the appropriate levels of mathematics and science into the curriculum (93.8%); (2) having appropriate tools and test equipment to teach engineering design (92.4%); (3) having appropriate type of lab layout and space to teach engineering design (91.6%). This study sought to better understand the status of technology education with respects to engineering design, and although 90% of the technology teachers surveyed considered themselves to be teaching courses and topics related to engineering or engineering design, questions remained about what teachers meant when they responded in this way.

The National Center for Engineering and Technology Education (NCETE) identified that the field of technology education should determine what should be included in a technology education curriculum that infuses engineering design, where the goal is technological literacy (Childress & Rhodes, 2008). Childress and Rhodes conducted a modified Delphi study to determine what engineers believe high school students should learn prior to entering post-secondary engineering programs. Upon completion of the focus groups phase of the Delphi, Childress and Rhodes asked engineers to identify what are the engineering student outcomes that a prospective engineering student in high school should know and be able to do prior to entering a post-secondary engineering program? The study surveyed thirty-four participants in the field of engineering: either, practicing engineers, engineering educators, or worker in fields closely related to engineering. After, the sixth round of the Delphi survey, 44 outcomes were identified and grouped into the following areas: (a) engineering design; (b) application of engineering design; (c) engineering analysis; (d) engineering and human values; (e) engineering communication; (f) engineering science; (g) emerging fields of engineering. Consensus of rankings for only three of the groups was accomplished. The grouping of outcomes titled *engineering design* was ranked #1, followed by *engineering analysis* ranked the third most important grouping, followed by *emerging fields of engineering* rank seventh or last. The single outcome that received the greatest ranking was *Ability to identify problems that could be solved through engineering design*. Although the final results of this research stopped short of obtaining consensus of rankings of the engineering outcomes groupings, it does provide great insight into what engineers and engineering educators believe are core outcomes critical to high school students' preparedness for post-secondary engineering programs.

Smith (2006) also conducted a modified Delphi study to determine the essential aspects and related academic concepts of an engineering design process in secondary technology education curriculum with the goal of establishing technological literacy. Twelve participants completed the survey to the fourth round. The research questions were: (1) What aspects of the engineering design process best equip secondary students to understand, manage, and solve technical problems? (2) What mathematics concepts related to engineering design should secondary students use to understand, manage, and solve technical problems? (3) What specific science principles related to engineering design should secondary students use to understand, manage, and solve technical problems? (4) What specific skills, techniques, and engineering tools related to engineering design should secondary students use to understand, manage, and solve technical problems? The results of the study yielded forty-eight (48) items that met the required level of significance. Some of the highest ranked items were (a) ability to handle open-ended/ Ill-defined problems; (b) ability to synthesize; (c) systems thinking; (d) basic algebra; (e) geometry. Some of the results of this study mirrored the Childress and Rhodes study (2006) results with similarities in identified student outcomes for secondary technology education with an engineering design focus.

In a similar vein of research, Asunda and Hill (2007) conducted a study to determine the critical features of engineering design that can be incorporated within technology education learning activities. The researchers also developed a rubric for assessing these identified features. The study used a phenomenological approach through a semi-structured interview process working with three professors of engineering education. The interview process revealed four core themes for emphasis in technology education with an engineering design focus. The four core themes are (a) the process of engineering design; (b) societal benefits of engineering design; (c) attributes of engineering design; (d) assessment. Qualitative data from the interviews was summarized and organized by the four themes. This data was used to construct an assessment rubric for evaluating the design (process and product), the communication (oral and written), and the teamwork demonstrated throughout the activity.

Each of these pivotal research studies (Asunda & Hill, 2006; Childress & Rhodes, 2008; Gattie & Wicklein, 2007; Smith, 2006;) have helped to define the new construct of engineering design as a focus for technology education at the high school level, and the results are vital to identifying the appropriate activities, outcomes, and assessments for engineering design at the high school level.

Theoretical Perspectives of Technology Education

Early in the 1990s, in the midst of the name change from industrial arts to technology education, the *Journal of Technology Education* (JTE) chose to publish a special theme issue dedicated to examining the state of technology education from different theoretical perspectives (Herschbach, 1992). With the field of technology education on the verge of a new shift in focus, it is appropriate to return to these key seminal works that examine the theoretical underpinnings of technology education. Herschbach explains that although curriculum development is not an exact science, there are five basic curriculum patterns generally recognized by curriculum theorists. He identifies the five patterns as academic rationalist (separate subjects), technical/ utilitarian (competencies), intellectual processes, personal relevance, and social reconstruction.

The special 1992 issue of JTE featured five authors from the field of technology education (Erekson, Herschback, Johnson, Petrina, & Zuga) each discussing one of the five theoretical frameworks as they relate to technology education. Erekson (1992) takes the view of technology education from an academic rationalist theory. According to Erekson, *academic rationalism* views curriculum as distinct subjects or disciplines. Erekson believes this is a theoretical view that lends itself to helping organize technology education. "Given the theoretical perspective of organizing subjects around conceptions of knowledge, the academic rationalist perspective of technology education will emanate from a characterization of technology as knowledge, which provides the boundaries or framework for a discipline" (p. 7).

Erekson (1992) cited *A Conceptual Framework for Technology Education*, (Savage & Sterry, 1990) as a prime example of an academic rationalist theory because the document refers to technology as a body of knowledge. The *Jackson's Mill Project,* (Snyder & Hales,1981) also identified industrial arts as having a distinct domain of knowledge organized around three areas: technologies, humanities, and sciences. Wright (1992) also supported the idea that technology education has a distinct body of knowledge that makes it a distinct subject or discipline, thus aligning with an academic rationalist. As Erekson pointed out, academic rationalist theory embraces the notion of developing a structured pattern to transmit knowledge involving students in the creation of new knowledge, a theory embraced by technology educators supporting the notion of immersing students in *doing* technology.

Herschbach (1992) highlighted a standard theoretical model used in the development of most industrial arts curriculum. This theoretical model is called the *technical/utilitarian* design pattern and is heavily based upon competencies as content. This theoretical model is ideal for those who view technology education as a vehicle to prepare students to enter the world of work. This viewpoint aligns with Prosser's view of manual training of the early 1900s. Developers of such a program would look to businesses and industry to help identify key competencies needed in the workforce. Herschbach indicated that although the field of technology education has made a move away from the competency-based model of the industrial arts era, it still exists in many technology education classrooms across the country.

Johnson (1992) provided a theoretical framework for technology education centered around intellectual processes emphasized through experiential learning opportunities common in technology education. Johnson cited Marzano et al. who identify five dimensions of thinking that can provide a theoretical framework for technology education. These five dimensions are thinking processes, core thinking skills, critical and creative thinking, metacognition, and the relationship of content to thinking. Johnson identified that this type of framework calls upon the teacher as a facilitator of the learning process and to focus on creating an environment where students can construct their own learning.

Petrina (1992) suggested a *personal relevance* theoretical framework for technology education. He presented that personal relevance theory is grounded in a humanistic theoretical view. Personal relevance is just that, development of learning experiences based on what is determined relevant to the student. In personal relevance theory, students are given the freedom to develop or actively help in defining their own curricula based on their own personal problems, development levels, goals, interests, capabilities, needs, etc. This theory of curriculum development has no place for behavioral objectives, the means and ends are not predetermined.

Zuga (1992) embraced the ideas of Dewey (1916) by suggesting a curriculum theory based upon *social reconstruction* popularized by the progressive movement. The premise behind this line of thinking is that education should work to educate the child to enter fields of science and technology, not for private purposes (capitalism), but for a social purpose.

Social purpose guides the development and selection of course content and activities that make up the curriculum. Although Dewey and other Progressives never saw these ideals widely spread throughout classrooms in the United States, Zuga believed that such a theory could be embraced by technology education. She suggested:

> In order to implement a social reconstruction curriculum orientation in technology education social problems, which have particular relevance to technology, are chosen and become the means for organizing technical processes. Technical processes are taught only as the need to know them in order to solve the social problems arises. (p. 54)

Zuga provided some suggestions of social problems that can be explored through the technology education content organizers of transportation, manufacturing, and communication. Zuga observed that although social reconstruction theory has been applied to some technology education activities, few technology education programs exist that use this theory as a foundation.

The Global Workforce, Technological Literacy, and Engineering Design

Wicklein (2006) and Daugherty (2005) endorsed engineering design as an ideal platform for addressing the standards for technological literacy (ITEA 2000/2002), while it also creates an instructional model that attracts and motivates students from all academic levels. Technological literacy is important for all citizens living in a technological society for a variety of reasons. First, all students are, and will continue to be, consumers of technology. Proper technological literacy teaches students how to be responsible consumers of the technology they purchase and use. Students in a technology education course with an engineering design focus will learn how to critically think about the technology they purchase including the positive and negative impacts that result from its use. Students will become technologically literate about the social, political, environmental, and cultural impacts of technology when they successfully complete a technology education course with an engineering design focus, especially if the course teaches systems thinking and requires the consideration of the social and cultural impacts of a design solution. Technological literacy also prepares K-12 students to be responsible voters, making decisions about the development of new technology that will also have social, political, environmental, and cultural impacts.

Today’s workforce requires job skills that move beyond excelling in the basic core subjects (Grasso & Martinelli, 2007). A national employer survey identified desired job skills needed in today’s workforce “require a portfolio of skills in addition to academic and technical skills. These include communication skills, analytical skills, problem-solving and creative thinking, interpersonal skills, the ability to negotiate and influence, and self-management (The National Center on the Educational Quality of the Workforce, 1995, p. 3). Dearing and Daugherty (2004) conducted a study to identify the core engineering-related concepts that also support a standards-based technology education curriculum by surveying 123 professionals in technology education, technology teacher education, and engineering education. The top five ranked concepts were:

1. Interpersonal Skills: teamwork, group skills, attitude, work ethic
2. Ability to communicate ideas: verbally, physically, visually, etc.
3. Working within constraints/ parameters
4. Experience in brainstorming and generating ideas
5. Product design assessment: Does a design perform its intended function? (p. 9).

The researchers surmised that these concepts, based upon the standards for technological literacy, were ranked so high due to the nature of the work environment in today’s society and the need for growing diverse workforce. Hill (2006) recants Dr. Richard Miller's words at a University of Georgia engineering conference about the need for engineers who have good communication skills, ability to work in teams, skills in social interactions, and have good business ethics. Hill suggested that technology education is an ideal program to team up with engineering education to help young people develop these attributes. Roman (2004) considered the needs of an American workforce struggling to survive in a global economy. He writes: "Thinking globally requires individuals who can think multi-dimensionally, integrating the technical and economic aspects of problem solving with the social, political, environmental, and safety concerns" (p. 22).

The question arises as to what is the best approach to teach these skills, abilities, and attitudes required of a competent and capable worker prepared to work and live in a global economy of the 21-century. *The Engineer of 2020* indicates that the engineer of the future will need to work in teams to study social issues central to engineering (National Academy of Engineering, 2004). McAlister (2003) observed that four of the twenty standards address technology and society so teaching social/cultural impacts of design is appropriate. I suggest using a systems thinking approach to engineering design to study technology related social problems because this platform is an excellent way to foster technological literacy and promote attitude, thinking skills and job skills listed above; however, this approach should not be applied for social engineering (Weinberg, 2003).

Systems Thinking Applied to Engineering Design

What is systems thinking? Jacobson and Wilensky (2006) write: "Complex systems approaches, in conjunction with rapid advances in computational technologies, enable researchers to study aspects of the real world for which events and actions have multiple causes and consequences, and where order and structure coexist at many different scales of time, space, and organization" (Jacobson & Wilensky, p. 12.). Kay and Foster (1999) added: "In short, systems thinking is about synthesizing together all the relevant information we have about an object so that we have a sense of it as a whole". (p. 2). Mapping out the complex issues of a system by reducing the system down to its parts and studying the relationships within those various parts is a process leading to a better understanding of the system. Furthermore, tensions may be identified that will likely emerge when a new approach to the system is applied. Failing to understand that these tensions exist and that the system contains these complex relationships will likely result in a design that is short lived or fails immediately. It is critical to understand that these relationships impact the entire system and manipulation of one relationship, in turn, affects the entire system. Biologist Lewis Thomas (1974) wrote,

> When you are confronted by any complex social system, such as an urban center or a hamster, with things about it that you're dissatisfied with and anxious to fix, you cannot just step in and set about fixing with the hope of helping. This realization is one of the sore discouragements of our century…You cannot meddle with one part of a complex system from the outside without almost certain risk of setting off disastrous events that you hadn't counted on in other, remote parts. If you want to fix something you are first obliged to understand…the whole system (p. 90).

Bar-Yam (n.d.) confirms this dogma by making the case that the ability of science and technology to expand human performance through design is dependant upon the understanding of systems and not just the components that lie within that system.

> The insights of complex systems research and its methodologies may become pervasive in guiding what we build, how we build it, and how we use and live with it.

> Possibly the most visible outcome of these developments will be an improved ability of human beings aided by technology to address complex global social and environmental problems, third world development, poverty in developing countries, war and natural disasters"(Bar-Yam, n.d., p. 2).

Frank (2005) maked a strong case for a systems approach for technology education. He pointed out that traditionally engineering and technology education often used bottom-up instructional approach, one that attempts to determine and deliver all the knowledge and skills needed by compartmentalizing the subjects: a separate math course, a physics course, statics, etc. Frank proposes a different approach based on the systems thinking approach, what follows is a proposal for a way to teach technology and instill technological literacy without first teaching the details (for instance, electricity basics and linear circuits for electronics, or calculus and dynamics basics for mechanical engineering). (p. 20)

The premise to this approach is that complete systems can be studied conceptually and functionally without needing to know the details, a top-down approach. A top-down approach focuses on characteristics and functionality of the entire system and the interrelating subsystems. This approach to teaching engineering design addresses issues raised by some that suggest teaching engineering design in technology education excludes some students who have not had, or lack an aptitude for, upper level math or science. A top-down approach also provides a feasible solution to high school courses with students enrolled at various stages of learning, for example, freshmen and seniors in the same class. These issues are of great concern when suggesting that technology education with an engineering design focus is for all learners.

Frank also shared the benefits of project-based learning for technology education that include student engagement, increased motivation, and increase multidisciplinary knowledge to name a few. Shepherd (cited in Frank, 2005) who found through research that students who experienced project-based learning significantly increased student's scores on the Critical Thinking Test compared with students in traditional instruction. Project-based learning requires students to work in teams to build a product. A misnomer in technology education is that the product created must be tangible, but Frank brought clarity to this issue. He writes:

> The product may be something tangible (such as a model/prototype, a system or a robot), a computerized product (such as software, a presentation, or a multimedia product), or a written product (such as a report, an evaluation summary or a summary of experimental findings (p.21).

A common concern in technology education of moving to engineering design is what will happen to the traditional hands-on projects that produce a physical product? I believe to best answer that question is to identify and understand appropriate engineering related problems to be explored in technology education. Some problems will lend themselves to tangible products; others will not, and technology educators will need to come to grips with the idea that not every problem solving activity will or should require a physical prototype or artifact.

A Constructivist Approach to Engineering Design and Systems Thinking

Jacobson and Wilensky (2006) suggest that young learners can handle complex systems thinking even at the middle school level. They suggest using a constructivist approach to learning, a philosophy of learning based upon foundational works of Dewey, Piaget, and Vygotsky. They write: "A central tenet of constructivist or constructionist learning approach is that a learner is actively constructing new understandings, rather than passively receiving and absorbing 'facts'" (p. 22). They believed that this method of learning can increase students' understanding of complex systems as well as being more interesting, engaging, and motivating for students when assigned authentic problems studied within cooperative learning environments. Blikstein et al. (cited in Jacobson and Wilensky, 2006) have conducted research that has been done in this area of systems thinking approach with results suggesting pedagogical approaches involving student generated questioning, theory development, and hypotheses about a particular phenomena. Next, students are required to develop experiments or create conceptual models using multi-agent or qualitative modeling software to confirm or refute their theories. Jacobson and Wilensky recommend a constructivist approach to teaching systems thinking within a team or group-learning environment.

Wankat (2002) agreed that a constructivist approach was key to improving the teaching of engineering and technology education. Reflecting on the work in *How People Learn*, Wankat believed that the student, not the teacher, must be in the “driver seat” of learning. Wankat described the ideal classroom environment to include:

> *Learn 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;
>
> *Community centered* --The context of learning is important. Combined argumentation plus cooperation enhances cognitive development (p. 5).

Wankat also warned against *content tyrant,* which takes place when you let the need to cover certain content control the teaching and learning that takes place in the classroom, a fact I note has plagued engineering education for years (National Academy of Engineering, 2004). Finally, Wankat pointed out that a successful graduate of such a program will have the ability to transfer knowledge from one experience to another. Dyer, Reed, and Berry (2006) cited

Crawford and the Center for Occupation Research and Development who suggested there are 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; 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).

Contextual Learning

Notice that the constructivist teaching strategies suggested by Crawford and by Wankat emphasize *context* as a key piece of learning in the constructivist approach. Contextual learning as described by Borko and Putnam (2000) is situated, distributed, and authentic. They suggest that all learning should take place in or be situated in specific physical and social context, to acquire knowledge that is intimately associated with those settings. Borko and Putnam also advocate that for transfer of learning to occur, students must be provided with multiple similar experiences allowing for an abstract mental model to form. Hanson, Burton, and Guam (2006) propose contextual learning has been a key strength for technology and engineering education programs allowing for transfer of knowledge from core subjects. Additionally, they suggested that contextual learning is a key concept helping technology education align with *No Child Left Behind* and provide learning opportunities for students to become prepared to work in a global economy. Context of learning is also essential in designing a solution. Glegg (1972) suggested that the context in which a solution will be applied is not only an important design consideration but also critical to learning design. Teaching engineering design must be done within a context that is authentic. Newmann and Wehlage (cited in Hutchinson, 2002) suggested that authentic activities have five dimensions which include: (a) involve higher order thinking where students manipulate information and ideas; (b) require a 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) require substantive communication among students; (d) and support achievement of all through communication of high expectations of everyone contributing to the success of the group.

Hutchinson (2002) suggested an additional field of inquiry worthy of consideration is problem-based instruction. Problem-based learning presents students with a problem situation, and then they are asked to determine what is happening. “Problem solving, in this approach, involves a process of a) engagement; b) inquiry and investigation; c) performance; and d) debriefing” (Hutchinson, 2002, p. 4). Pierce and Jones (cited in Hutchinson 2002) recommended the world of contextual learning theory and problem-based instruction can converge to produce highly conceptualized learning focused on questions/problems relating to real-world issues. Problem-based instruction is self-directed and collaborative. Authenticity of problem-based instruction is accomplished by encouraging dialogue with practicing experts and the manipulation of real data. Hutchinson also suggested formative assessments and student performance before a panel of experts. These methods have been used successfully in engineering to develop critical thinking skills in students (Woods, Felder, Rugarcia, & Stice, 2000).

Why Systems Thinking and Engineering Design for Technology Education?

If technology education is to be successful at implementing a new program with an engineering design focus, it must be able to articulate that learning engineering design can generate a type of thinking that can be applied to many occupations. With the application of engineering design and systems thinking, students learn how to use critical thinking skills to solve complex ill-defined problems that are necessary to live and function in the 21st century, regardless of whether the student plans to work in the factory, on the farm, or in the courtroom. No matter what occupations students select, they will encounter many ill-defined problems, none of which can be solved with a single textbook answer. Engineering design and systems thinking provides a systematic approach to solving ill-defined problems. Using the engineering design process, along with a systems thinking approach, can provide a vital universal skill that can transcend all vocations.

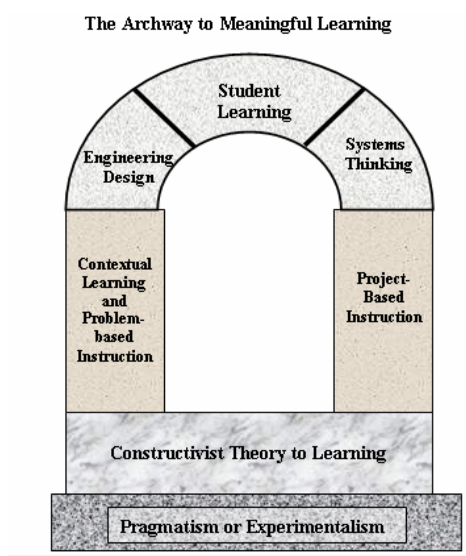


Figure 2.2. The Archway to Meaningful Learning.

To explain the graphic above, student learning is at the keystone, at the heart of why we need to teach from a constructivist approach. Student learning rests on, or is supported by, all the other "building blocks". Engineering design and systems thinking are next as are the "drivers" of the learning experience. I have placed engineering design under contextual learning and problem-based instruction because I believe that engineering design provides meaningful learning through a real-world context and is the type of critical thinking that is needed for today's global worker. Because systems thinking is required for solving open-ended and ill-defined problems which society faces today and which are also prevalent in engineering design projects, systems thinking is placed on top of project-based instruction. Laying a foundation upon which all the other concepts can rest is a constructivist approach to learning through a pragmatist or experimental over-arching philosophy. Valesey (2003) presented a philosophic line of thinking for technology education in Helgeson and Schwaller (2003) that aligns with the philosophy and learn theories presented here.

The Purpose of Technology Education

From the days of manual arts, through the industrial arts movement, to the development of today's technology education programs, an underlying dichotomy of philosophical views for the purpose of technology education remains unresolved. Dakers (2006) suggested two opposing philosophies exist that can serve as a framework for technology education, both of which are inspired by Pascal's writings of the mathematical mind and the perceptive mind. Dakers suggested that the one philosophy of technology education is grounded in the technical, empirical, and rule driven world that serves the needs of industry, versus the antithesis, a philosophy that advocates learning experiences that are hermeneutic, interpretative, and academic in nature.

Two major figures in modern educational philosophy, Charles Prosser and John Dewey, represent the debate that continues today over the purposes and implementation of Career and Technical Education (CTE) to which technology education is linked. Prosser, classified as an essentialist, embraced CTE as it was outlined in the Smith-Hughes Act. He believed that its primary goal was to provide specifically trained individuals for the labor needs of business and industry. John Dewey, a pragmatist, argued that CTE should focus more on the individual needs rather than market needs (Rojewski, 2002). Individual differences and problem solving skills, according to Dewey (1915, 1916), were essential to CTE. Later the debate continued in print in columns in the *New Republic* between Dewey and David Sneeden (1915).

Dakers suggested that Rousseau, in the mid 1700s, addressed the argument of academic verses vocational, and concluded that the overall purpose of education was either to make a man (human being) or a citizen. Rousseau concluded that to do both through education was not possible. Dakers traced this logic of thinking back even further to ancient Greece, with the works of Descartes and the birth of positivism, which once and for all separated the mind from the body and hand from the head, a idea that is still very prevalent in the minds of many today. The very fact that the field of technology education has never definitively identified its sole purpose is likely the reason why some have suggested that the field of technology education has never been fully established or has never communicated a clear mission (Wicklein, 2006).

Dr. William E. Warner, along with a group of doctoral students, published *A Curriculum to Reflect Technology*, which proposed for the first time the notion of teaching all students about technology (Warner, Gray, Gekbracht, Gilbert, Lisack, Kleintjes, et al., 1947). Warner et al. proposed a curriculum that taught students about technology, not with a career or jobs skills focus, but one that taught technology to educate the individual as a consumer, often as a producer, in recreation, and as a citizen living in a technological society. Warner et al. stressed technology education was for all learners, not merely for those students that plan to major in technological fields of study. Warner et al. also advocated that technology education curriculum must be adjusted so that the content did not go beyond the spectrum of general education.

Many technology educators today would contend that technology education is important for all students; this is especially true if one considers technology is a vehicle for technological literacy for all students (Technology for All Americans, ITEA, 1996). Does adopting this viewpoint for the purpose of technology education force one to abandon the benefits of technology education as pre-vocational education? Clearly, the opposing viewpoints of the purpose of technology education have caused some division among those who might normally be in support of technology education. Foster (1997) identified that the history of industrial arts/ technology education reveals that a great debate in the 1970s all but split the field in two; the debate was the uncertainty of whether industrial arts should focus on general education or on vocational education. Foster and Wright (1996) have revealed that the former industrial and technical education models have existed simultaneously and had been a source of competition, splitting the field in separate directions. They further wrote that the field of technology education has never been completely in consensus about the direction the field of technology education should take. Hill (2006) suggested that representing this division in philosophies is the simultaneous existence of Technology Education Division (TED) within the Association for Career and Technical Education (ACTE) and International Technology Education Association (ITEA). The lack of uniformity in the field of technology education is well documented (Petrina, 1993; Wicklein, 2006; Wright, 1992; cf.).

If one considers that a major purpose for technology education is to create a learning environment which fosters technological literacy for students, then justification must exist for teaching technology education in general education. However, there is equal justification for teaching technology education with an engineering design as a career pathway for those entering fields of engineering as suggested by Wicklein (2006) and Daugherty (2005).

Often those who view technology education as a part of general education are sometimes forced to consider a compromise when faced with the idea of missing out on federal funding that supports career and technical education. This fence sitting approach has been a sore spot in the field of technology education for some time (Karnes, 1999). Lewis (1996) used Woodward (1894) as an example of one who was forced to compromise his ideals for manual arts for all children's general education. Woodward possessed a liberal education viewpoint of manual training that moved way beyond just manual training as trade training; however, with the passing of the Smith-Hughes Act of 1917, Woodward was faced with a border crossing. Supporters of manual training saw manual training as a way to loosen union stranglehold on apprenticeships, Woodward and his 'camp' were forced to sell manual training as a vocational training as opposed to a liberal education for all in order to go after Smith-Hughes monies.

Wicklein (2006) spoke to the damage done by technology educators today who choose to separate from CTE. This paradox has required many technology educators to shun or avoid professional connection with CTE associations while at the same time seeking financial support from the same agencies. This inconsistency has not been healthy for the technology education profession and has diluted our efforts to advance the cause of the field (p. 28). Clearly damage has been done by those in the field who sit on the fence and collect necessary funds for their program while at the same time look down upon CTE.

Lewis (1996) suggested Woodward crossed borders to manual arts as vocational training to acquire necessary funding provided by Smith-Hughes monies and still today technology education is often looking to cross borders to career and technology education. The legislation of Perkins 1998 and the School to Work Opportunities Act of 1994 created border crossing opportunities for those within technology education who view it as general education but are forced to look favorably on technology education as career education to acquire federal dollars to fund technology education programs. *Project Lead the Way* is an example of technology education with a pre-engineering focus that aligns with Perkins legislation by providing students with career pathways for engineering related fields. The tides have shifted for many in technology education to come to the realization that technology education is an excellent place to foster career skills needed for the world of work while still providing technological literacy. Karnes (1999) noted in a review of perspectives from thirty-five leaders in the field of technology education that most have moved on in their thinking of a separation of technology education and vocational education. He cites Moss who sums up the new perspective on this division by saying:

As vocational education redefines itself, vocational curricula are becoming less specialized. At the same time the academic subjects are becoming more concerned about practical applications beyond schooling. The time is propitious to exploit, rather than resist, the natural connections between technology education and the world of work. The occupational implications of technologies and technological change provide a rich resource for exploring a wide variety of careers. Technology education teachers should deliberately plan and provide for a wide range of experiences that help students learn about themselves in relation to relevant occupations. (p. 33)

Lewis discussed this potential border crossing opportunity today for technology education in the Perkins legislation called Tech Prep. Lewis made a clear distinction between the compromises made during the Woodward era of the Smith-Hughes Act when a political stronghold was on vocational education; however, recently the Perkins Act has survived reauthorizations and several shifts in philosophy, and has emerged to emphasize the belief that strong academics are essential in vocational education. Several strong initiatives from this act support the efforts to integrate vocational and academic education (Hayward & Benson, 1993). Moreover, the Perkins revisions of 2005 require that CTE programs demonstrate their ability to successfully integrate subjects and raise academic standards, a reality that makes engineering an appropriate career path that aligns with Perkins legislation.

A political debate that occurred between the Democrats and Republicans as the Perkins legislation was redrafted in 1998 provides an appropriate justification for a career pathway with an engineering design focus. The debate was founded on the idea that vocational education only served a select special population of students and was therefore not accessible to all; revisions were made to ensure Perkins funded programs were open and accessible for all learners (Scott & Sarkees-Wircenski, 2001). Providing a career pathway that allows students to explore engineering careers in a population of learners not typically served in former career and technical education programs. The language of the Perkins Improvement Act of 2005 suggests career and technological education programs must find ways to improve students overall academic abilities of the students it serves. In section 3, the definition section of the document, career and technical education is describe as: "(A) offer a sequence of courses that – (i) 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). Further in the same section of the legislation, the focus remains on career and technical education courses designed to prepare individuals academically and technically: "(9) support to improve or develop new career and technical education courses and initiatives, including career clusters, career academies, and distance education, that prepare individuals academically and technically for high skill, high wage, or high demand occupations" (p. 45).

A few key pieces to consider in these sections of Perkins legislation is that CTE programs must (a) develop higher-order reasoning, problem-solving, technical, and occupational-specific skills (b) integrate academics (especially mathematics and science) with career education. (c) focus on technical and non-traditional careers, (d) prepare students with high skills for high paying and high demand careers. Each of these skills and attributes can be effectively developed in a career path focused on engineering related careers embedded within a technology education program. Integrating subjects and career education is addressed by Wicklein (2006) who made the case that moving technology education to an engineering design focus also provides an ideal platform for integrating mathematics, science, and technology. Another of Wicklein's five good reasons to move to engineering design for technology education is engineering provides a focused curriculum leading to multiple career pathways. Colelli (1993) in an ITEA document called *Tech Prep and Technology: A Positive Focus for Competitive Literacy* writes:

The goal of technology education is technological literacy and its major purpose is for the holistic understanding of technology for the liberal education of all citizens in a democratic society. Technology education also serves as a wonderful foundation for individuals who are interested in pursuing an engineering related career. (p. 17)

This document proceeds to provide details in which technology education should educate students in a career pathway that leads to associate degrees in engineering technology or completion of professional education in engineering related disciplines. Dearing and Daugherty (2004) suggested that the standards for technological literacy provide an appropriate connection between technology education and engineering. “The standards have provided an opportunity to move technology education and pre-engineering closer together and have help illustrate the mutual relationships and the benefits of technologically literate secondary students to the engineering profession” (p. 8).

Currently, there exists a high demand for qualified workers in the field of engineering. The U.S. Department of Labor reports that a twenty percent increase in the demand for engineers will occur before the end of the decade, and currently many engineering jobs remain unfilled because of the lack of qualified candidates. Moreover, the National Society of Professional Engineers reports that engineering programs hit a 17-year low in 1999. Compounded by the fact that attrition rates are high at colleges of engineering, these figures prove there is a high demand for competent, qualified engineers (Southern Regional Education Board, 2001).

Technology Education with an Engineering Design Focus

Daugherty (2005) supported the notion of using a design and engineering focus to address the standards. He writes, “The standards also introduced, in a not so subtle way, the notion that technology should facilitate technological literacy, with a focus on design and engineering” (p.42). Rogers (2005) conducted a study in the State of Indiana to determine pre-engineering’s place in technology education and its effects on technological literacy as perceived by two groups, teachers of Project Lead the Way and Non-Project Lead the Way technology teachers. The results from this study indicated that 69.4% of the Hoosier technology educators surveyed indicated that pre-engineering was a very valuable component of technology education. Moreover, both Project Lead the Way teachers and Non-Project Lead the Way teachers ranked the overall effectiveness of a variety of pre-engineering activities for their effectiveness in developing technological literacy. The top five activities were as follows: (1) Applying the engineering design process, (2) Designing and prototyping solutions; (3) Designing automated manufacturing systems; (4) Applying geometric constraints; (5) Designing CIM processes.

These examples are not the first time that the topic of engineering is addressed in the field of technology education. Lewis (2004) indicated that a course called *Principles in Engineering* has been taught in technology education in New York State since the late 1980s. Furthermore, Lewis cited Delmar Olsen as the first to include engineering as a representative curriculum component published in his doctoral thesis in 1957. The Engineering Concept Curriculum Project (ECCP) began its work in 1965. This national project was created as a response of national studies that indicated the United States had entered an age of technology, and curriculum must reflect this change by teaching technology through the context of engineering. Over 10,000 students participated in this curriculum project called *The Man Made World* between 1965 and 1970. The focus of this curriculum was on systems technology and explored the many impacts both positive and negative that technology has had on society in the twentieth century. The developers of this project had engineering backgrounds and most learning activities focused on problem solving methods embedded within engineering related projects (Engineering Concept Curriculum Project, 1971).

Current Curriculum Projects Focused on Engineering and Engineering Design

Project Lead the Way (PLTW) seeks to implement pre-engineering curriculum into technology education courses and boasts serving over 1250 schools in 44 states and teaching over 160,000 students (McVearry, 2003). Project Lead the Way began with 11 high schools in upstate New York in 1997 (Rogers, 2005). Project Lead the Way Inc. is a not-for-profit organization that works with public schools, the private sector and higher education to increase the quantity and quality of engineers and engineering technologists by providing high school students with engaging pre-engineering studies (Southern Regional Education Board, 2001, p. 2). PLTW courses are taken in conjunction with a college preparation course of study; these courses use a project and problem-based learning curriculum designed to allow students to apply knowledge to real-world problems.

PLTW learning experiences allow students to:

> (a) Understand the scientific process, engineering problem solving, and the application of technology; (b) understand how technological systems work with other systems; (c) use mathematics knowledge and skills in solving problems; (d) communicate effectively through reading, writing, listening, and speaking; and (e) working effectively with others. (Phelps & Alder, 2007, p. 11)

The four-year pre-engineering course sequence consists of four foundational courses that include (a) Principles of Engineering; (b) Introduction to Engineering Design; and (c) Digital Electronics. Four specialization courses include: (d) Aerospace Engineering; (e) Biotechnical Engineering; (f) Civil Engineering and Architecture; and (g) Computer Integrated Manufacturing. The capstone course is (h) Engineering Design and Development (www.pltw.org/curriculum/hs-engineering.html).

Project Probase is a National Science Foundation funded curriculum project that has developed high school technology education curricula designed to help prepare high school students who plan to attend a community college technician education program or university-level engineering programs. Probase has developed a set of eight learning units for the 11th and 12th grade level. These learning units come directly from the context identified in the Standards for Technological Literacy and are developed to use hands-on problem solving activities teaching the fundamentals of technology in the following fields of study: (a) agriculture; (b) information and communications; (c) entertainment and recreation; (d) energy and power; (e) transportation; (f) medicine; and (g) construction and manufacturing (http://www.probase.ilstu.edu/). Each of these learning units consists of forty hours of instructional time. Students are challenged to solve primary and secondary engineering design problems by conducting research, gathering information, asking technical questions, and studying core technological concepts. The premise behind the creation of Probase curriculum is to address the need for upper high school level standards based courses that promote technological literacy and also provide a specialized knowledge base required for post-secondary engineering or technical education. The creators of Probase curriculum have worked extensively with six Illinois community colleges to create bridge competencies, educational experiences that will assist students in the transition from high school into a post secondary technical college (Wyse-Fisher, Daugherty, Satchwell, & Custer, 2005).

The International Technology Education Association's Center to Advance the Teaching of Technology and Science (ITEA-CATTS) created *Engineering by Design* (EbD), a K-12 standards-based curriculum design around themes in the STEM and IT clusters. The purpose of EbD is to increase students’ achievement in technology, science, mathematics, and English. The curriculum is built around seven principles or large concepts creating major content organizers for the curriculum. These organizing principles include: (a) engineering through design improves life; (b) technology has and continues to affect everyday life; (c) technology drives invention and innovation and is a thinking and doing process; (d) technologies are combined to make technological systems; (e) technology creates issues that change the way people live and interact;

(f) technology impacts society and must be assessed to determine if it is good or bad; and (g) technology is the basis for improving on the past and creating the future. *Engineering by Design* includes the Probase curriculum in its course sequences for grades 11 and 12. Partners in the Engineering by Design project include National Aeronautics and Space Administration (NASA) and National Science Foundation (NSF) (ITEA CATTS, n.d.).

The Massachusetts Department of Education has taken a strong lead in K-12 engineering education by creating a state curriculum guide called "Science and Technology/ Engineering Framework", completed and implemented in the spring of 2001 (http://www.doe.mass.edu/frameworks/scitech/2001/standards/te9_101.html#). The standards for engineering design are written under a broad concept: engineering design involves practical problem solving, research, development, and invention and requires designing, drawing, building, testing, and redesigning. Engineering design standards have been created for pre K-grade 10. A list of suggested learning activities for each of the grade levels are posted on the state's department of education website and indicate how each learning activity meets various state standards. Lewis (2004) indicated that Tufts University engineering school has highly influenced the technology education curriculum in the state of Massachusetts.

A New Type of Problem Solver

The literature is clear about a changing workforce: jobs that formerly required problem solvers with analytical skills and left-brain thinking are being replaced with computers or are outsourced to foreign competitors (Felder, 2006). Literary works such as *The World is Flat* (Friedman, 2005) and *A Whole New Mind* (Pink, 2005) call for a new kind of problem solver. One who competes on a global scale must have the following attributes: (a) creative researchers; (b) ability to design aesthetically and for functionality; (c) holistic, and multidisciplinary thinkers who can recognize complex patterns common in a global economy and develop effective strategies, (d) strong interpersonal skills, (e) effective communicators and cultural awareness, (f) and self-directed learners (Felder, 2006). Similar identification of the needed attributes of the worker for the 21st Century is present in other literature (Dearing & Daugherty, 2004; Dakers, 2006; Grasso & Martinelli, 2007; Hill, 2006; Roman, 2004; The National Center on the Educational Quality of the Workforce, 1995).

Approaches to Analytical Design for Technology Education

One missing piece in the technological design process commonly used by technology educators that is key to the engineering design process is the attention paid to analysis (Hailey, Erekson, Becker, & Thomas, 2005; Hill, 2006; Wicklein, 2006). Lewis (2005) makes the case that a major challenge to infusing engineering design in technology education is how to interpret engineering design authentically. Lewis believes that the root of this challenge is not in the teaching of conceptual design, but rather in the limits of analytical design. Lewis suggested three approaches to addressing this challenge. First, he suggested the Petroski's (1998) approach to teaching design to freshmen engineering students, where the focus is not on calculations, but on the essence of design, the critique of design, and the role of trade-offs, teamwork, invention. A second strategy suggested by Lewis is to limit the analytical design by including a set of completely worked out engineering design cases. Arguments have been made against immersing students new to engineering into full-scale engineering design problems since they typically lack the analytical tools necessary for a successfully developed design; consequently, providing engineering design cases is a feasible solution (Dym, 1994; Petroski, 1998). McAlister (2003) suggested that historical design cases should be used in technology education to study the social and cultural aspects of technology. A third option suggested by Lewis involves a collaborative approach to design, where technology teachers team with mathematics and science teachers, as well as with practicing engineers, to teach engineering design. Although this strategy provides a blend of experts in the analytical and conceptual, it also requires buy-in from a variety of stakeholders, thus providing considerable logistics in implementation and sustainability.

Organizing Engineering Design in Technology Education

Hill (2006) suggested perspectives vary greatly in the field of technology education as to the role that engineering should play within the field of technology education, with a range of perspectives that include technology education as pre-engineering to presenting engineering design as a creative activity. Bensen and Bensen (1993) suggested organizing engineering and technology through four possible approaches: 1) the Disciplines, 2) the Systems, 3) the Processes, and 4) the Impacts (see Figure 2). They propose that these different approaches can serve as a model upon which to design educational programs. Hill (2006) takes the perspective that technology education should retain its general education purpose while at the same time providing a focus for technology education and provide career pathways through engineering. He suggested extending design and problem solving beyond engineering to embrace aesthetics and artistic creativity. Returning to the Bensen and Bensen model, the area that focuses on the processes used to solve problems or design products seems to be a logical way to organize courses and embrace the aesthetic and artistic creativity of the art world suggested by Hill. Some suggest that the process (problem solving and design) are at the core of technology education (Plaza, 2004). Flowers (1998) identified that a strong movement toward design and problem solving occurred in technology education in the 1990s, yet it has been in our history since the 1920s (Foster, 1994). Wicklein and Rojewski (1999) suggested that a unified curriculum with a focus on the mental processes and techniques used in a technical problem can remain constant over time as compared to a curriculum based on obtaining technical knowledge that quickly becomes obsolete. Snyder (2004) suggests that as technology education seeks opportunities to define its role in American education, the process is key. He believed emphasis should be on the development of student's capabilities through design and problem-solving activities and using a broad, interdisciplinary approach to promote learning knowledge and developing skills necessary for living and working in a technological society. Lewis (2004) also identified that design and problem solving have been the anchoring ideas for technology curriculum. The engineering design method of problem solving can serve all students through out their lives (Garmire, 2003).

Thus, it seems natural to use the *processes* of design and problem solving as the content organizer instead of engineering domains or technology systems. If the design and problem solving process is so essential to the technology education experience, especially considering the infusion of engineering design, make it the central focus of the curriculum.

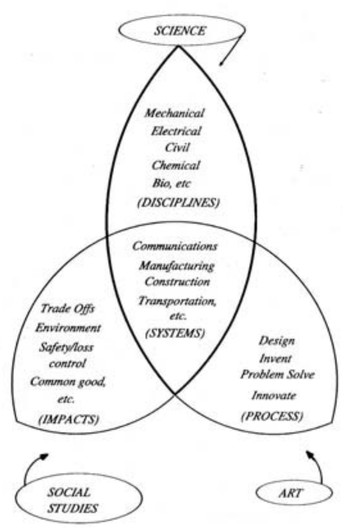


Figure 2.3. (Bensen & Bensen, 1993, p. 5) Integrating Engineering Model into Technology Education.

Moreover, Bensen and Bensen proposed that approaching engineering in technology education through processes is universal and includes technical dimensions in addition to human dimensions (See figure 2.3). I believe that organizing courses through the process provides a more universal and holistic approach to technological literacy through engineering design while at the same time expanding career pathways for students. One major argument of opposition for moving to a narrow focus of technology education is that many students do not have an interest in engineering, thus reducing the enrollment into technology education courses. Many graduate fellows in the National Center for Engineering and Technology Education identified this argument in their reflective journals (Gattie, 2006). Using the processes of engineering and technology to organize courses allows for the study of: 1) the seven areas of the design world identified by the standards for technological literacy (ITEA, 2002, p. 139); 2) the impacts of engineering and technology; 3) the systems of technology; 4) the disciplines of engineering. Using the process of engineering and technology to organize courses allows for students to construct (see theory question) their learning through a program of study that focuses on their individual areas of interest that lead to a career pathway while at the same time obtaining necessary work skills needed for today's global economy identified in the literature (The National Center on the Educational Quality of the Workforce, 1995; Dearing and Daugherty, 2004; Roman, 2004). *Engineering by Design* has also proposed a constructivist approach to curriculum development and has moved away from technology systems as content organizers, using design and engineering design as a content focus. *Engineering by Design* provides learning experiences that are Science, Technology, Engineering, and Mathematics (STEM) based to provides career pathways (http://www.iteaconnect.org/EbD/ebd.htm).

CHAPTER 3 METHOD

Introduction

This chapter contains a description of the procedures and methodology used to conduct this research study. This section contains the purpose of the study, design of the study, description of the participants, instrumentation, procedure, and data analysis.

Research Design

This descriptive study examined the degree to which technology educators were implementing elements of engineering design in their curriculum. Although technology education programs across the country have implemented engineering content into courses in recent years (Lewis, 2004; Rogers, 2005), little was known about the status of this curriculum change with respect to current technology education curriculum content, assessment practices for engineering design activities, or degree of engineering design program implementation. One curriculum program, Project Lead the Way (PLTW), seeks to implement pre-engineering curriculum into technology education courses and boasts serving over 1250 schools in 44 states and teaching over 160,000 students (McVearry, 2003). There are also other high school technology education programs that infuse engineering content in the curriculum or have engineering design as a focus. However, it was unclear to what degree engineering design content was being implemented in technology education courses. Likewise, some technology education programs not designed specifically with engineering design as its’ focus may indeed have been teaching engineering design content. Therefore, a descriptive study is needed to gather information to fully understand the degree to which technology educators are implementing elements of engineering design in their curriculum in high school technology education courses.

Descriptive research studies inquire about the nature, frequency, or distribution of variables and /or relationships among variables. Descriptive studies make no attempt to manipulate variables but serve to provide descriptions of variables and/or the relationships among these variables (Ary, Jacobs, & Razavieh, 1990). A descriptive study seeks to describe a construct the way it is as it naturally occurs (Huck, Cormier, & Bounds, 1974). Descriptive studies can help educators understand frequent curriculum implementation problems and other issues in current teaching practices (Gersten, n.d.).

A disadvantage of descriptive research is that it does not establish cause-and-effect relationships like experimental research. However, an advantage is that it can provide information for developing an accurate description of a selected phenomenon (Gall, Gall, & Borg, 2007). This study served as a foundation for future research that will examine technology education with an engineering design focus. Descriptive research was an appropriate design to answer the questions puzzling the field of technology education about the current status of technology education programs with a focus on engineering design or engineering content.

Participants

This descriptive study drew a sample of high school technology teachers from the current ITEA membership list. The sample consisted of all high school technology teachers regardless of whether they indicated they were teaching engineering design in their classroom. The International Technology Education Association (ITEA) membership list represents individuals who are practicing high school teachers for the 2007-2008 school year in the United States. ITEA is a professional organization with a focus on technology education and caters to education professionals from elementary to high school classroom teachers, local, state/province supervisors, and college/university faculty both nationally and internationally for more than 65 years (http://www.iteaconnect.org/AboutITEA/about.htm, 1995). ITEA is the largest professional organization for technology education, the primary voice for the field of technology education, and serves as an information clearinghouse dedicated to implementation of technological literacy in K12 schools (Gattie & Wicklein, 2007). As of September 2007, ITEA had nearly 3800 total members; of those 1043 were high school teachers (Price, 2007). Using the ITEA membership list to locate in-service high school technology education teachers was a convenient way to locate participants for this study however; targeting a population such as ITEA has limitations because the organization's members may not be a true representation of the entire population of technology education teachers in the United States.

The identified population of this study consisted of (N) 1043 high school technology education teachers as of September 11, 2007 ITEA membership roll. Krejcie and Morgan (1970) created a table to locate sample size for a given population size using a formula obtained from the United States Office of Education (Gay & Airasian, 2000). Using the Krejcie and Morgan (1970) table, the size of the sample needed for the targeted population was 285. The original research design for this study called for an increase of the initial mailing of the survey by 48.1 percent, the average success rate of an initial mailing (Gall et al; 2007). However, close communication with ITEA personnel revealed that ITEA survey mailings typically yield a 20-25% rate of return (Price, 2007). The researcher determined that a mailing to all ITEA high school members was necessary to achieve the desired sample size.

Instrumentation

There were three dependent variables for this study. The first was the degree to which engineering design content was delivered in technology education courses. To measure the degree of implementation of engineering design content, the following seven categories were generated from previous research (Childress & Rhodes, 2008; Smith, 2006) (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. The second dependent variable was assessment strategies for engineering design activities as identified by previous research (Asunda & Hill, 2007). The third dependent variable was selected challenges implementing engineering design as identified by (Wicklein & Gattie, 2007).

It is important for the leadership and in-service teachers in the field of technology education to understand the current practices and content being taught in high school technology education programs in the United States. Many of these programs are designed to teach engineering concepts and or engineering design in high school. However, little was known about the degree to which technology educators were implementing elements of engineering design in their curriculum. This study sought to better understand this construct by using existing research that identified learning objectives and assessment strategies identified by practicing engineers and engineering education faculty as critical content and assessment practices for implementing engineering design concepts in high school curriculum (Asunda & Hill, 2007; Childress & Rhodes, 2008; Gattie & Wicklein, 2007; Smith, 2006). 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. The researcher reviewed the results from these various studies and the instruments that were used. The researcher removed any redundant content as well as any items that were deemed not statistically significant by the previous research studies. The researcher followed content validation methods and scale development procedures as outlined in the literature (Crocher & Algina, 1986; Devellis, 2003; Netemeyer, Bearden, & Sharma, 2003).

The identified learning outcomes and assessment strategies were compiled into a list and presented to another panel of experienced engineering education faculty for farther verification. Open- ended questions accompany each section of the instruments seven subset categories, as well as at the end of the assessment strategies section. The list of outcome and assessment strategies were presented to the panel asking experienced engineers and engineering education faculty to identify any missing learning outcomes or assessment strategies they deem important for implementation of engineering design content in high schools (Crocker & Algina, 1986).

An initial pilot test of the draft survey was given to 25 technology education teachers who were members of ITEA at the time of this study. This sample group was asked to complete the questionnaire and identify any items that were confusing or caused difficulty to respond. The pilot test participants were also asked to explain their interpretation of each of the seven subset categories. There was space available for participants to provide feedback or make recommendations to improve the instrument (Gall et al., 2007). Upon receiving these pilot test results, the researcher revised or removed items that were indicated as problematic by the sample group. The results from this list were used to develop a survey for this study. The student learning objectives and assessment practices were reframed into questions asking participants to indicate how closely each item represented the learning outcomes and assessment strategies they were using while teaching technology education at the high school level. A set of questions were presented with a Likert-type scale response format asking participants to rate their level of agreement regarding the content and assessment strategies they employed compared with content and assessment strategies identified by experienced engineers and engineering faculty. A Likert scale consists of statements, characteristics, or questions to which the respondent indicates the degree of intensity on an agreement scale by selecting a number that best represents his or her response. A Likert scale is similar to a Thurstone scale but does not require a panel of judges to construct it, thus, is easier and less time consuming to construct. Moreover, a Likert scale has yielded similar results as a Thurstone Scale (Best & Kahn, 2006). The Likert scale method is the most widely used scale in survey research (Lodico, Spaulding, & Voegtle, 2006). Often a Likert scale consists of a five-point scale to record a participant's response. Responses on each item is quantified by assigning value from strongly agree to strongly disagree.

Iterations of Item Development

Gall et al. (2007) suggested the following seven steps in instrument development:

Step 1. Define the construct to be measured. Give careful thought about the specific construct, or constructs, that the test (instrument) will measure. Consider whether there is a theoretical basis for the constructs. The use of experts in content validation is a sound method to address this issue (DeVellis, 2003).

Step 2. Define the target population. Characteristics of the target population must be considered in making many of the decisions involved in test construction. Therefore, define the population in detail.

Step 3. Review related tests (instruments). Review other tests that measure similar constructs to generate ideas about such matters as test format and methods for establishing validity.

Step 4. Develop a prototype (pilot test). Prepare a preliminary version of the test (i.e. a prototype).

Step 5. Evaluate the prototype (pilot test). Obtain a critical review of the prototype from experts in test development and the construct being measured. Then, field-test the prototype with a sample from target population, and do an item analysis on the resulting data.

Step 6. Revise the test (instrument). Revise the prototype test (pilot-test) based on the evaluations, and field-test the revised version. This cycle of field-test and revision may need to be repeated several times.

Step 7. Collect data on test validity and reliability. Collect evidence to support the reliability of the test's scores (instrument results) and the validity of the inferences that you wish to make from these scores (results) (p. 223).

Upon completion of step number 5 where a pilot test of a draft sample was administered to a sample group from the population, an extensive item analysis was conducted using the sample data. DeVellis (2003) suggested the following components for a comprehensive item analysis: (a) Frequency distributions, (b) Correlation matrices, (c) Statistics available from reliability programs (alpha if item deleted, skewedness, and kurtosis), (d) Examination of item wording (face validity).

These techniques were used to provide an accurate assessment of each item on the draft instrument; modifications were made to the final instrument to ensure that it would accurately and efficiently measure the construct. First, a careful examination of frequency distributions provided a picture of how spread out the responses were, and whether or not some selections were ignored or others chosen exclusively. When the pilot assessment contained a neutral or no response choice, frequency of this choice were examined to determine if it was an indicator of an item poorly worded or confusing. Skewness and kurtosis are measurements of item distribution. Skewness measures if an item deviates significantly from symmetry of distribution. Although it is natural for the results to be slightly skewed, a skewness value outside the absolute value of 2 is considered problematic. Kurtosis is a measurement of the degree to which the area in a distribution is primarily in the middle and at the tails of the distribution, thus, a typical distribution. Kurtosis is similar to skewness in that an absolute value of more than 2 is considered a departure from normal distribution. Items with high positive kurtosis indicate that the results show most participants' chose the same response, and the item may be problematic. Output from each of these measurements of distribution was easily obtained using Statistical Package for Social Services (SPSS) software. Calculating correlations among instrument items was another item analysis method used to consider the effectiveness of the items. Items on an instrument were designed in such a way that they are measuring the same construct, so conducting inter-item correlations and obtaining a correlation matrix of all the items provided an effective insight into how correlated the items were to one another. If certain items were outliers, these items were examined more closely to determine if they were problematic and should be removed. *Alpha if item deleted* is a statistical procedure that provides a computed coefficient alpha for each item, if that particular item was deleted from the item set, allowing a researcher to know if the item is helping or hurting coefficient alpha, a measure of internal consistency of the instrument. This was an efficient way to analyze individual instrument items for their effectiveness and determine what items were needed and what should be eliminated; producing an instrument that is concise yet reliable was critical to the effectiveness of the instrument. Jackson (1970) speaks to the idea of test reliability as a function of the number of items on an instrument; consequently, the researcher must make sound decisions to the length of the instrument to ensure the cost (e.g., the time allotted for testing) is low. Many of the methods presented above were used to measure individual item reliability, and it is important to note that a survey instrument is interested in the average response of a group as opposed to the response of an individual, so, in that regard, a lower level of item reliability is acceptable when reporting group responses Gall et al. (2007).

Demographics of participants were collected at the end of the survey including: years of teaching experience, school setting (rural, suburban, urban), gender, age at last birthday, college degrees attained, and college major. Demographic information about school setting and school size was collected for exploratory data to lay groundwork for further studies. School Setting was defined by descriptions from the U.S. Census Bureau and the Ohio State University Department of Agricultural, Environmental, and Development Economics (Exurban Change Program, n.d.) recommendations to define the following: (a) urban is defined as a population of at least 1,000 persons per square mile that is surrounded by census block with at least 500 people per square mile; (b) suburban / exurban with suburban defined as 325 to 1,000 persons per square mile and exurban areas is all block groups with a density of 40 to 325 persons per square mile; and (c) rural is defined as a population density of less than 40 persons per square mile. School size was defined as small (less than 500 students), medium (500-1500 students) and large (greater than 1500 students) at the high school level.

"A major problem associated with descriptive research is the interpretation of the data. Since the researcher has no control beyond choosing what data to gather, interpretations are highly subjective" (Hopkins, 1976, p. 139). Descriptive studies make no attempt to manipulate variables but serve to provide descriptions of variables and/or the relationships among these variables (Ary et al, 1990). One might consider that very little is left under the control of the researcher with respects to data manipulation, however, research techniques can be applied to the data collection in order to have the ability to report the data in a way that is meaningful. Lodico et al. (2006) suggest an extensive literature review can provide insight into existing similar survey instruments that have been developed in a similar vein to the proposed research, in doing so a number of data collection techniques and methods were discovered which would aid in reporting the results used in descriptive studies of teacher practices. Mullens and Gayler (1999) report that although surveys are among the most cost-effective and least burdensome methods; a survey may not produce an accurate and reliable picture of instruction. In an effort to improve surveys collecting data about teacher practices, Mullens and Gayler with the National Center on Education Statistics conducted a national study of eighth to twelfth grades mathematics classes. Surveys used in the Mullens and Gayler study collected information about specific topics covered, the level of emphasis teachers placed on certain skills and concepts, student learning objectives, assessment content, integration with other subjects, and nonacademic time. Beyond just asking teachers to report on student outcomes addressed in the course, the survey asked for the participants to respond to frequency, delivery style, assigned student problems and projects, as well as teaching conditions with respects to availability of required materials. Each of these aspects of teacher practices was considering for this research study. Moreover, how the survey instrument was organized was unique and allows for more in-depth description of teacher practices by reporting frequency and time per typical used. The structural layout of the survey instrument is presented in Table 3.1.

Table 3.1. Survey Data Organized by Frequency and Time (Sample)

	Frequency of Use					Time Per Typical Use		
	Never	1 or 2 periods per semester	1 or 2 periods per month	One period per week	> 1 period per week	≤ to 10 minutes	< ½ of a class period	≥ ½ class period
Lesson Content Emphasis:								
Example: Design, produces, and tests prototypes								

Organizing the data collection in the way presented above is a logical and appropriate way to report the results in a more meaningful way. Using frequency and time per typical use provides added insight into the teaching practices and content delivered by the participant with respect to teaching engineering design, and will provide a means to report the emphasis of such teaching practices as it relates to content delivered and assessment practices. However, a limitation to using frequency and time as a way to report emphasis of content delivered and assessment practices used is that schools organize the school day in different ways. The two most common methods of scheduling classes and organizing time is a *traditional* school schedule (50 minute class period and meeting 184 days in a school year) and *block* scheduling (90 minute class periods, meeting 92 days in a school year). The method used by Mullens and Gayler (1999) did not consider the various approaches to organizing the school day. Mayer (1999) developed a method to break down the school day into measurable units for a typical school day schedule. One limitation of Mayer's method of capturing teacher practices is due to the assumption the all participants would be from a school organized with a 50 minute period and 184 day school year. This assumption failed to consider other scheduling methods, the most common alternative approaches is A/B and 4 x 4 block scheduling. To overcome these limitations, the researcher added to Mayer's method (1999) by including typical block schedule units of meeting days and time per period. Although this method may not consider all possible school scheduling techniques, it provided a method that accurately quantifies the three of the most common school scheduling methods (Philips, 1997). Mayer (1999) reported another limitation to his method for capturing time and frequency of teacher practices that had an impacted the results the study. Mayer concluded that respondents did not have an accurate way to determine between categories such as *nearly every day*, *daily*, and *once or twice a week*. Mayer believed that low correlations in the pretest and posttest were due to these categories being too closely clustered with no way to accurately quantify the categories without a teaching style scale conversion for the participants' reference. The researcher for this study provided the teaching style scale conversion table (see Table 3.2) in the instrument for the participants to use as they completed the questionnaire. Providing this table ensured clarity of the time and frequency categories. A composite score of total instructional minutes was computed using the total score for frequency multiplied by total score for time.

Table 3.2. Teaching Style Scale Conversion

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.

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

Procedure

A research proposal outlining the details of this study was submitted to the University of Georgia Institutional Review Board. An approval of the proposal was on file and the survey cover letter received by the Institutional Review Board was used with the mailing of the surveys. The researcher informed the Institutional Review Board that confidentiality of participants would be ensured. Participants were informed that all responses were to be held in strict confidence and only the group results would be published. The participants names were not revealed in the study and the participant's identity was not associated with their responses. Only the researcher involved in this study had access to the data results. Identification information of particpants was not retained on any data or forms used in the study.

An e-mail 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 (APPENDIX C). The cover letter also informed participants about how confidentiality was maintained by using identification numbers on the questionnaires for follow-up purposes. The identification numbers were created by Hostedware Company and were not used to track the questionnaire back to the participant (Ary et al.). More recent research reveals that established techniques that are proven to work for a traditional hard copy cover letters and questionnaire mailings can be applied to e-mailed cover letters and on-line instruments (Schaefer & Dillman, 1998). The cover letter was sent electronically through e-mail for all ITEA members in the sample who listed an active e-mail address. However, any ITEA member in the sample who did not list an e-mail address or whose electronic address was found inactive were skipped and the next available sample participant with active e-mail address was selected. The electronically delivered cover letter contained specific instruction of how to fill-out the on-line questionnaire and directed participants to visit: http://www.hostedsurvey.com/home.html to obtain and complete the questionnaire that will contain its own URL. The on-line questionnaire was developed using the guidelines and recommendations outlined by Dillman, Tortora, and Bowker (1999). There was a request to return the survey on a specified date.

The researcher sent out the surveys to the entire sample group of 1043 high school teachers. After waiting three 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 e-mail delivered letter containing the URL for the on-line survey link. This has been a proven method used by other researchers to achieve compliance from non-respondents (Gall et al., 2007).

Data Analysis

Gall et al. indicated that descriptive statistics are a mathematical technique used to organize and summarize a set of numerical data. They identify that mean, median, and mode are three different measures of central tendency, which is a measure used to describe the average of an entire set of scores. Mean is generally considered the best measurement of central tendency due to the fact that it remains more stable over median and mode. Moreover, Gall et al. identify that standard deviation is the reported measure of variability most often used in research and the advantage of its use is similar to a mean score, it remains stable.

Descriptive statistics including mean, median, mode, and standard deviation were generated for the results collected from participants regarding the dependent variables, (see Table 3.3). A composite score of total instructional minutes was computed by the total group mean score for frequency multiplied by total group mean score for time for each of the seven engineering design content categories and for each of the assessment practices for engineering design projects.

Table 3.3. Data Analysis of Dependent Variables

Instrument items (Dependent variables)	*Statistical Procedures*
Dependent Variable 1: Results of each instrument item for curriculum content addressing engineering design will be complied into the following seven categories: (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.	$\bar{X}$, median, mode, SD, %,
Dependent Vaiable 2: Assessment strategies facing teachers .	$\bar{X}$, median, mode, SD, %
Dependent Vaiable 3: Selected challeges faced in implementing engineering design in high school technology education courses.	$\bar{X}$, median, mode, SD, %

Frequency counts and mean scores were calculated for all demographic information collected, see Table 3.4. Percentages of demographics were reported for school setting, highest college degree obtained, and college major. Group mean scores and standard deviation was reported for the results and a composite score of total instructional minutes.

Table 3.4. Demographic Information Collected

General descriptive statistics reported in narrative	
Years of teaching experience	n, %
School setting: (Rural, Urban, Suburban) Defined and measured in the survey	n,%
Gender	n , %
Age	n,%
Highest college degree obtained	n, %
College major	n, %

CHAPTER 4 FINDINGS

Introduction

The purpose of this descriptive study was to examine the current status of technology education programs teaching engineering design. A survey instrument was constructed to determine the current teacher practices of high school technology teachers as defined by: (a) content and engineering design knowledge being taught in high school technology education programs, (b) implementation of assessment practices for engineering design projects, and (c) challenges faced by technology education teachers who implement engineering design concepts in high school technology education. The instrument was created from current research in the field of technology education that had identified curricular goals, content recommended for teaching an engineering design focused program at the high school level, and appropriate assessment practices for evaluating engineering design projects (Asunda & Hill, 2007; Childress & Rhodes, 2008; Gattie & Wicklein, 2007; Smith, 2006). A set of questions was presented with a Likert scale response format that asked participants (secondary level teacher members of ITEA) to rate their level of agreement regarding their content and teaching practices compared with engineering design content and assessment practices identified from the previous research. Participants were asked to respond to instrument items regarding their teaching practices by indicating frequency of use and time per typical use for each instrument item (see Table 3.2).

Content and Construct Validation

Content validation procedures were followed as outlined in the educational research protocol literature (Crocher & Algina, 1986; Devellis, 2003; Netemeyer, Bearden, & Sharma, 2003). These methods required presenting a list of instrument items, in this case the identified learning outcomes and assessment strategies, to a panel of experienced engineering education faculty for content and construct verification. Open-ended questions accompanied each section of the instrument's seven categories, as well as the end of the assessment strategies section. The panel of experienced engineering educators were asked to identify any missing learning outcomes or assessment strategies they deemed important for implementation of engineering design content in high schools (Crocker& Algina, 1986). To properly address content validity, a group of items were generated for an instrument that was representative of the content of the construct. In this research study, the content needed to be indicative of an engineering design program for the high school level (Mason & Bramble, 1997). It is important to note because the instrument developed for this research used items from prior studies, two of which were identifying appropriate outcomes and content using a Delphi study (Childress & Rhodes, 2008; Smith, 2006), the final instrument items have already gone through extensive content and construct validity.

The experienced panel consisted of five engineering education faculty located at four universities across the United States. The panel members' years of experience ranged from 7 to 35 years in engineering and engineering education. These panel members were chosen by their years of experience in engineering education, their knowledge of engineering education, and their understanding of the construct of engineering design for the high school level and were selected based upon recommendations from committee members.

Comments received from the experienced panel members were carefully considered and the instrument was revised based upon the feedback received. The entire section titled: Emerging Fields of Engineering was removed due to the fact that it was the lowest ranked category of the

Childress and Rhodes (2008) study and because experts from the panel indicated that these items were problematic and questioned if they were a part of the construct being studied. Other revisions included rewording items to reflect student learning objectives as suggested by one panel member. Furthermore, some items, when appropriate, were combined to reduce the length of the instrument as suggested by one panel member. A complete list of comments from the content validation panel members can be reviewed in Appendix A.

Pilot Study Results

Upon completion of content validation, a pilot study was created to assess the effectiveness of the instrument and to analyze each instrument item. Twenty-five high school technology teachers and members of ITEA were randomly selected from ITEA's database and invited to participate in the pilot study. The invitation e-mail was sent out via e-mail to these twenty-five teachers on September 15, 2007 with a closing date set for October 30, 2007. The initial response to the pilot test was limited with only a few teachers responding, so, a follow-up message was sent on October 8, 2007 and the closing date was extended to midnight on Thursday, October 18, 2007. Eleven of the twenty-five teachers agreed to participate in the pilot test. After unsuccessful attempts to obtain the complete sample of 25, the researcher proceeded to conduct item analysis of the 11 respondents to the pilot study. Gall et al. (2007) method for instrument development was used which calls for field testing instruments using a pilot test with a small sample of the target population. However, the literature does not define a specific sample size for pilot testing. An extensive individual item analysis was conducted using a method endorsed by Devellis (2003) that included conducting a pilot study and examining survey data of (a) frequency distributions, (b) correlation matrices, (c) statistics available from reliability tests (Cronbach's alpha if item deleted, skewedness, and kurtosis), and (d) examination of item wording (face validity). Close examination of results from these various tests revealed that 17 items could potentially be problematic. The results of these various tests reveal that these 17 items were either poorly correlated to the other items in the survey category, or responses to the items in question yielded abnormal distribution ie: skewedness and kurtosis. The final test for instrument item analysis was to carefully examine item wording and consider whether items should be reworded or removed from the instrument. Upon completion of this final item analysis step and consulting members of the dissertation committee, five instrument items were removed. These items were as follows: in the category, Application of Engineering Design, the item removed was *apply basic power and energy concepts*. The Engineering Communication category contained two problematic items that were removed: *understanding scale and proportion in design* and *understanding basic personal computer operations*. The Engineering Design and Human Factors section contained one item that was removed: *working effectively on a team*. Finally, the item *implements experimentation of design products, processes, and materials* was removed from the instrument under the category Application of Engineering Science. It is important to note that these individual instrument items were not necessarily poor items, but the pilot study results using the item analysis revealed that these items were not strongly correlated with the other items in the instrument, therefore they were not strong indicators for the construct being studied as examined in the instrument.

A total of five items were removed from the instrument due to the results of the item analysis process. The final total of all instrument items was 83; however, due to the design of the instrument, 59 items required two responses (frequency of use and time per typical use) for a grand total of individual responses to 142. A breakdown of items by category is as follows: 51 items for engineering design curriculum content, 8 items for assessment practices, 15 items for challenges, and 9 items for general demographic information. For a complete listing of the instrument items which were identified as potentially problematic through the pilot test item analysis; see Appendix B.

Instrument Content and Organization

The first category of investigation of teacher practices was in the area of engineering design knowledge and content delivered to technology education students. Seven categories were used to organize this section of the survey instrument culminating with a total of 51 individual items. The seven categories used to organize this section were identified from previous research (Childress & Rhodes, 2008; Smith, 2006). These categories were Engineering Design, Engineering Analysis, Application of Engineering Design, Engineering Communication, Design Thinking as It Relates to Engineering Design, Engineering and Human Values, and Engineering Science.

The second category of investigation measured in the instrument was Assessment Practices for Evaluating Engineering Design Activities. This section of the instrument inquired about teachers' practices in the area of assessment and consisted of eight instrument items. These items were constructed using assessment practices identified in the Asunda and Hill study (2007).

The final area of investigation measured through the instrument was Challenges Implementing Engineering Design into technology education. A total of 15 instrument items were used to measure this particular area of the construct and were created from previous research results (Gattie & Wicklein, 2007). A different five point Likert scale was created for this section of the instrument, with Never = 0, Rarely = 1 Sometimes = 2 Very often = 3 and Always = 4. One open-ended question completed this section of the instrument. This open-ended question asked participants to identify any other challenges that they face when seeking to implement technology education curriculum changes.

Each of the methods employed to organize and present the items in the instrument were based upon the procedures outlined and recommended by research literature (Gall et al., 2007; Lodico, et al., 2006).

Demographic Data of Sample

The last section of the survey collected was general demographic information. The demographic section was placed at the end of the survey to allow respondents to exert most of their energies on answering the earlier survey items (Lodico, et al.). A total of eight questions inquired about participants' teaching grade level, years of experience, gender, age, education, school setting, and school size. The final question in this category was optional, asking for the participant's e-mail address to use as contact information if the participant won one of the ten $100 dollar gift cards. The use of a lottery incentive to generate a higher response rate of return is discussed later in this chapter. One additional demographic data item constructed was the very first item presented in the instrument, asking participants to indicate how their school day schedule was organized (traditional or block). This item was separated from the other demographic information because it was vital for each participant to consider this item before using the Likert scale table that organized responses based upon each participant's school day schedule.

Summary of Responses

The identified population of this study consisted of (N) 1043 high school technology education teachers as of September 11, 2007 ITEA membership roll. Krejcie and Morgan (1970) created a table to locate sample size for a given population size using a formula obtained from the United States Office of Education (Gay & Airasian, 2000). Using the Krejcie and Morgan (1970) table, the size of the sample needed for the targeted population was 285. The original research design for this study called for an increase of the initial mailing of the survey by 48.1 percent, the average success rate of an initial mailing (Gall et al; 2007). However, close communication with ITEA personnel revealed that ITEA survey mailings typically yield a 20-25% rate of return (Price, 2007). The researcher determined that a mailing to all ITEA high school members was necessary to achieve the desired sample size.

Furthermore, an incentive of winning one of ten $100 gift cards was used to help generate a high response rate. Although the literature on the effects of these types of incentives on response rate for web-based surveys is inconclusive due to the mixed results of various studies (Bauman, Jobity, Airey, & Atak, 2000; Birnholtz, Horn, Finholt, & Bae, 2004; Cobanoglu & Cobanoglu, 2003). Porter and Witcomb (2003) found a significant increase in response rate to web-based surveys when providing a lottery incentive of $100. Moreover, it was also discovered that providing an incentive such as a gift card raffle 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 was carefully constructed using University of Georgia Internal Review Board procedure that included: (a) a statement of confidentiality of the respondent, (b) a thorough description of the study, (c) a description of the importance of the participant's assistance, and (d) the relevance of the study for the field of technology education. A web-link to the on-line survey was imbedded within the e-mail message with a statement inviting respondents to click the link to access the on-line survey. The on-line survey was created, housed, and maintained using the services of the Hostedware company (www.hostedware.com).

A total of 28 teachers were removed from the population size due to teacher retirements, job transfers to other fields, leave of absences, or individual teachers not teaching at the high school grade level. This information was obtained through e-mail reply messages to the researcher or through information obtained from phone follow-up telephone calls. A final total population size of high school teachers who were ITEA members as of September, 2007 was determined to be 1018. At the end of the first week the survey was activated, a total of 66 ITEA members completed the survey for a 6.5% rate of return. Although the researcher provided an incentive of ten $100 gift cards was provided, the initial response to the survey was poor. Additional efforts to contact ITEA members were necessary to yield an acceptable rate of return. A total of 195 (19% of the total population) ITEA members were phoned as an effort to follow-up the survey deployment. Moreover, the researcher contacted leaders in technology education from 13 states to assist in further dissemination of the survey to ITEA members in the states they represent. A number of leaders were state supervisors for technology, several leaders were professors of technology education, and several leaders were state officers in technology education teacher associations. All 13 technology education leaders also deployed the survey message and, in most cases, provided a personal message of encouragement to complete the survey for the greater benefit of the field of technology education. These additional follow-up efforts to the ITEA members yielded an additional 15.7% rate of return. A final total of 226 technology education teachers logged on and completed the on-line survey. Using the total population size of 1018, the rate of return was calculated at 22.2 %.

Demographic Results

Results from the school demographic section of the survey revealed that 62.4% of respondents worked in schools that use a traditional school schedule with classes meeting five days a week for approximately 50 minute each class period; the other 37.6% of those responding to the survey work in schools that implement a block schedule to organize the school day (see Table 4.1). Of those responding to the survey, 27% teach in schools in a rural setting, 47.4% teach in schools in a suburban setting, and 25.6% teach in schools in an urban setting. School size was another item measured in the school demographic section. A total of 14.6% of the participants from this study teach in small (less than 500 students) high schools, 45.1% teach in medium size (500-1500) high schools, and 40.3% of respondents teach in large (greater than 1500 students) size schools; see Table 4.1 for a detailed breakdown of the general demographics of the respondents.

Table 4.1. Demographics of School

	Variable	Frequency	% of Total
What best describes your high school day schedule?			
	Traditional schedule (meets daily 5 days a week)	141	62.4%
	Block schedule (AB Block or 4X4 Block)	85	37.6%
What best describes your school setting?			
	Rural (less than 40 persons per square mile or 40 or more acres per housing unit)	61	27%
	Suburban / Exurban (40 to 999 persons per square mile or 5 to 39 acres per housing unit)	107	47.4%
	Urban (1,000 + persons per square mile or 1/3 to 1.5 acres per housing unit)	58	25.6%
What best describes your school size?			
	Small (less than 500 students)	33	14.6%
	Medium (500 -1500 students)	102	45.1%
	Large (greater than 1500 students)	91	40.3%

The biographical demographic section of the survey revealed that 10.0% of the respondents teach at a middle and high school, compared with 88.0% of respondents indicating they are assigned exclusively to high schools, while 2.0% selected *other* to describe the grade level they teach. The majority of respondents had multiple years of experience with 62.8% possessing 11 or more years of experience; within that 62.8%, 37.6% have 20+ years of teaching experience. A total of 35.0% of the responses to the survey came from technology education teachers with one to 10 years of experience, and 2.2% of teachers who responded to the survey were in their first year of teaching; see Table 4.2 for further breakdown of the biographical demographic information. A total of 195 participants were male for a total of 86.3% of responders, leaving 13.7% being female. As mentioned before, the respondents were veterans of the teaching profession, thus, they were deemed as a mature group of professionals. Survey results revealed that 65.0% of the participants are over the age of 40. A total of 32.0% of the teachers who completed the survey are between the ages of 25 to 40. Only 3% of respondents are under the age of 25. The teachers who responded to this survey were not only experienced but were also highly educated with 64.2% holding a Master's degree, and 3.5% having earned an educational specialist degree. A total of 32.3% have obtained just the required B.S./B.A, a degree necessary to teach technology education in public schools.

Table 4.2. General Demographic Information

Variable		*f*	% of Total
Which best describes your current position?			
	Middle/High school teacher	23	10.2%
	High School teacher	198	87.6%
	Other	5	2.2%
Years of experiences as a technology educator at the start of the 2007-2008 school year			
	no prior experience	5	2.2%
	Less than one year	12	5.3%
	1-5 years	36	15.9%
	6-10 years	31	13.7%
	11-15 years	32	14.2%
	16-20 years	25	11.1%
	20+ years	85	37.6%
Gender			
	Male	195	86.2%
	Female	31	13.7%
Age at last birthday			
	Under 25	7	3.1%
	25-30	33	14.6%
	31-35	20	8.9%
	36-40	19	8.5%
	41-45	31	13.7%
	46-50	34	15.0%
	51-55	52	23.0%
	56-60	22	9.7%
	61-65	7	3.1%
	+65	1	0.4%
Highest college degree attained (Check only highest)			
	B.S./B.A.	73	32.3%
	Masters	145	64.2%
	EdS-Specialist	8	3.5%

Curriculum Content Related to Engineering Design

One goal of this research was to accurately describe the degree to which current curriculum content of secondary technology education programs reflect engineering design concepts. Items for this section of the instrument were constructed from results of previous research that sought to define appropriate engineering design content for high school technology education programs (Childress & Rhodes, 2008; Smith, 2006). The first category of engineering design content presented in the instrument was titled *Engineering Design* and presented six general engineering design concepts. Using a five-point Likert scale response that corresponded with the frequency and time table (see Table 3.2), respondents were asked to indicate their level of teaching practice as it related to each item within each category. Each respondent was required to indicate how often (Frequency) they were teaching the engineering design content in question, and also for how long (Time). Results for the *Engineering Design* category are presented in Table 4.3. This category received the highest group mean score (3.15) for frequency of use, indicating that most technology education teachers teach some basic level of engineering design content in their technology education programs.

Table 4.3. Engineering Design Results

Engineering design content	*M f*	SD *f*	*M* Time	SD Time
understand engineering design is an iterative process	3.03	1.21	2.27	1.20
understand creativity is an important characteristic for engineers to apply in design	3.33	1.21	2.51	1.34
recognize that there are many approaches to design and not just one design process	3.26	1.32	2.42	1.28
recognize engineering as a potential career option	3.05	1.31	2.12	1.22
are able to identify good and bad design	2.96	1.19	2.40	1.16
believe in his/her ability to design a solution to a technological problem	3.27	1.19	2.58	1.31
Total Group Mean	3.15		2.38	

The next section of the engineering design curriculum content was titled *Engineering Analysis*. This section of the instrument presented student learning outcomes related to the analysis phase of the engineering design process. Mean scores measured by frequency of use in the *Engineering Analysis* section ranged from 2.09 to 3.44. Mean scores for time per typical use in the *Engineering Analysis* section ranged from 1.26 to 1.40. This section contained varied results with one of the individual items yielding the third highest overall mean score at 3.44 and several individual items (*use optimization techniques to determine optimum solutions to problems*, and *use physical and/or mathematical models to estimate the probability of events*) yielded the second and third lowest mean scores (1.82 and 1.93) when measured by time per typical use. Total results can be reviewed on Table 4.4.

Table 4.4. Engineering Analysis

Engineering Analysis Content	*M f*	SD *f*	*M* Time	SD Time
understand that knowledge of science and mathematics is critical to engineering	3.44	1.20	2.61	1.25
apply engineering science principles when designing solutions	3.15	1.25	2.59	1.29
use measuring equipment to gather data for troubleshooting, experimentation, and analysis	3.09	1.25	2.69	1.26
use physical and/or mathematical models to estimate the probability of events	2.12	1.42	1.93	1.35
use optimization techniques to determine optimum solutions to problems	2.09	1.41	1.82	1.38
use models or simulations to study processes	2.82	1.40	2.58	1.40
Total Group Mean	2.79		2.37	

The third section of the engineering design curriculum content was titled *Engineering Application*. This section of the instrument presented student-learning outcomes related to the application of the engineering design process. Mean scores measured by frequency of use in the *Engineering Application* section ranged from 2.02 to 3.46. Mean scores for time per typical use in the *Engineering Application* section ranged from 2.24 to 3.32. A notable result from this section was second highest overall mean score individual item measuring by time per typical use was *develop basic student's skills in the use of tools* with a mean of 3.32. The complete results for the *Engineering Application* category are presented in Table 4.5.

Table 4.5. Application of Engineering Design

Application of Engineering Design Content	*M f*	SD *f*	*M* Time	SD Time
apply knowledge for manufacturing products to the engineering design	2.62	1.22	2.39	1.28
identify problems that could be solved through engineering design	2.82	1.23	2.48	1.24
understand no perfect design solution exists	2.91	1.41	2.24	1.31
conduct reverse engineering to analyze product design	2.02	1.34	2.26	1.51
organize and manage design process for optimal use of materials, processes, time, and expertise	2.50	1.33	2.39	1.34
design, produce, and test prototypes	2.89	1.34	3.15	1.39
apply research to designing products, processes, and materials	2.65	1.24	2.62	1.32
develop skills to use, manage, and assess technology	2.94	1.29	2.65	1.31
demonstrate the ability to handle open-ended/ ill-defined problems	2.79	1.30	2.50	1.33
develop basic students' skills in the use of tools	3.46	1.26	3.32	1.34
understand design often requires tradeoffs	2.86	1.24	2.44	1.25
Total Group Mean	2.77		2.59	

The fourth section of the engineering design curriculum content was titled *Engineering Communication*. This section of the instrument presented student-learning outcomes related to the communication within engineering design and communicating design solutions. Mean scores measured by frequency of use in the *Engineering Communication* section ranged from 2.03 to 3.39. Mean scores for time per typical use in the *Engineering Communication* section ranged from 2.00 to 3.35. The complete results for the *Engineering Communication* category are reported in Table 4.6.

Table 4.6. Engineering Communication

Engineering Communication Content	*M f*	SD *f*	*M* Time	SD Time
communicate design ideas orally, through presentations, and graphics	2.96	1.35	2.94	1.29
communicate through writing technical reports	2.03	1.29	2.25	1.39
use technical drawings to construct or implement an object , structure, or process	3.34	1.26	3.30	1.25
visualize in three dimensions	3.26	1.31	3.19	1.32
develop and maintain an engineering design portfolio	2.54	1.87	2.07	1.71
use computer-aided design to construct technical drawings	3.39	1.52	3.35	1.49
apply the rules of dimensioning	3.09	1.49	2.98	1.51
apply rules of manufacturing tolerance	2.10	1.35	2.00	1.37
use basic computer applications such as word processors, spreadsheets, and presentation software	3.27	1.39	3.15	1.36
Total Group Mean	2.89		2.80	

The fifth section of the engineering design curriculum content was titled *Design Thinking Related to Engineering Design*. This section of the instrument presented student-learning outcomes related to the thought process and characteristics of design thinking as it relates to engineering design. Mean scores measured by frequency of use in the *Design Thinking Related to Engineering Design* section ranged from 2.58 to 3.65. Mean scores for time per typical use in the *Design Thinking Related to Engineering Design* section ranged from 2.61 to 3.15. The complete results for the *Design Thinking Related to Engineering Design* category are reported in Table 4.7.

Table 4.7. Design Thinking Related to Engineering Design

Design Thinking Related to Engineering Design Content	*M f*	SD *f*	*M* Time	SD Time
think critically	3.65	1.10	3.15	1.22
synthesizes simple parts into complex systems	2.73	1.25	2.61	1.29
apply SYSTEMS THINKING- understanding and considering the multiple facets of a design solution result in positive and negative impacts	2.58	1.42	2.34	1.34
apply brainstorming and innovative concept generation	3.24	1.20	2.98	1.30
have the ability to approach open-ended/ ill defined problems	2.80	1.41	2.62	1.44
Total Group Mean	3.00		2.74	

The next section of the engineering design curriculum content was titled *Engineering and Human Values*. This section of the instrument presented student learning outcomes related to human values embedded within engineering problems and engineering design solutions. Mean scores measured by frequency of use in the *Engineering and Human Values* section ranged from 1.75 to 2.47. Mean scores for time per typical use in the *Engineering and Human Values* section ranged from 1.76 to 2.25. The complete results for the *Engineering and Human Values* category are presented in Table 4.8.

Table 4.8. Engineering and Human Values

Engineering and Human Values Content	*M f*	SD *f*	*M* Time	SD Time
understand how engineers put ethics into practice	1.75	1.23	1.76	1.32
are aware of social, economical, and environmental impacts on design solutions	2.31	1.24	2.21	1.24
understand that the solution to one problem may create other problems	2.47	1.28	2.23	1.30
consider cost, safety, appearance, and consequences of design failures	2.47	1.34	2.25	1.33
take human values and limitations into account when designing and solving problems	2.27	1.33	2.07	1.31
apply knowledge of basic ergonomics to engineering design process	2.04	1.32	1.95	1.35
Total Group Mean	2.22		2.08	

The final section of the engineering design curriculum content was titled *Engineering Science*. This section of the instrument presented student-learning outcomes regarding elements of engineering science. Mean scores measured by frequency of use in the *Engineering Science* section ranged from 1.65 to 3.15. Mean scores for time per typical use in the *Engineering Science* section ranged from 1.76 to 2.84. The complete results for the *Engineering Science* category are presented in Table 4.9.

Table 4.9. Engineering Science

Engineering Science Content	*M f*	SD *f*	*M* Time	SD Time
apply math and science to the engineering design process	3.15	1.26	2.84	1.24
apply knowledge of basic mechanics to the engineering process	2.88	1.33	2.69	1.29
apply knowledge of basic statics and strengths of materials to engineering design process	2.02	1.28	1.98	1.32
apply knowledge of dynamics to the engineering design process	1.81	1.40	1.76	1.39
use of algebra to solve problems or predict results to design solutions	2.19	1.47	1.98	1.35
use geometry to solve problems or predict results to design solutions	2.60	1.35	2.30	1.32
use trigonometry to solve problems or predict results to design solutions	1.65	1.37	1.58	1.34
apply knowledge of material process to engineering design process	2.37	1.35	2.19	1.37
Total Group Mean	2.33		2.16	

The results of engineering design content category group mean scores when measured by *frequency of use* were as follows. The highest group mean score for frequency of use was *Engineering Design* with a group mean of 3.15. The second highest group mean score for frequency was the category *Design Thinking Related to Engineering Design* with a group mean of 3.00. *Engineering Communication* received the third highest mean score for frequency of use. See Table 4.10 for complete listing of categories based upon group mean scores when measuring frequency of use.

Table 4.10. Engineering Design Category Group Mean (Frequency)

Engineering Design Content Category	Total Group *M f*
Engineering Design	3.15
Design Thinking Related to Eng. Design	3.00
Engineering Communication	2.89
Engineering Analysis	2.79
Application of Engineering Design	2.77
Engineering Science	2.33
Engineering and Human Values	2.22

The results of engineering design content category group mean scores when measured by time per typical use were as follows. The *Engineering Communication* category received the highest group mean score (2.80) for time per typical use. The second highest group mean score for time per typical use was the teaching of *Design Thinking Related to Engineering Design* with a group mean of 2.74. Finally, the third highest group mean to measure time per typical use was in the category of *Application of Engineering Design* with a total group mean of 2.59; see Table 4.11. Frequency counts are often the only measure teacher self-reporting of teacher practice (Mayer, 1999) on a survey instrument of a descriptive study; however, the results of this study indicate that time is a valuable measure to better understand the employed teaching practices. Moreover, researchers have discovered that using both frequency and time will provide a more accurate picture of what is occurring in the classroom regarding teacher practices (Mullens & Gayler, 1999). Relying on the results of one measurement alone could be misleading. More details on this topic will be presented in Chapter five.

Table 4.11. Engineering Design Category Group Mean (Time)

Engineering Design Content Category	Total Group *M* Time
Engineering Communication	2.80
Design Thinking Related to Eng. Design	2.74
Application of Engineering Design	2.59
Engineering Design	2.38
Engineering Analysis	2.37
Engineering Science	2.16
Engineering and Human Values	2.08

Highlights of the results of individual survey items are as follows. Reviewing the results of highest mean scores for *frequency of use*, the survey item *think critically* yielded the highest response with a total mean score of 3.65. The next, item was *developing basic student's skills in the use of tools*, received a mean score of 3.46. The third highest total group mean score for frequency of use was *understanding that knowledge of science and mathematics is critical to engineering* with a mean of 3.44. Low scoring mean scores for individual items measured by frequency were as follows: *use trigonometry to solve problems or predict results to design solutions* with a mean of 1.65, *use mathematical models to optimize, describe, and/or predict results* received a mean of 1.72, and *understanding how engineers put ethics into practice* received a mean of 1.75. For a review of the top five mean scores for individual items measured by frequency of use, see Table 4.12.

Table 4.12. Top Five Individual Engineering Design Mean Scores Items (Frequency)

Engineering Design Content Item	*M* Score *f*
think critically	3.65
developing basic student's skills in the use of tools	3.46
was understanding that knowledge of science and mathematics is critical to engineering	3.44
use computer-aided design to construct technical drawings	3.39
use technical drawings to construct or implement an object, structure, or process	3.34

Individual survey items pertaining to *time per typical use* yielded the following results. The item *use of computer-aided design to construct technical drawings* was the highest mean score single item for time per typical use with a mean score of 3.35. The second highest rated individual survey item measuring time per typical use was *develop basic student's skills in the use of tools* with a mean of 3.32. While, the item *use technical drawings to construct or implement an object, structure, or process* rounded out the top three highest mean scores with a mean score of 3.30. To review the top five mean scores for individual items for time per typical use, see Table 4.13. Other notable results for individual items were the lowest scoring mean for time per typical use including the items *use trigonometry to solve problems or predict results to design solutions* (mean of 1.58), *understanding how engineers put ethics into practice* (mean of 1.76), *using optimization techniques to determine optimum solutions to problems* (mean of 1.82), and *use physical and/or mathematical models to estimate the probability of events* (mean of 1.93). These particular results identify engineering design content items that are not strongly emphasized or taught at all in those technology education programs represented in the sample.

The reliability of the instrument results measured using Cronbach's internal constancy coefficient alpha; the results yielded α .982 (Cronbach Alpha).

Table 4.13. Top Five Individual Engineering Design Mean Scores Items (Time)

Engineering Design Content Item	*M* Score Time
use of computer-aided design to construct technical drawings	3.35
develop basic student's skills in the use of tools	3.32
use technical drawings to construct or implement an object, structure, or process	3.30
visualize in three dimensions	3.19
think critically	3.15

Composite Score: Total Hours Per Content Category

A composite score for total hours of teaching time dedicated to the seven engineering content categories was generated using the units of time and frequency identified in the teaching style scale conversion table (see Table 3.2). This composite score methodology to determine teaching time for curriculum content has been used in previous research to accurately capture the total instructional time dedicated to a specific curriculum content or to a specific teaching strategy employed the teacher (Mayer,1999; Mullens & Gayler,1999; Supovitz & Turner, 2000). The composite score was generated by using the units of days per school year for frequency and minutes per class period for duration or time; these numbers multiplied together to generate the final composite score. When a group mean score fell between two whole Likert scale units, which was often the case, the decimal number was multiplied by the difference between the units (either units in days or minutes) as identified in Table 3.2 and added to the number of minutes determined by the Likert scale. For example, the results for category *Engineering Design* for time per typical use for teachers teaching in a traditional school schedule is a group mean of

2.36. To determine the total hour value of .36, the units between the Likert scale of 2 and 3 must be determined. Examining Table 3.2, it is determined that the Likert scale of 2 equals 15 minutes, the units between 2 and 3 is 10 units (25-15 minutes). So, (.36) x (10) = 3.6 minutes which are added to 15 minutes to equal 18.6 minutes. The same process is used for frequency to determine the total number of days; in the case of *Engineering Design* for teachers in a traditional school schedule was computed to be 68 days. The final composite score for *Engineering Design* for teachers in a traditional school schedule was generated by (68) x (18.6) =1264.8 total minutes/60 minutes = 21.08 total hours class time dedicated to the *Engineering Design* category.

The researcher split the files; separating traditional and block scheduling results in order to accurately calculate a composite score. Splitting the file was necessary because the units of day and units of duration were different between the groups. Figure 4.1 shows the breakdown of total number of hours (composite score) in a given school year for each of the seven categories of engineering design for technology education teachers teaching in a traditional school day. Figure 4.2 presents the breakdown of total hours in a given school year for each of the seven categories of engineering design for technology education teachers teaching in a school using block scheduling.

Figure 4.1. Composite Score for Traditional Schedule

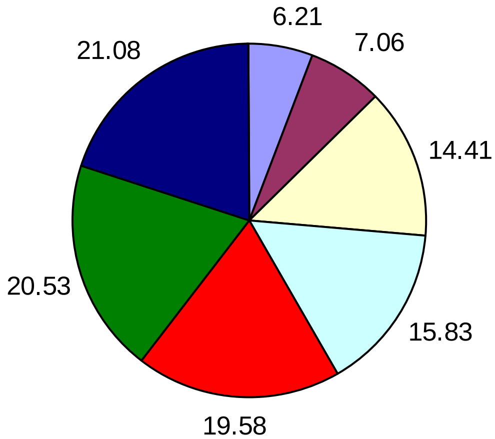
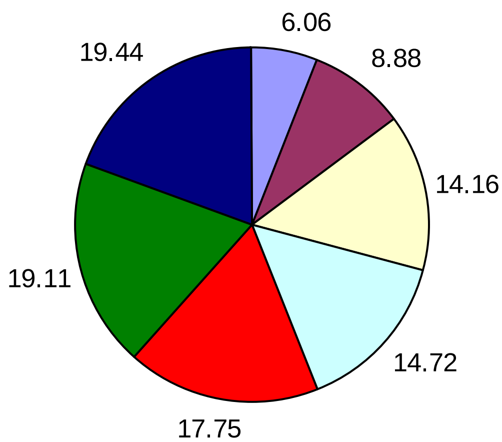
Traditional Schedule Breakdown of Total Hours	Key :
	Engineering and human Value Engineering Science Engineering Analysis Application of Engineering Design Engineering Communication Design Thinking Related to Engineering Design Engineering Design

Figure 4.2. Composite Score for Block Schedule

Block Schedule Breakdown of Total Hours	Key :
	Engineering and human Value Engineering Science Engineering Analysis Application of Engineering Design Engineering Communication Design Thinking Related to Engineering Design Engineering Design

Comparisons of the difference between the total hour composite scores for each of the engineering design category between the two groups are reported in Table 4.14. The differences in total hours between traditional and block scheduling was computed to determine if there were major differences between the two groups for each of the seven categories. The total hour differences varied from the largest difference of 1.83 hours for the *Engineering Communication* category to as little difference as 0.15 of an hour for *Engineering and Human Values* category. Overall these differences were very minimal considering the total hours of instruction time was 104.7 for traditional schedule to 100.12 for block schedule.

Table 4.14. Comparison of Difference of Total Hours between Traditional and Block Schedule for Engineering Design Content

Engineering Design Content Category	Total Hours Traditional Schedule	Total Hours Block Schedule	Difference	% Difference
Engineering and Human Values	6.21	6.06	0.15	0.15
Engineering Science	7.06	8.88	1.82	1.78
Engineering Analysis	14.41	14.16	0.25	0.24
Application of Engineering design	15.83	14.72	1.11	1.08
Engineering Communication	19.58	17.75	1.83	1.79
Design Thinking Related to ED	20.53	19.11	1.42	1.39
Engineering Design	21.08	19.44	1.64	1.60
Total Hours	104.7	100.12	102.41 (Average)	

Assessment Practices for Engineering Design Projects

The survey instrument contained 8 items related to assessment practices for engineering design projects. These assessment items were constructed from results of recent research designed to identify appropriate assessment practices for engineering design projects (Asunda & Hill, 2007). The top mean scores for individual items were as follows: *provide evidence of idea generation strategies (e.g. brainstorming, teamwork, etc.)* (mean of 2.92), *develop a prototype model of the final design solution* (mean of 2.69), *and work on a design team as a functional inter-disciplinary unit* (mean of 2.53). Overall, the assessment practice category yielded relatively low mean scores, none of which yielded a mean of 3 or higher. The lowest mean scores were items *using mathematical models to optimize, describe, and/or predict results* (mean of 1.72), while *properly record design information in an engineer's notebook* also yielded a low mean of 2.01; see Table 4.15 for total results of the assessment practice category.

Table 4.15. Assessment Practices for Engineering Design Projects

Assessment practices	*M f*	SD *f*	*M* Time	SD Time
use support evidence / external research (research notes, illustrations, etc)	2.32	1.38	2.25	1.37
provide evidence of formulating design criteria and constraints prior to designing solutions	2.33	1.45	2.19	1.43
use design criteria such as budget, constraints, criteria, safety, and functionality	2.45	1.34	2.31	1.39
provide evidence of idea generation strategies (e.g. brainstorming, teamwork, etc.)	2.92	1.46	2.69	1.50
properly record design information in an engineer's notebook	2.01	1.76	1.78	1.64
use mathematical models to optimize, describe, and/or predict results	1.72	1.43	1.62	1.39
develop a prototype model of the final design solution	2.69	1.43	2.87	1.55
work on a design team worked as a functional inter-disciplinary unit	2.53	1.50	2.79	1.60
Total Group Mean	2.37		2.31	

A composite score was generated for assessment strategies for traditional schedules (see Figure 6) and block schedule (see Figure 7). The same method for calculating the composite score for curriculum content was also used for computing the assessment strategies composite score. A comparison of the difference between the total hour composite score for each of the assessment strategies between the two groups are reported in Table 4.16.

Figure4.3. Composite Score for Assessment Strategies for Traditional Schedule

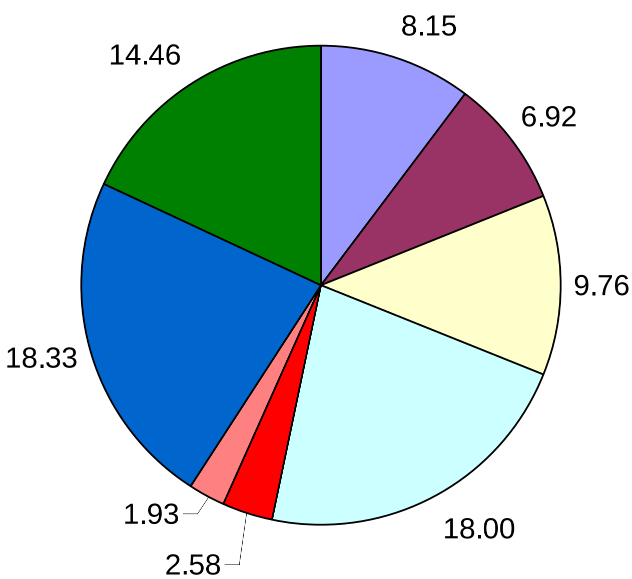
Total Hours Per Assessment Strategy	Key :Assessment Strategy
	use support evidence / external research (research notes, illustrations, etc) provide evidence of formulating design criteria and constraints prior to designing solutions use design criteria such as budget, constraints, criteria, safety, and 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 team worked as a functional inter-disciplinary unit

Figure 4.4. Composite Score for Assessment Strategies for Block Schedule

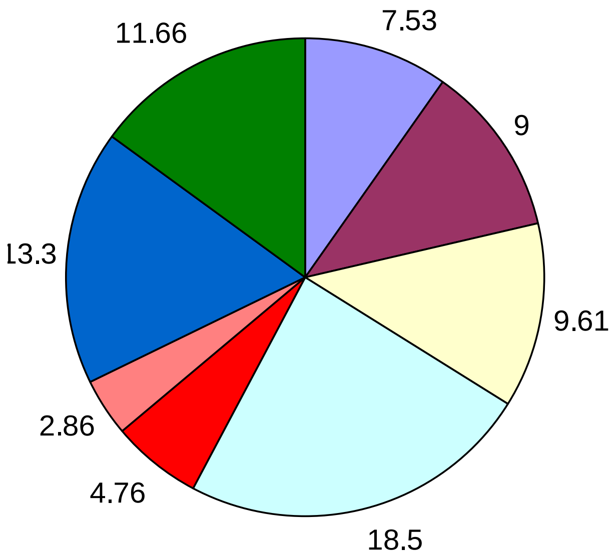
Total Hours Per Assessment Strategy	Key :Assessment Strategy
 	use support evidence / external research (research notes, illustrations, etc) provide evidence of formulating design criteria and constraints prior to designing solutions use design criteria such as budget, constraints, criteria, safety, 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 team worked as a functional inter-disciplinary unit

Table 4.16. Comparison of Difference of Total Hours Between Traditional and Block Schedule for Assessment Practices

Engineering Design Assessment Strategies	Total Hours Traditional Schedule	Total Hours Block Schedule	Difference	% Difference
use support evidence / external research (research notes, illustrations, etc)	8.15	7.53	0.62	0.79
provide evidence of formulating design criteria and constraints prior to designing solutions	6.92	9.00	2.08	2.64
use design criteria such as budget, constraints, criteria, safety, and functionality	9.76	9.61	0.15	0.19
provide evidence of idea generation strategies (e.g. brainstorming, teamwork, etc.)	18.00	18.5	0.5	0.64
properly record design information in an engineer's notebook	2.58	4.76	2.18	2.77
use mathematical models to optimize, describe, and/or predict results	1.93	2.86	0.93	1.18
develop a prototype model of the final design solution	18.33	13.3	5.03	6.39
work on a design team worked as a functional inter-disciplinary unit	14.46	11.66	2.8	3.56
Total Hours	80.13	77.22	78.68 (Average)	

Like the engineering design category composite score results, comparisons of the difference between the total hour composite scores for each of the assessment strategies between the two groups are reported in Table 4.16. The differences in total hours between traditional and block scheduling was computed to determine if there were major differences between the two groups for each of the assessment strategies. The assessment strategy that assessed the *developing a prototype model of the final design solution* received the greatest total hour difference of 5.03

hours. The assessment strategy that required students to *use design criteria such as budget, constraints, criteria, safety, and functionality* resulted in the greatest consensus among responders with only a 0.15 of an hour difference. Overall these differences were greater than the engineering design category; however, these differences are still very minimal considering the total hours of assessment time which was 80.13 for traditional schedule to 77.22 for block schedule.

Teacher Challenges to Implement Engineering Design

The final section of the survey instrument asked participants to rate 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 4 = Always). These selected teacher challenges were obtained from previous research (Gattie & Wicklein, 2007). The highest rated challenges were *integrating the appropriate levels of math and science into instructional content* (mean of 2.49), *locating appropriate laboratory equipment to teach engineering design* (mean of 2.40), and *acquiring funding to purchase tools and equipment to teach engineering design* (mean of 2.31). Complete results of the teacher challenge section are presented in Table 4.17.

Table 4.17. Teacher Challenges Infusing Engineering Design

Teacher Challenges	*M*	SD
integrating the appropriate levels of math and science into instructional content	2.49	0.88
locating and learning the appropriate levels of math and science to teach engineering design	2.27	0.93
locating and learning knowledge of engineering fundamentals (statics, fluid mechanics, dynamics)	2.10	0.97
locating appropriate textbooks to teach engineering design	2.14	1.08
locating the appropriate laboratory equipment to teach engineering design	2.40	1.10
locating the appropriate laboratory layout and space to teach engineering design	2.18	1.17
acquiring funding to purchase tools and equipment to teach engineering design	2.31	1.23
acquiring funding to purchase materials to teach engineering design	2.25	1.21
networking with practicing engineers for consultation	2.04	1.15
obtaining support from math and science faculty	1.96	1.08
obtaining support from school administration and school counselors	2.11	1.16
obtaining support to promote engineering design course by school administration	1.94	1.22
obtaining community support to implement engineering design courses	1.73	1.09
obtaining parent support to implement engineering design course	1.73	1.08

This section of the survey also contained one open-ended response question at the end of the section, allowing participants to identify any additional challenges they face that impedes them from infusing engineering design into technology education. These additional challenges were summarized and categorized into common themes. A careful review of these individually identified teacher challenges revealed that many respondents took the opportunity of the open-ended response question to further emphasize some of the previously identified challenges in the survey. The top challenges that were re-emphasized were *lack of Funding -acquiring funding to purchase tools and equipment to teach engineering design* (frequency of 14), and *lack of support- from administration, guidance, math and science faculty, community, or state education department* (frequency of 11).

Other top teacher challenges that were identified by respondents were *Curriculum- a lack of clear and concise curriculum that is unrestricting and contains a proper blend of technical skills and knowledge* (frequency of 11), *Enrollment- a fear of lost of students due to lack of interest in engineering, low academic ability, and or motivation to take engineering courses* (frequency of 11), and *Time- a lack of time for professional development and teacher prep time* (frequency of 9). See Table 4.18 for a review of the entire additional teacher challenges identified by responders in the open-ended response question.

Table 4.18. Additional Teacher Challenges Identified by Participants (Open Ended Response)

Teacher Challenge	*f*
Money - lack of funds to purchase state of the art equipment, budget cuts, changes are costly	14
Curriculum Lack of clear and concise, unrestricting, appropriate blend of skill and knowledge	11
Support -lack of support from administration (3), guidance(1) math and science teachers(1) community (2) State Education Dept (4)	11
Enrollment - fear of loss of students due to lack of interest, academic ability, motivation	11
Time - lack of time for professional development, teacher prep time, etc	9
Equipment and Software - lack of needed equipment, tools, and software	8
Student Schedule -lack of room in student schedule for electives due to graduation requirements	7
Teacher Knowledge - lack of teacher knowledge about engineering design content	3
Lab Space	3

CHAPTER 5 DISCUSSION

Introduction

This chapter consists of a review of the rationale and conceptual framework of the study, a review of the statement of purpose and research questions, followed by a review of the methodology used in the study. Upon completion of this review, findings of the study will be discussed and implications on how these results may be applied to practice and future research within the field of technology education and the broader STEM community.

Summary of the Study

Many educators inside and outside of technology education have viewed the move from industrial arts to technology education a change in name only (Clark, 1989); a fact that may have provided grounds to accuse the field of technology education of failing to establish a clear mission (Wicklein, 2006). Research on this topic backs up this claim. Akmal, Oaks, and Barker (2002) conducted research seeking to assess the progress the field of technology education had made with respects to moving from industrial arts to technology education. A survey instrument solicited information from all technology education state supervisors in the nation; all but 4 of the 39 states that responded reported their states no longer used the program title "industrial arts". However, 34 states report that traditional industrial arts and technology education programs are currently operating simultaneously throughout their state, a fact that Clark (1989) suggested has stifled the movement to technology education. In a similar study, Sanders (2001) conducted research in which he surveyed technology education teachers and found 40% of respondents identified their programs with vocational education. When Sanders compared 2001 survey results to 1960 and 1970's survey results, overall the responses were similar, indicating little progress had been made regarding the move to technology education in two decades (Dugger et al., 1980). In a similar vein, Hansen and Lovedahl (2004) asked an important question: "If instructional methodologies, content, clientele, and purpose are pragmatically the same before and after a name conversion, aren't the new technology education programs really vocational-technical education?"(p. 21). If many technology educators still remain focused on methods and instructional strategies more aligned with industrial arts, it would seem that the issues of implementing engineering design would be questionable within the technology education field. Due to these facts, it was determined that research was needed to determine the degree to which technology educators are implementing elements of engineering design in their curriculum. Furthermore, there have been a number of new curriculums designed to infuse engineering content into technology education courses such as *Project ProBase*, *Principles of Engineering*; *Project Lead the Way*, *Principles of Technology*; *Engineering Technology*; and *Introduction to Engineering* (Dearing & Daugherty, 2004). Each of these programs proposes teaching engineering concepts or engineering design in technology education as a vehicle to address the standards for technological literacy. Although there are new engineering design curriculum programs in development and others are decades old, it is unclear as to the degree to which technology educators are implementing engineering design content in their curriculum. Certainly, research was needed to determine the magnitude these programs are implemented into technology education classrooms and to what degree engineering design content was being presented.

It has been documented in the past that a need exists for research that identifies and describes the teaching practices of in-service technology education teachers (Boser & Daugherty, 1994). The AAAS Research on Technology Education Conference held in 2000 resulted in a general consensus from those in attendance that research in technology education should focus on what is happening in the classroom regarding how teachers teach and how students learn; however, since that time very little research has focused on teacher practices regarding content delivered or assessment strategies employed (Benenson, 2001). A paper reflecting on technology education research by Zuga (2000) also indicated that little research was focusing on teaching and learning in technology education classrooms. Review of recent literature in the field of technology education indicates that need has continued due to the lack of research done to identify common teaching practices of technology education teachers. Moreover, a need to understand where technology educators are in practice regarding a move to an engineering design focus has been expressed by leaders in technology education (NCETE meeting report, Oct, 2006). It was clear that a descriptive study could help the field of technology education understand the depth of implementation of engineering design content infused into technology education.

Conceptual Framework

The recent trend to move to engineering design in technology education has also caused researchers to investigate what outcomes should be a part of a program that integrates engineering design into high school technology education (Asunda & Hill, 2007; Childress & Rhodes, 2008; Gattie & Wicklein, 2007; Smith, 2006;). These recent studies have obtained input from practicing engineers, engineering educators, mathematics educators, and technology teacher educators, and technology education teachers about the essential aspects and related academic concepts that are required to properly infuse engineering design into secondary technology education.

The conceptual framework for this study consisted of knowledge obtained from these four studies of engineering design as a focus for technology education. Although some professionals in the field of technology education have begun to agree that engineering design should be a curricular focus for technology education (Dearing and Daugherty, 2004; Wicklein & Gattie, 2007), debate continues with respect to what content should be taught in high school technology education classes. Furthermore, what are the outcomes for students completing a course in engineering design, and what strategies are appropriate for assessing engineering design activities? These research studies (Asunda & Hill, 2007; Childress & Rhodes, 2008; Gattie & Wicklein, 2007; Smith, 2006) have sought to answer these questions by polling experts in the field of engineering and technology education. Two of these studies have created a framework to define the ideal engineering design curriculum content with respect to the necessary learning outcomes for high school students (Childress & Rhodes, 2008; Smith, 2006). Specifically, a framework to define curriculum content that addresses engineering design concepts was discussed and consisted of the following seven categories: (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. Results of Asunda and Hill's (2007) study create a frame to identify appropriate assessment strategies for secondary technology educators when assessing engineering design activities.

Finally, Gattie and Wicklien (2007) established a list of identified challenges commonly facing technology educators seeking to infuse engineering design into the curriculum. The results of each of these studies framed this research construct by providing criteria with which to define the degree that technology educators are implementing elements of engineering design in their curriculums.

Purpose and Research Questions

This descriptive study examined the degree to which technology educators are implementing elements of engineering design in their curriculums. A full sample was taken of all secondary technology educators who were members of the International Technology Education Association (ITEA) as of September 2007. The sample consisted of all high school technology teachers regardless of whether they indicate they are teaching engineering design in their classroom. The survey instrument gathered data about the degree to which engineering design concepts were incorporated into the curriculum content, assessment practices employed by secondary technology educators, and challenges to implementing engineering design concepts in the secondary technology education curriculum. The instrument was developed from current research in technology education that identified curricular goals, content recommended for teaching an engineering design focused program at the high school level, appropriate assessment practices for evaluating engineering design projects, and perceived challenges facing teachers implementing engineering design content (Asunda & Hill, 2007; Childress & Rhodes, 2008; Gattie & Wicklein, 2007; Smith, 2006).

The study sought to answer the following questions:

1. To what degree does the current curriculum content of secondary technology education programs reflect engineering design concepts?

2. To what degree do current assessment practices of secondary technology educators reflect engineering design concepts?

3. What selected challenges are identified by secondary technology educators in teaching engineering design?

Methodology

This descriptive study examined the degree to which technology educators are implementing elements of engineering design in their curriculum. Although technology education programs across the country have implemented engineering content into courses in recent years (Lewis, 2004; Rogers, 2005), little is known about the status of this curriculum change with respect to current technology education curriculum content, assessment practices for engineering design activities, or degree of engineering design program implementation. This descriptive study sought to describe the current engineering design content and assessment practices using the results of four recent research studies (Asunda & Hill, 2007; Childress & Rhodes, 2008; Gattie & Wicklein, 2007; Smith, 2006) to create items for the survey instrument.

Sample

This descriptive study drew a full sample of high school technology teachers from the current International Technology Education Association (ITEA) membership list. The sample consisted of all high school technology teachers regardless of whether they indicate they are teaching engineering design in their classroom. The identified population of this study consisted of a total of (N) 1043 high school technology education teachers in the ITEA membership database as of September 11, 2007. Using Krejcie and Morgan (1970) method to locate sample size for a given population size, the required sample size was set at 285 (Gay & Airasin, 2000). The original research design for this study called for an increase of the initial mailing of the survey by 48.1 percent, the average success rate of an initial mailing (Gall et al; 2007). However, close communication with ITEA personnel revealed that ITEA survey mailings typically yield a 20-25% rate of return (Price, 2007). The researcher determined that a full sample mailing to all ITEA high school members was necessary to achieve the desired sample of 285.

Measures

The first main section of the survey instrument gathered data about degree to which engineering design concepts were incorporated into technology education curriculum content. The curriculum content items were created from the results of Childress and Rhodes study (2008) and Smith's study (2006) to create the framework for defining engineering design curriculum content. Seven categories were used to organize the curriculum content that addresses engineering design concepts and were as follows: (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. Each instrument item for this section consisted of the identified necessary learning outcomes for high school students enrolled in an engineering design focused technology education program (Childress & Rhodes, 2008; Smith, 2006). The curriculum content section was the largest section of the survey instrument containing a total of 51 individual items.

Participants were required to respond to each curriculum content item twice, once for *frequency of use* and once for *time per typical use*. A six-point Likert scale with 0 indicating *never* and 5 indicating *Daily* was used to rate participant's level of agreement regarding their content and teaching practices to the identified learning outcomes that made up the instrument items. A table was provided to participants that contained units to further breakdown the six-point Likert scale of frequency and time as it relates to school day schedule; see Table 3.2.

The second section of the survey instrument consisted of identified assessment practices for evaluating engineering design activities (Asunda & Hill, 2007). Participants rated their level of agreement regarding their assessment practices of engineering design activities with the identified assessment practices presented in the instrument. A total of eight individual instrument items made up the assessment practices section. The same six point Likert scale response that was formerly described was also used for the assessment practice section.

A third section of the survey instrument contained identified teacher challenges relating to implementing curriculum changes to infuse engineering design into technology education curriculum. Participants used a five-point Likert scale to rate their levels of experience with fourteen identified selected teacher challenges. The five-point Likert scale was as follows: Never = 0, Rarely = 1, Sometimes = 2, Very Often = 3, and Always = 4, this is a common scale method used in survey research (Lodico, et al.). A final question in this section was open-ended allowing participants to identify any challenges faced when implementing curriculum changes that were not previously identified in the survey instrument.

The final section of the survey instrument collected general demographic information of each participant. A total of eight questions inquired about participants' teaching grade level, years of experience, gender, age, education, school setting, and school size.

Limitations

One important point must be mentioned regarding the limitation of this study. Using Krejcie and Morgan (1970) method for calculating sample size for a given population size, the appropriate sample size for this study was determined to be 285. The final results of the study yielded a total of 226 respondents; therefore, the results of this study cannot be generalized to the entire population. However, the researcher comparing the demographic data results from this research to similar national status of technology education research (Gattie & Wicklein, 2007) that achieved an acceptable response rate level to generalize to the population. The demographic results of both studies were very similar, thus, suggesting that these results were representative to the population. However, it is acknowledged that statistical significance was not achieved in this study.

Summary of Results

This descriptive study was carefully constructed in such as way to not only provide a better understanding of the status of the infusion of engineering design in technology education but to also present these findings in a meaningful and quantifiable method. One technique employed to accomplish this goal was to quantify teaching units of time and frequency by using the teaching style scale conversion table, see Table 3.2. As mentioned earlier in chapter four, it has been found that using both frequency and time will provide a more accurate description of teaching practices and learning experience (Mullens & Gayler, 1999).

Another feature that this research design implemented to assist in organizing the results was the application of the seven content categories as identified in prior research (Childress & Rhodes, 2008). It is important to carefully consider how each item response is captured and how each survey item is organized (Farmer & Rojewski, 2001). When studying a construct within a domain as large as engineering design, it is vitally important to have a way to organize the elements of engineering design curriculum content. Using the identified seven content categories as a way to organize engineering design content was an appropriate and effective method. Moreover, these seven content categories provide an accurate way to describe the various elements of engineering design content providing the researcher the ability to describe specifically what elements of engineering design are being implemented and those elements that are being neglected. Using the seven categories provided a concise way to report the finding for teacher practices related to teaching engineering design content.

Furthermore, another unique feature of the instrument was the reference table of *frequency of use* and *time per typical use* based on participant's school schedule. Light, Singer and Willett (1990) suggested using a method to further quantify a scale or as they call it "lengthening the scale" in order to increase the precision of the response. To "lengthen the scale" in this research study, the researcher used Table 3.2 to provide participants a method to quantify the Likert scale with units of instruction time. Light et al.(1990) indicated that "lengthening the scale" and combining variables not only provides the researcher with the ability to create a composite but also provides a statistical argument for reliability of the instrument. The results of this research yielded a .982 Cronbach's Alpha for internal consistency, which supports the notion that "lengthening the scale" helps to provide a reliable indicator. Mayer (1999) used Light et al. rationale to create a six-point Likert scale and later converted the scale into days per year for frequency and minutes per class period for duration similar to the conversion table used in this study; see Table 3.2. Also, Mullens and Gayler (1999) concluded that when seeking to identify employed teaching practices, it is important to consider frequency and time of the implemented practice; the instrument for this study measured both. However, Mayer (1999) indicated that a limitation of his study resulted in his failure to provide the conversation table to the participants resulting in Likert scale response options which were hard to distinguish for the participants. To overcome this limitation, this research study provided the table of conversion (Table 3.2) to the participants as they responded to the Likert scale throughout the survey instrument, and instructions were provided at the beginning of the study prompting participants to continually consult the table as they responded to the instrument items.

Engineering Design Curriculum Content

Upon review of the results of this study, the most striking conclusion about the status of technology education teacher practices related to engineering design curriculum content is what is emphasized when measured by instruction time. It appears that humans are often asked to consider what they value most by considering where the majority of their time is spent. For many technology educators, it may not be surprising that the highest scoring group mean by category of engineering design curriculum content measured by time per typical use was *Engineering Communication* with a group mean score of 2.80. This may not be a surprising result for many technology educators because several individual items in this category relate to computer-aided-design, a very time-consuming technology topic. In fact, the highest mean score individual item measured by time per typical use was *use of computer-aided design to construct technical drawings* with a mean score of 3.35. Another computer-aided-design related item was *use technical drawings to construct or implement an object, structure, or process* with a mean score of 3.30, which the third highest mean score individual item overall measured by time per typical use. Keep in mind that these mean scores indicate technology teachers responses fall between *1or 2 times a week* and *nearly everyday* (frequency) and between *about half the class period* and *more than half the class period* (time). For those technology educators who have taught a computer-aided-design (CAD) course, the high mean score of this category is logical because teaching this subject is very time consuming, requiring a great deal of instruction and practice time to master the software. Sanders (2001) found in a national study of technology education that CAD was the most frequently taught high school technology education course category at that time. Other status studies in technology education have also found an emphasis on teaching CAD in technology education (Dearing & Daugherty, 2004; Warner & Mumford, 2004; Warner, Morford-Erli, Johnson, & Greiner, 2007). One conclusion that can be drawn from these results is that technology education teachers are emphasizing design through the use of computer-aided design in their technology education programs. Furthermore, if computer-aided design demands a large amount of instruction time and practice time, it can raid technology instructors of time to teach other fundamentals of engineering design.

Another result of this study of particular interest for the field of technology education is that the second highest mean score item measured by time per typical use was *develop basic student's skills in the use of tools* with a mean of 3.32. It appears that the field of technology education has not moved far from its industrial arts roots. As a matter of fact, a similar survey item, *developing skill in using tools and machines,* was the highest mean score item in the SfIAP project (1980) and Schmitt and Pelly study (1963) according to Sanders (2001). Although it is undeniable that there must continue to be some learning opportunities in the basic development of tool skills in an engineering design focused technology education curriculum, a proper balance of instructional time for tool skill development must be determined. Certainly, more research would need to be conducted to accurately describe what specific skills are being developed and what tools are being used in technology education programs and if the teaching of these skills and tools enhance the learning of engineering design.

In light of the results of high mean scoring items in the area of computer-aided drafting and tool skill development, one has to consider if in practice, technology education is much more vocational in its focus than many technology educators and technology education leaders want to admit. Sanders (2001) made the argument that technology programs focusing on CAD were vocational by nature. Furthermore, with many in technology education claiming that the field's purpose is to foster technological literacy for all (ITEA, 1996) as apart of general education and not as a part of vocational education, it would appear these results indicate that technology education still has not established its core mission as suggested by Wicklein (2006). Moreover, those in opposition to technology education programs with a career pathway must recognize that according to the results of this study, curriculum content currently emphasized in technology education classrooms can be largely considered vocationally focused. Technology educators must come to grips with the results of this study that reveals that technology education still has an identity problem regarding its core mission.

Another important area of the study results to carefully consider is the curriculum content categories that received low mean scores. The lowest group mean score categories based on composite scores for total instructional time were, *Engineering and Human Values* (6.21 hours for traditional schedule; 6.06 hours for block schedule), *Engineering Science* (7.06 hours for traditional schedule; 8.88 hours for block schedule), and *Engineering Analysis* (14.41 hours for traditional schedule; 14.16 hours for block schedule); see Figure 3 and Figure 4. Upon further examination of these results, factors can be revealed as to why these categories are low scoring by reviewing the mean of individual items. Individual items with low scoring mean including the items for time per typical were *use trigonometry to solve problems or predict results to design solutions* (mean of 1.58), *understanding how engineers put ethics into practice* (mean of 1.76), *using optimization techniques to determine optimum solutions to problems* (mean of 1.82), and *use physical and/or mathematical models to estimate the probability of events* (mean of 1.93). These results help clarify and extend the results of prior research that has sought to understand the status of technology education regarding the infusion of engineering design. Gattie and Wicklein's (2007) study found that 90% of the technology educators who responded to their survey indicated that they were teaching engineering design while 45.4% of their instructional content was dedicated to that subject. Yet, Gattie and Wicklein also found that an instructional need existed for teachers to determine the appropriate levels of math and science knowledge to teach engineering design as well as need of the teachers to acquire fundamental knowledge of engineering science. The results of this study suggested that technology teachers are not emphasizing these curriculum content areas and quite possibly these teachers do not have the necessary knowledge to do so effectively. Gattie and Wicklein (2007) also indicated that typically the mathematics requirements in undergraduate technology education programs do not go beyond college algebra or trigonometry, a possible factor for teachers not properly equipped to teach these elements of the engineering design process.

Additionally, one important factor that may affect the lack of emphasis of engineering analysis and engineering science in high school technology education programs is the design process itself. A number of recent articles have presented the major difference between the technology design processes as it appears in the Standards for Technological Literacy (2000/2002) compared with the engineering design process as defined by Eide, et al. (2001) (Hailey, Erekson, Becker, & Thompson, 2005; Hill, 2006; Gattie & Wicklein, 2007). The major differences in the two design processes is the emphasis of building a model or prototype in the technological design process and the missing steps of the engineering analysis and optimization stages that are present in the engineering design process. The adoption of a design process (The Technological Design Process) with key stages of the engineering design process missing (engineering analysis and optimization) logically will lead to the lack of emphasis in those areas of the engineering design process. Furthermore, Gattie and Wicklein (2007) also found that only about half (54.2%) of respondents of their study indicated that they were aware of local or state approved courses or curricula focusing on engineering design and over half (53.2%) surveyed were not satisfied with current engineering related textbooks, these results cause one to wonder if technology educators have access to curriculum materials or textbooks that present an engineering design process with analysis and optimization stages.

When faced with the reality that the use of mathematics is not emphasized to predict design results or as a part of optimization techniques to select final design solutions, one can conclude that the engineering design process is not being properly infused into the technology education classroom. Although these results indicate that technology educators are implementing some *engineering analysis* and *optimization* into the curriculum content, the overall low mean scoring of these items suggest that technology educators place less emphasis on these phases of the engineering design process. Some suggest that these phases of the engineering design process are what make the engineering design process different from the technological design process (Hailey, et al., 2005; Hill, 2006; Gattie & Wicklein, 2007). If you remove the engineering design stages *engineering analysis* (application of mathematics and science) and *optimization* as defined by Eide, Jenison, Mashaw, and Northup (2001), what remain are the basic elements of technological design process as defined by the Standards for Technological Literacy (ITEA, 2000). When examining these results based upon this philosophy, technology educators are, at best, making a slow move toward the infusion of engineering design but are still lacking in the essential phases of the engineering design process. Furthermore, the lack of emphasis on these key phases of engineering design could cause some to again accuse the field of technology education of another name-change only curriculum reform (Clark, 1989). Moreover, if engineering analysis and optimization phases of the design process are removed from the design process then the rationale proposed by some (Daugherty, 2006; Wicklein, 2006) to move to engineering design as a focus is an ideal way to integrate math and science into the technology education is lost. It is evident that technology educators must make an effort to properly infuse engineering analysis and optimization into the curriculum content in order for the field of technology education to properly infuse engineering design into the curriculum; otherwise this change in curriculum focus is only semantic in nature.

The low mean scoring of the category *Engineering and Human Values* is of particular interest to those educators who advocate the teaching of the social, political, and environmental impacts of technology on society, including education regarding ethical issues embedded within engineering and technical design. Hill (2006) presented the case for a need to teach about the social aspects of engineering design. Hill (2006) cited the words of Dr. Richard Miller, founding President of Olin College who, when speaking about the engineering profession emphasized the need for engineers who had strong business and ethical skills. Moreover, the Standards for Technological Literacy (2000/2002) clearly identify the need to teach about the social, political, and economic issues related to technology. Standards 4-6 address the social, political, environmental and general societal role in the development and use of technology. Leaders in the field of technology education have also supported teaching of these topics with the recent publication of the 53rd CTTE yearbook titled *Ethics for Citizenship in a Technical World*. Although there is a strong support for the teaching of social and ethical issues related to engineering and technical design from the technology education leadership, the results of this study indicate that this topic is less emphasized in the practice of teaching of secondary technology educators when considering engineering design curriculum content.

Assessment Practices

The assessment practices of secondary technology teachers regarding engineering design projects were measured by time per typical use and frequency of use. The individual items in this section of the instrument were constructed from the results of prior research (Asunda & Hill, 2007). Computing a composite score for the assessment practices of high school technology teachers by using mean scores for time and frequency provided an indicator to reveal areas of emphasis and deficiencies regarding assessment practices. See Figures 3 and 4 for a complete review of the assessment practices based on total assessment hours.

The top three individual assessment items based upon time per typical use were *provide evidence of idea generation strategies (e.g. brainstorming, teamwork, etc.)* (mean of 2.92), *develop a prototype model of the final design solution* (mean of 2.69), and *worked on a design team as a functional inter-disciplinary unit* (mean of 2.53). Overall, the assessment practice category yielded relatively low mean scores, none of which yielded a mean of 3.00 or higher. It is important to note that a response of a 3 on the five point Likert scale indicates *1 or 2 times a week* (frequency) and *about half the class period* (time). The lowest mean scores for time per typical use were individual items *using mathematical models to optimize, describe, and/or predict results* (mean of 1.72), while *properly record design information in an engineer's notebook* also yielded a low mean of 2.01; see Table 4.16 for total results of the assessment practices category. The results of the assessment practice section of this study reaffirm the results found in the engineering design curriculum content section. According to the results of this study, secondary technology education teachers place lower emphasis on using mathematics to optimize and predict results. These results are strong indicators that the engineering analysis phase of the engineering design process is not emphasized in assessment practices. Furthermore, lesser emphasis is placed on assessing student's record keeping of design information in an engineer's notebook. Another low mean score item was *providing evidence of formulating design criteria and constraints prior to design solutions* (Mean of 2.33 (time); Mean of 2.19

(frequency)). Identifying constraints and criteria early in the design process is an important feature of the engineering design process but is a practice not widely adopted within the field of technology education (Hill, 2006). The low mean score of this individual item confirms this statement.

Teacher Challenges

Turning to the results of the teacher challenges section of the study, the results once again confirm discoveries found in the engineering design curriculum content and assessment practice sections of the instrument. This final section of the survey instrument asked participants to rate 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 4 = Always). In the support of the results presented earlier in this chapter, the teacher challenge section results found respondents indicating challenges locating and integrating appropriate levels of math and science for engineering design. Technology teachers participating in this study indicated that *integrating the appropriate levels of math and science to teach into instructional content* was a challenge (mean 2.48; SD 0.88). The fourth highest mean score item was similar in context *locating and learning the appropriate level of math and science to teach engineering design* (mean 2.27; SD 0.93). Other high mean scoring challenges were in locating and acquiring appropriate tools and equipment to teach engineering design effectively. The second highest identified challenge was *locating the appropriate laboratory equipment to teach engineering design* (mean 2.40; SD 1.10). The third highest mean scoring individual item was *acquiring funding to purchase tools and equipment to teach engineering design* (mean of 2.31; SD 1.23). Locating appropriate funding to acquire proper tools and equipment has often been identified as a top challenge for technology education teachers (Wicklein, 1993, 2005). It is also logical that technology teachers are identifying challenges in locating the appropriate laboratory equipment and acquiring the proper funds to purchase such equipment. Similarly, in a study of the status of engineering design in Georgia's technology education programs, Denson, Kelley, and Wicklein (2007) found that over 88.0 % of Georgia's technology education teachers identified a need to locate and acquire appropriate types of tools and test equipment to teach engineering design (mean of 3.20; SD 1.12). These results indicate that technology education teachers have a struggle to locate appropriate tools and equipment to teach engineering design in technology education. Moreover, there is little evidence in literature to suggest that anyone in the field of technology education has properly described the appropriate equipment to teach engineering design within technology education. The fact that appropriate tools and testing equipment have not currently been identified spurred the Engineering and Technology Education Advisory Committee for Georgia Department of Education to recommend that a subcommittee be formed of technology education teachers, university professors, and school administrators in the state of Georgia to investigate and identify appropriate tools and test equipment that will assist technology teachers to teach engineering design in middle and high school technology education programs (Advisory Committee on Engineering and Technology Education in Georgia, 2008).

Implications for Professional Development

In recent years, efforts have been made to provide professional development opportunities for teachers seeking to infuse engineering content into curriculum (Asunda, 2007; Cunningham, Knight, Carlsen, & Kelly, 2007; Hailey, et al.). Furthermore, as more states take a closer look at revising technology education curriculum to focus on engineering design or pre-engineering it is likely more professional development programs will be developed to equip technology teachers to properly teach engineering concepts. As mentioned above, the

Engineering and Technology Education Advisory Committee for the state of Georgia investigated engineering design as a possible focus for technology education for that state. The advisory committee reported recommendations to the Director of Career, Technical and Agriculture Education; one major recommendation was to provide professional development opportunities for technology education teachers in Georgia. The advisory committee suggested that the professional development programs be focused, consistent, and relevant to engineering design content. The results of this study provides an excellent opportunity for leaders in the state of Georgia, and any other state seeking to design professional development, to be informed about the teaching practice, assessment strategies, and identified challenges of current technology education teachers seeking to implement engineering design curriculum.

These results have described the amount of instructional and classroom time that is dedicated to various engineering design concepts; identifying areas of deficiency as well as potential over emphasis of certain content. Moreover, the results of this study provide description of the assessment practices regarding engineering design currently implemented and the degree of implementation. Finally, the results have identified teacher challenges faced when seeking to implement an engineering design focused technology education program. Information obtained from this research can help professional developers create workshops, curriculum, and support materials that will properly address teacher concerns and equip these educators with the necessary skills and knowledge to properly infuse engineering design into the classroom.

Conclusions

The results of this descriptive study have yielded valuable information for the field of technology education. There has been a body of literature regarding the issues related to engineering design as a focus for technology education (Daugherty, 2005; Hill, 2006; Lewis, 2004; 2005; Wicklein, 2006). Several research studies in technology education have investigated the appropriate outcomes and assessment strategies for a high school level engineering design program (Asunda & Hill, 2007; Childress & Rhodes, 2008; Smith, 2006). Other studies have sought to better understand the perceptions and attitudes of technology teachers, technology teacher educators, and other leaders in technology education regarding the benefits of infusing engineering design into technology education (Gattie & Wicklein, 2007). This study sought to extend the results of those prior studies by using those results to help describe the current status of technology education regarding the engineering design curriculum content, assessment strategies, as well as challenges facing technology teachers seeking to infuse an engineering design focus. It is imperative for educational researchers in technology education to have the ability to identify where the field of technology education is, as a whole, regarding issues and needs related to an engineering design focus. Current literature reveals that technology education teachers believe there are potential benefits of an engineering design focused curriculum (Gattie & Wicklein, 2007). However, those benefits may never be realized unless our field is properly informed as to the status of its practitioners regarding the implementation of engineering design into the technology education classroom; this study sought to provide such information. Moreover, curriculum developers, educational leaders, state supervisors, and professional developers cannot properly design interventions to aid technology educators unless they are fully informed as to the areas of deficiencies and challenges facing technology educators. This study has revealed specific areas of technology teacher needs, engineering design curriculum content deficiencies, and constraints faced by technology educators as they work to integrate engineering design into the field of technology education.

Establishing a Core Mission

The evidence from this study provides rationale to conclude that technology education curriculum content currently emphasizes career and technical education skills such as CAD and general tool skills. Leaders in the field of technology education should embrace these findings and use it as a way to define a clear mission for the field of technology education, one that provides a career pathway to engineering. Technology education would be best served to embrace the idea that it can provide a logical career pathway for high school students and at the same time provide the universal skill of problem solving used in the engineering profession but which is also applicable to a variety of other important careers. The proper engineering design curriculum would serve students well even for those who do not choose engineering as a lifetime career. An engineering design curriculum in technology education could become all encompassing to provide a career pathway for student preparing to enter a four-year baccalaureate engineering school, while other students in the program seek to enter a two-year engineering technology program. A well-designed engineering design curriculum in technology education could also provide necessary skills and knowledge for students entering many other STEM related career fields. Some participants of this study indicated in the final open-ended question that they feared losing students using the rationale that an engineering pathway would narrow the focus for technology education, and thus, narrow the technology education audience. However, a well-designed engineering design curriculum could attract students to technology education that might not typically choose current technology education courses while at the same time retain existing technology education clientele. Furthermore, an engineering design curriculum could also attract students from other demographics currently underrepresented in technology education classrooms.

Another conclusion related to the core mission is that the field of technology education must determine what is the appropriate depth and scope of engineering design curriculum content necessary for high school technology education focused on engineering design. Although a number of studies have sought to locate appropriate outcomes for a high school technology education program with an engineering design focus (Childress & Rhodes, 2008; Smith, 2006) there remain questions about what are the appropriate degrees of infusion of the engineering design elements. For example, how much mathematics and science are necessary to successfully implement engineering design at the high school level? In reporting the findings and conclusions of this study, it was difficult to determine if the extent to which the seven engineering design categories were being implemented were at acceptable and appropriate levels. It will be necessary for the field of technology education to define the appropriate levels of the seven engineering design curriculum content categories are necessary for a high school engineering design program. More research must be conducted to exploring this area of the construct.

Addressing the Needs of a Global Workforce

In recent years, some in technology education have endorsed the concept that technology education's purpose is to foster technological literacy in all students. This purpose for technology education is a noble and worthy mission; however, an equally important mission is to prepare young people to become efficient workers in a global society while at the same time become technological literate. The U.S. Department of Labor reported that a twenty percent increase in the demand for engineers would occur before the end of the decade, and currently many engineering jobs remain unfilled because of the lack of qualified candidates (Southern Regional Education Board, 2001). Moreover, there are several commissioned reports that accurately describe the needs and the job skills necessary for individual to be prepared to work in a global economy (Committee on Prospering in the Global Economy of the 21 Century, 2007; National Center on Education and the Economy, 2006). Technology education with an engineering design focus can help address these needs while at the same time prepare students that are technologically literate.

Some of the results of this study indicate that technology education is already providing some learning opportunities for high school students that can develop necessary job related skills needed of workers in a global economy. The literary works of Friedman (2005) and Pink (2005) not only documented the changes taking place nationally and internationally regarding a global economy, but also describe some attributes of the new kind of problem solver needed to address the complex issues that will emerge from global workforce competition. Some of the highest mean score items in this study addressed these needs including *thinking critically* (highest mean score item measured by frequency) and *worked on a design team as a functional inter-disciplinary unit*. These attributes are necessary for a global worker, and, according to the results of this research, are well supported by current technology education curriculum content. One particular area of improvement for technology education curriculum content to properly address the needs of a global workforce is the category of *Engineering and Human Values* (the lowest group mean scoring category by composite score). Some low mean scoring items within the *Engineering and Human Values* category are those outcomes related to making ethical decisions about engineering problems and also outcome that provide awareness of social, economical, and environmental impacts of technology on our society. The field of technology education would be better served by addressing these issues with improved curriculum content identified in the Engineering and Human Values category as well as implementing a systems thinking approach to problem solving in order to provide a way for students to learn how to address sustainability design issues.

Including Mathematics in the Designer's Toolbox

One rationale for the importance of teaching technology education with an engineering design focus is that it can provide a real-world context for the application of math and science (Daugherty, 2006; Wicklein, 2006). However, the results of this study indicate that there is little emphasis on the application of mathematics and engineering sciences in current technology education curriculum. As mentioned earlier, a low mean score for time per typical use was the individual item *using mathematical models to optimize, describe, and/or predict results* (mean of 1.72). In the engineering science category, a low mean score result of 1.58 was determined for *use of trigonometry to solve problems and predict results.* It is clear that if the field of technology education uses a rationale that the study of technology education helps provide a real-world context for the application of mathematics then technology education curriculum must provide more learning opportunities that include the use of mathematics as a part of the design process. Furthermore, a number of leaders in technology education have indicated that a major difference between the technological design process and the engineering design process is *analysis* and *optimization* (Hailey, et al., 2005; Hill, 2006; Gattie & Wicklein, 2007). The results of this study indicate that *analysis* and *optimization* stages of the engineering design process are not presently emphasized in technology education curriculum content, which might cause some to question if the engineering design process is being properly implemented. Clearly, the participants in this study provided some indication why mathematics is not emphasized in technology education curriculum when they indicated that *integrating the appropriate levels of math and science to teach into instructional content* (mean 2.48; SD 0.88) and *locating and* *learning the appropriate level of math and science to teach engineering design* (mean 2.27; SD 0.93) were major challenges. These results indicate fertile ground of opportunity for professional development to assist technology educators to properly infuse engineering design into technology education curriculum. It is important to note that the debate is very much alive about what are the appropriate levels of mathematics and engineering science for teaching engineering design at the secondary level, more research is needed to determine the appropriate levels.

In conclusion, it is the desire of this researcher that the results of this study will be used by those in the field of technology education to help design new engineering design curriculum, assessment strategies, and professional development experiences that will help high school technology educators successfully implement engineering design focused technology programs around the country.

Recommendations for Future Research

This research study has provided great insights into the current national status of technology education regarding engineering design curriculum content, assessment strategies, and challenges facing secondary teachers seeking to infuse engineering design into their classes. From this study, those in the field of technology education will better understand what is taking place in technology education classrooms regarding engineering design. However, more information is needed to help properly inform the field about this construct. Consequently, the following recommendations are suggested for further research to inform the field of technology education:

a. Conduct similar descriptive research should be conducted using participants other than ITEA members to compare the results with this study. Moreover, a follow-up study using a different database could yield a larger sample size that would allow the researcher to statistically generalize to the entire population of technology education teachers. One possible database of technology education teachers that could be used for a follow-up study is the Engineering and Technology Education Division (eTED) of the Association for Career and Technical Education (ACTE).

b. Conduct descriptive research using specific curriculum programs (*Project Lead the Way*, *Probase*, etc.) as the grouping variable to examine the student outcomes addressed as they relate to engineering design competencies. A study of this design could provide valuable information about outcomes and competencies achieved by these specific curriculum projects and about curriculum deficiencies.

c. Conduct qualitative case studies of high school technology education teachers who have successfully implemented an engineering design focused technology education program in order to identify strategies necessary for infusing engineering design concepts into technology education. Furthermore, these types of studies could seek to explore the challenges and constraints facing these teachers as they implemented a technology education program focused on engineering design.

d. Conduct descriptive research using urban, suburban, and rural school settings as a grouping variable to determine if there exists a statistical difference in the challenges facing teachers seeking to infuse engineering design into technology education when grouped by school setting.

e. Replicate this study using the same instrument and a sample of ITEA members five years in the future. A comparison of the results of this study and a study five years out could help identify the progress made with the infusion of engineering design in technology education curriculum content.

f. Conduct qualitative and quantitative research to determine the levels of mathematics and engineering science that are appropriate for teaching engineering design at the secondary level in order to remain authentic to the engineering design process and remain manageable for technology education teachers.

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APPENDICES

Appendix A

CONTENT VALIDATION FEEDBACK

Content Validation Comments

Reviewer #1
General comments: good grasp of the design process. Do the teachers in your audience have this background?

Identified problems

Engineering Design section overlaps with other sections on Engineering Design. Shorter surveys stands better chance of being completed, so I would think about combining some of the topics with similar questions to reduce length. It looks like you may have considered the ABET criteria when developing the survey. If you haven't already looked at ABET, it would be worth checking out.
Total Years in Engineering: 25
Total Years in Engineering Education: 25
Engineering Domain: Agricultural Engineering/Structural Engineering

Reviewer #2
General Comments
Very comprehensive document, I would have like to seen something about the about student's understanding that engineering requires a commitment to lifelong learning.

Identified Problems
I am not sure what the last objective is saying. Are we saying that an objective is to provide the student confidence that they have the ability to provide a solution to technological problem?

Total Years in Engineering: 25
Total Years in Engineering Education: 15
Engineering Domain: Civil Structures

Review #3
General Comments: Most questions are good. Should be very good. Beta test first and get feedback.

Identified Problematic Items

Separate the "How Often" and "How Many Minutes" tables with some space.

Very good, except repeat the "How Often" and "How Many Minutes" tables for ease of use.

Content Validation Results
(Continued)

Reviewer #3 (Continued)

Add "apply knowledge of physical laws (such as Laws of Thermodynamics) and same as above

Total years in Engineering: 35
Total Years in Engineering Education: 7
Engineering Domain: Mechanical Engineering

Reviewer #4

General Comments:
This is a very long and cluttered instrument. I would work toward reducing the amount of verbiage and spacing items with a bit more room around them. I also think it is important to eliminate design terminology that you interpret as specific design terminology and the respondents are likely to interpret in a colloquial or "everyday" sense.

Identified Problematic Items

"Develop basic skills in the use of tools for material processes" reads to me like a question regarding a class in machining or machine shop -- and that is not design to me.

In the first, I do not have a clear vision of what is meant by "engineering principles." Perhaps you mean scientific principles.

These items are too closely space; they would read more easily with some additional space between them. The second item makes no sense in its current form.

I don't know what you mean by computer-aided engineering. Scale and proportion is generally used in reference to drawing, not to design.

The ergonomics item seems to be out of place; it would fit better with the Human Factors questions.

The items that use terms such as criteria and constraints are dubious to me. You are relying on the respondents understanding of these terms. Secondary teachers are, for the most part, not design engineers and it is unlikely that they know the true meaning of such design terms. It is unreasonable to expect any meaningful results from such items.

Total years in Engineering: 9
Total Years in Engineering Education: 5
Engineering Domain: Material Science and Engineering

Content Validation Results
(Continued)

Reviewer #5

General Comments:
This survey is too long. The instructions are confusing and some questions are rather nebulous.

Identified Problematic Items:
In its present form, it confuses me. I have difficulty understanding what you mean by technology teachers and whether or not you are addressing the High School Core Area Academic Standards. The questions are all over the board and don't appear to be focused on engineering design.

I don't think the results of this survey will reflect the degree to which high school technology teachers are teaching engineering design, because the survey is not structured in a way that resembles their core areas: Math, Physical Science, Biology, Chemistry, Physics, or Earth Science.

Putting myself in the position of a high school teacher and trying to answer this survey is rather difficult. The survey forces the respondents to think like engineers and they are not engineers, they are high school math (algebra, calculus, and geometry), science, biology, or physics teachers. JKP

The word model should be plural. Experimentation is misspelled. I like these questions better than the previous section because they seem to be related to the academic standards.

I believe the responses to these questions will be all over the board, because of the diverse subject matter and experience level of the "technology" teachers. I recommend that you find an Education department and use teachers/graduate students to correlate these questions to the Core Area Standards.

I have to stop here because either I am missing something, or this questionnaire is too long and confusing. The better questions could be based on HOW the "technology" teachers teach the required content and assess the applicable indicators.

Total Years in Engineering: 20
Total Years in Engineering Education: 6
Engineering Domain: Civil and Environmental Engineering

Appendix B

PILOT STUDY ITEM ANALYSIS

Pilot Study Individual Item Analysis Results for Problematic Items

Item in question	Skewed -ness	Kurtosis	Corrected item-total correlation	Chronbach Alpha for category	Chronbach Alpha if item deleted
apply basic power and energy concepts	.213	-2.444	-.130	.929	.932
	.535	-.598	-.329		.939
apply research to designing products, processes, and materials	1.081	1.206	.551	.929	.927
	-.610	-.239	.309		.929
develop skills to use, manage, and assess technology	-.448	-.291	.056	.929	.932
	-.594	-1.78	.067		.934
demonstrate the ability to handle open-ended/ill-defined problems	-.442	-.688	.324	.929	.931
	-.781	-.660	.219		.932
communicate design ideas orally, through presentations, and graphics	1.418	1.418	.210	.907	.910
	-1.510	1.672	-.119		.916
communicate through writing technical reports	.448	-.789	.501	.907	.904
	-.594	-.546	-.005		.913
understand scale and proportion in design	-.586	-.795	.604	.907	.902
	-.864	-.155	.670		.901
understand basic personal computer operations	-.856	-.260	.332	.907	.907
	-.750	-.810	.192		.911

Note: Items in bold were removed from final instrument

Individual Item Analysis Results Problematic Items (continued)

Item in question	Skewed-ness	Kurtosis	Corrected item-total correlation	α for category	α if item deleted
use basic computer applications such as word processor, spreadsheets, presentation software	-.344	-.054	.332	.907	.907
	-.932	.081	-.140		.918
think critically	.190	-1.485	.420	.875	.875
	-.206	-.919	.341		.881
understand how engineers put ethics into practice	-.155	-1.225	.821	.907	.894
	.676	.951	.044		.922
work effectively on a team	-.630	-.886	.895	.907	.889
	-.136	.270	.078		.918
take human values and limitations into account when designing and solving problems	-.213	-.984	.711	.907	.896
	-.630	-.136	.206		.914
implements experimentation to design products, processes, and materials	-.641	-.444	.632	.907	.954
	-.875	-.533	.431		.958
Develop a prototype model of final design solution	-.899	-1.704	.746	.933	.926
	.303	3.902	.238		.938
locate appropriate textbooks to teach engineering design	-1.414	1.781	.424	.944	.948

Note: Items in bold were removed from final instrument

Appendix C

COVER LETTERS

Dear Engineering Education Faculty Member 9/10/07

I am a graduate student at the University of Georgia and a Fellow with the NSF's National Center for Engineering and Technology Education studying the infusion of engineering design in high school technology education programs. A faculty member in engineering education at UGA suggested I contact you, as an expert in engineering education, to request your assistance in the content validation of the instrument for this study.

If you agree to participate in this content validation, you and other panel members will be asked to independently review the on-line survey and provide your perspective on the appropriateness of the instrument items and ensure that I have accurately represented the construct of engineering design for secondary education. This process should only take about thirty minutes.

Please reply to this e-mail message if you are willing to assist me in this content validation process. Thank you very much for your time.

With warm regards,

Todd Kelley
Doctoral Candidate
University of Georgia
National Center for Engineering and Technology Education
(706)542-7059
kelley30@uga.edu

Pilot Study Solicitation Letter

To: High School Technology Educators September 15, 2007
From: Todd Kelley

Reference: Examination of Curriculum Content and Assessment Practices of Secondary Technology Education

I need your valuable insight. I am conducting research to determine the instructional practices of an engineering focus for the field of technology education. The Examination of Engineering Design in Curriculum Content and Assessment Practices of Secondary Technology Education Survey is available at the following link:

http://www.hostedsurvey.com/takesurvey.asp?c=720072_01

Please take a few minutes to complete the on-line survey and submit it no later than October 18th, 2007. Please read all the directions carefully prior to completing the survey instrument. Regardless of whether you are currently teaching engineering design topics, your insight is needed. Copy and paste the above URL into your internet browser (Internet Explorer works best).

Your honest and professional responses are needed so that an accurate analysis can be accomplished. Your participation will involve completing an on-line survey and should take no more than 30 minutes. Your involvement in the study is voluntary, and you may choose not to participate or to stop at any time. Be assured that your responses will be held in strict confidence; only group results of this research will be reported. The results of the research study may be published, but your name will not be used.. In fact, the published results will be presented in summary form only. Your identity will not be associated with your responses in any published format.

The findings from this project may help inform the field of technology education, practioners and the community on the current teaching practices associated with an engineering design focus for technology education. The results of the study are important to the field of technology education and will provide invaluable insight into the improvement of technology education. There are no known risks or discomforts associated with this research.

Please note that Internet communications are insecure and there is a limit of confidentiality that can be guaranteed due to the technology itself. However, once we receive the completed surveys, we will store them in a locked cabinet in my office and will destroy any names and contact information that we have by December 31st, 2007. If you are not comfortable with the level of confidentiality provided by the Internet, please feel free to print out a copy of the survey, fill it out by hand, and mail it to me: 224 Rivers Crossing, Athens, GA 30602 with no return on the envelope.

Pilot Study Solicitation Letter (Continued)

If you have any questions about this research project, please feel free to call me Mr. Todd Kelley at (706) 542-7059 or send an e-mail to kelley30@uga.edu. Questions or concerns about your rights as a research participant should be directed to The Chairperson, University of Georgia Institutional Review Board, 612 Boyd GSRC, Athens, Georgia 30602-7411; telephone (706) 542-3199; email address irb@uga.edu.

Thank you in advance for your prompt return of the survey. Be assured that your input is providing a valuable service to the profession of technology education as well as overall efforts in educational reform. We will be pleased to send you a summary of the survey results if you desire. By completing and returning this survey, you are agreeing to participate in the above described research project. Please keep this letter for your records. Upon successful submission of your survey, you will be eligible for a $50.00 stipend when the study is completed on or before October 22, 2007. Thank you for your cooperation.

Sincerely,

Mr. Todd Kelley

To: High School Technology Educators October 29, 2007
From: Todd Kelley
Reference: Examination Curriculum Content and Assessment Practices

I need your valuable insight. I am conducting research to determine the instructional practices of an engineering focus for the field of technology education.

Your honest and professional responses are needed so that an accurate analysis can be accomplished. Your participation will involve completing an on-line survey and should take no more than 30 minutes. Your involvement in the study is voluntary, and you may choose not to participate or to stop at any time without penalty or loss of benefits. Be assured that your responses will be held in strict confidence; only group results of this research will be reported. The results of the research study may be published, but your name will not be used. In fact, the published results will be presented in summary form only. Your identity will not be associated with your responses in any published format.

The findings from this project may help inform the field of technology education, practioners and the community on the current teaching practices associated with an engineering design focus for technology education. The results of the study are important to the field of technology education and will provide invaluable insight into the improvement of technology education. There are no known risks or discomforts associated with this research.

Please note that Internet communications are insecure and there is a limit of confidentiality that can be guaranteed due to the technology itself. However, once we receive the completed surveys, we will store them in a locked cabinet in my office and will destroy any names and contact information that we have by December 31st, 2007. If you are not comfortable with the level of confidentiality provided by the Internet, please feel free to print out a copy of the survey, fill it out by hand, and mail it to me at the address on the survey, with no return on the envelope.

If you have any questions about this research project, please feel free to call me Mr. Todd Kelley at (706) 542-7059 or send an e-mail to kelley30@uga.edu. Questions or concerns about your rights as a research participant should be directed to The Chairperson, University of Georgia Institutional Review Board, 612 Boyd GSRC, Athens, Georgia 30602-7411; telephone (706) 542-3199; email address irb@uga.edu.

Thank you in advance for your prompt return of the survey. Be assured that your input is providing a valuable service to the profession of technology education as well as overall efforts in educational reform. We will be pleased to send you a summary of the survey results if you desire. By completing and returning this survey, you are agreeing to participate in the above described research project. Please keep this letter for your records. Upon successful submission of your survey, you will be eligible for one (1) of ten (10) $100 gift cards drawn randomly when the study is completed in November 2007. You will be notified if you are a lucky winner. Thank you for your cooperation.

Sincerely,
Mr. Todd Kelley
Todd R. Kelley
NCETE Fellow
224 Rivers Crossing
College Station Rd.
University of Georgia
30602
(706) 542-7059

Appendix D

IRB APPROVAL

The University of Georgia

Office of The Vice President for Research
DHHS Assurance ID No. : FWA00003901

Institutional Review Board
Human Subjects Office
612 Boyd GSRC
Athens, Georgia 30602-7411
(706) 542-3199
Fax: (706) 542-3360
www.ovpr.uga.edu/hso

APPROVAL FORM

Date Proposal Received: 2007-07-31 **Project Number:** 2008-10057-0

Name	Title	Dept/Phone	Address	Email
Mr. Todd Kelley	PI	Workforce Educations 224 River's Crossing +2639 706-542-7059		kelley30@uga.edu
Dr. Robert C. Wicklein	CO	Workforce Leadership and Social Foundations 223 Rivers Crossing +2639 706-542-4503		wickone@uga.edu

Title of Study: Practices of Technology Education Teachers Teaching Engineering Design

45 CFR 46 Category: Administrative 2
Parameters:
Informed consent documented via Informational Cover Letter.

Change(s) Required for Approval:
Revised Application;
Revised Consent Document(s);

Approved : 2007-09-04 **Begin date : 2007-09-04** **Expiration date : 2012-09-03**

NOTE: Any research conducted before the approval date or after the end data collection date shown above is not covered by IRB approval, and cannot be retroactively approved.

Number Assigned by Sponsored Programs: **Funding Agency:**

Your human subjects study has been approved.

Please be aware that it is your responsibility to inform the IRB:
. . . of any adverse events or unanticipated risks to the subjects or others within 24 to 72 hours;
. . . of any significant changes or additions to your study and obtain approval of them before they are put into effect;
. . . that you need to extend the approval period beyond the expiration date shown above;
. . . that you have completed your data collection as approved, within the approval period shown above, so that your file may be closed.

For additional information regarding your responsibilities as an investigtor refer to the IRB Guidelines.
Use the attached Researcher Request Form for requesting renewals, changes, or closures.
Keep this original approval form for your records.

Chairperson or Designee,
Institutional Review Board

Appendix E

PERMISSION LETTER

International Technology
Education Association
1914 Association Drive, Suite 201
Reston, VA 20191-1539
703-860-2100 Fax 703-860-0353

August 8, 2007

Todd Kelley
110 Timberwood Ct.
Athens, GA 30601

Dear Todd,

ITEA is happy to help you with your dissertation questionnaire entitled, *Practices of Technology Education Teachers Teaching Engineering Design*. To that end, we agree to deploy your e-message cover letter containing the questionnaire weblink to ITEA members that teach high school technology education in the U.S.

Sincerely,

Lari L. Price
Coordinator of Member Services

Appendix F

INSTRUMENT

Examination of Engineering Design in Curriculum Content and Assessment Practices in Secondary Technology Education

This survey is being used to determine your teaching and assessment practices as they relate to teaching engineering design in high school technology education. Please complete all items on this survey until you reach the final thank you page, indicating you have completed the survey. Please complete the survey by **November 30, 2007**. 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 of the survey; completion of the survey by the due date makes you eligible for a random drawing for **one (1) of TEN (10) $100 GIFT CARDS**. The survey contained 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 your pop-up blocker so an additional web browser window can display the table for your reference throughout the survey. The on-line questionnaire displays best on Internet Explorer.

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

Todd Kelley
kelley30@uga.edu
(706) 542-7059

PREVIEW / TEST MODE

Your Responses Will Not Be Permanently Saved.

Contact your survey administrator if you were directed to this INACTIVE version of the survey.

Begin Survey

If you are resuming this survey, please enter your return code here:

Examination of Engineering Design in Curriculum Content and Assessment Practices in Secondary Technology Education

What best describes your high school day schedule?

- ◯ Traditional Schedule (meets daily 5 days a week)
- ◯ Block Schedule (AB Block or 4X4 Block)

Engineering Design

The following items consists 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 provided for your reference to define the Likert scale based upon your school schedule (Traditional or Block). Please note these units are approximations, select the number that best reflects your instructional practices.

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.

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

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 design 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 good and bad design	○	○	○	○	○	○	○	○	○	○	○	○
believe in his/her ability to design a solution to a technological problem	○	○	○	○	○	○	○	○	○	○	○	○

Engineering Analysis

The following items consists 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 provided for your reference to define the Likert scale based upon your school 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 solutions	○	○	○	○	○	○	○	○	○	○	○	○
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	○	○	○	○	○	○	○	○	○	○	○	○

Application Of Engineering Design

The following items consists 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 provided for your reference to define the Likert scale based upon your school 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 be 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, produce, and test prototypes	○	○	○	○	○	○	○	○	○	○	○	○
	0	1	2	3	4	5	0	1	2	3	4	5
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	○	○	○	○	○	○	○	○	○	○	○	○

Engineering Communication

The following items consists 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 provided for your reference to define the Likert scale based upon your school 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	○	○	○	○	○	○	○	○	○	○	○	○
	0	1	2	3	4	5	0	1	2	3	4	5
apply the rules of dimensioning	○	○	○	○	○	○	○	○	○	○	○	○
apply rules of manufacturing tolerance	○	○	○	○	○	○	○	○	○	○	○	○

use basic computer applications such as word processors,

	Frequency of Use						Time Per Typical Use					
	0	1	2	3	4	5	0	1	2	3	4	5
spreadsheets, and presentation software	○	○	○	○	○	○	○	○	○	○	○	○

Design Thinking as it Relates to Engineering Design

The following items consists 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 provided for your reference to define the Likert scale based upon your school 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 innovative concept generation	○	○	○	○	○	○	○	○	○	○	○	○
have the ability to approach open-ended/ ill defined problems	○	○	○	○	○	○	○	○	○	○	○	○

Engineering and Human Values

The following items consists of student learning outcomes. Please carefully read each outcome as they relate to ENGINEERING AND HUMAN FACTORS of engineering design. Please respond to the choice that best reflects your teaching practice as it relates to frequency (column 1). The table provided for your reference to define the Likert scale based upon your school 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 consequences of design failures	○	○	○	○	○	○	○	○	○	○	○	○
take human values and limitations into account when designing and solving problems	○	○	○	○	○	○	○	○	○	○	○	○
apply knowledge of basic erogonomics to engineering design process	○	○	○	○	○	○	○	○	○	○	○	○

Engineering Science

The following items consists of student learning outcomes. Please carefully read each outcome as they relate to APPLICATION OF ENGINEERING SCIENCE in 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 provided for your reference to define the Likert scale based upon your school 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	○	○	○	○	○	○	○	○	○	○	○	○

	0	1	2	3	4	5	0	1	2	3	4	5
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	○	○	○	○	○	○	○	○	○	○	○	○

Assessment Practices for Evaluating Engineering Design Activities

The following items consists of student learning outcomes as they related to ASSESSMENT practices for evaluating engineering design activities. Please carefully read each outcome and respond to the choice that best reflects your assessment practices as it relates to frequency (column 1) and time per typical use (column 2). The table provided for your reference to define the Likert scale based upon your school 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.												

	0	1	2	3	4	5	0	1	2	3	4	5
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 team worked as a functional inter-disciplinary unit												

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.

	Never	Rarely	Sometimes	Very Often	Always
Integrating the appropriate levels of math and science into instructional content					
locating and learning the approriate 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 labortory equipment to teach engineering design					

	Never	Rarely	Sometimes	Very Often	Always
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	○	○	○	○	○

	Never	Rarely	Sometimes	Very Often	Always
obtaining support from school adminstration and school counselors	○	○	○	○	○
obtaining support to promote engineering design course by school adminstration	○	○	○	○	○
obtaining community support to implement engineering design courses	○	○	○	○	○
obtaing parent support to implement engineering design course	○	○	○	○	○

Do you experience other challenges when you seek to implement technology education curriculum changes? If so, please explain:

General Demographics

Check or complete the appropriate demographic criteria below

	Middle/High school teacher	High school teacher	Other
Which best describes your current position	○	○	○

Years of experiences as a technology education teacher as of the start of the 2007-2008 school year

Gender

Age at last birthday

Highest College Degree attained (Check only highest)

- ☐ B.S./B.A.
- ☐ Masters
- ☐ EdS-Specialist
- ☐ EdD
- ☐ PhD

School Setting

- ○ Rural (less than 40 persons per square mile or 40 or more acres per housing 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)

What best describes your school size?

- ○ Small (less than 500 students)
- ○ Medium (500 -1500) students
- ○ Large (greater than 1500 students)

Please provide your e-mail address where you can be contacted if you are a lucky winner of a $100 gift card.

PREVIEW / TEST MODE

Your Responses Will Not Be Permanently Saved.

Contact your survey administrator if you were directed to this INACTIVE version of the survey.

Submit

Finish Later

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Appendix G

RESULTS INCLUDING MEAN, MEDIAN, MODE, AND STANDARD DEVIATION

Table G1. Engineering Design Frequency of Use

Engineering Design Content	*M*	*Mdn*	Mode	SD
understand engineering design is an iterative process	3.03	3	3	1.21
understand creativity is an important characteristic for engineers to apply in design	3.33	3	3	1.21
recognize that there are many approaches to design and not just one design process	3.26	3	4	1.32
recognize engineering as a potential career option	3.05	3	3	1.31
are able to identify good and bad design	2.96	3	3	1.19
believe in his/her ability to design a solution to a technological problem	3.27	3	4	1.19
Total Group Mean	3.15			

Table G2. Engineering Design Time Per Typical Use

Engineering Design Content	*M*	*Mdn*	Mode	SD
understand engineering design is an iterative process	2.27	2	1	1.20
understand creativity is an important characteristic for engineers to apply in design	2.51	2	1	1.34
recognize that there are many approaches to design and not just one design process	2.42	2	2	1.28
recognize engineering as a potential career option	2.12	2	1	1.22
are able to identify good and bad design	2.40	2	2	1.16
believe in his/her ability to design a solution to a technological problem	2.58	3	1	1.31
Total Group Mean	2.38			

Table G3. Engineering Analysis Frequency of Use

Engineering Analysis Content	*M*	*Mdn*	Mode	SD
understand that knowledge of science and mathematics is critical to engineering	3.44	3	3	1.20
apply engineering science principles when designing solutions	3.15	3	4	1.25
use measuring equipment to gather data for troubleshooting, experimentation, and analysis	3.09	3	4	1.25
use physical and/or mathematical models to estimate the probability of events	2.12	2	2	1.42
use optimization techniques to determine optimum solutions to problems	2.09	2	2	1.41
use models or simulations to study processes	2.82	3	2	1.40
Total Group Mean	2.79			

Table G4. Engineering Analysis Time Per Typical Use

Engineering Analysis Content	*M*	*Mdn*	Mode	SD
understand that knowledge of science and mathematics is critical to engineering	2.61	3	2	1.25
apply engineering science principles when designing solutions	2.59	2	2	1.29
use measuring equipment to gather data for troubleshooting, experimentation, and analysis	2.69	3	2	1.26
use physical and/or mathematical models to estimate the probability of events	1.93	2	1	1.35
use optimization techniques to determine optimum solutions to problems	1.82	2	1	1.38
use models or simulations to study processes	2.58	3	3	1.40
Total Group Mean	2.37			

Table G5. Application of Engineering Design Frequency of Use

Application of Engineering Design Content	M	*Mdn*	Mode	SD
apply knowledge for manufacturing products to the engineering design	2.62	3	3	1.22
identify problems that could be solved through engineering design	2.82	3	3	1.23
understand no perfect design solution exists	2.91	3	2	1.41
conduct reverse engineering to analyze product design	2.02	2	2	1.34
organize and manage design process for optimal use of materials, processes, time, and expertise	2.50	2	2	1.33
design, produce, and test prototypes	2.89	3	2	1.34
apply research to designing products, processes, and materials	2.65	3	3	1.24
develop skills to use, manage, and assess technology	2.94	3	2	1.29
demonstrate the ability to handle open-ended/ ill-defined problems	2.79	3	4	1.30
develop basic students' skills in the use of tools	3.46	4	4	1.26
understand design often requires tradeoffs	2.86	3	3	1.24
Total Group Mean	2.77			

Table G6. Application of Engineering Design Time Per Typical Use

Application of Engineering Design Content	*M*	*Mdn*	Mode	SD
apply knowledge for manufacturing products to the engineering design	2.39	2	1	1.28
identify problems that could be solved through engineering design	2.48	2	2	1.24
understand no perfect design solution exists	2.24	2	1	1.31
conduct reverse engineering to analyze product design	2.26	2	1	1.51
organize and manage design process for optimal use of materials, processes, time, and expertise	2.39	2	1	1.34
design, produce, and test prototypes	3.15	3	4	1.39
apply research to designing products, processes, and materials	2.62	3	2	1.32
develop skills to use, manage, and assess technology	2.65	3	2	1.31
demonstrate the ability to handle open-ended/ ill-defined problems	2.50	2	1	1.33
develop basic students' skills in the use of tools	3.32	3	4	1.34
understand design often requires tradeoffs	2.44	2	2	1.25
Total Group Mean	2.59			

Table G 7. Engineering Communication Frequency of Use

Engineering Communication Content	*M*	*Mdn*	Mode	SD
communicate design ideas orally, through presentations, and graphics	2.96	3	2	1.35
communicate through writing technical reports	2.03	2	2	1.29
use technical drawings to construct or implement an object , structure, or process	3.34	4	4	1.26
visualize in three dimensions	3.26	3	4	1.31
develop and maintain an engineering design portfolio	2.54	3	5	1.87
use computer-aided design to construct technical drawings	3.39	4	5	1.52
apply the rules of dimensioning	3.09	3	3	1.49
apply rules of manufacturing tolerance	2.10	2	1	1.35
use basic computer applications such as word processors, spreadsheets, and presentation software	3.27	3	4	1.39
Total Group Mean	2.89			

Table G 8. Engineering Communication Time Per Typical Use

Engineering Communication Content	*M*	*Mdn*	Mode	SD
communicate design ideas orally, through presentations, and graphics	2.94	3	3	1.29
communicate through writing technical reports	2.25	2	2	1.39
use technical drawings to construct or implement an object , structure, or process	3.30	3	3	1.25
visualize in three dimensions	3.19	3	3	1.32
develop and maintain an engineering design portfolio	2.07	2	1	1.71
use computer-aided design to construct technical drawings	3.35	4	5	1.49
apply the rules of dimensioning	2.98	3	3	1.51
apply rules of manufacturing tolerance	2.00	2	1	1.37
use basic computer applications such as word processors, spreadsheets, and presentation software	3.15	3	4	1.36
Total Group Mean	2.80			

Table G10. Design Thinking Related to Engineering Design Frequency of Use

Design Thinking Related to Engineering Design Content	*M*	*Mdn*	Mode	SD
think critically	3.65	4	4	1.10
synthesizes simple parts into complex systems	2.73	3	3	1.25
apply SYSTEMS THINKING- understanding and considering the multiple facets of a design solution result in positive and negative impacts	2.58	3	3	1.42
apply brainstorming and innovative concept generation	3.24	3	3	1.20
have the ability to approach open-ended/ ill defined problems	2.80	3	3	1.41
Total Group Mean	3.00			

Table G11. Design Thinking Related to Engineering Design Time Per Typical Use

Design Thinking Related to Engineering Design Content	*M*	*Mdn*	Mode	SD
think critically	3.15	3	3	1.22
synthesizes simple parts into complex systems	2.61	3	2	1.29
apply SYSTEMS THINKING- understanding and considering the multiple facets of a design solution result in positive and negative impacts	2.34	2	3	1.34
apply brainstorming and innovative concept generation	2.98	3	3	1.30
have the ability to approach open-ended/ ill defined problems	2.62	3	2	1.44
Total Group Mean	2.74			

Table G 12. Engineering and Human Values Frequency of Use

Engineering and Human Values Content	*M*	*Mdn*	Mode	SD
understand how engineers put ethics into practice	1.75	2	2	1.23
are aware of social, economical, and environmental impacts on design solutions	2.31	2	2	1.24
understand that the solution to one problem may create other problems	2.47	2	2	1.28
consider cost, safety, appearance, and consequences of design failures	2.47	2	2	1.34
take human values and limitations into account when designing and solving problems	2.27	2	2	1.33
apply knowledge of basic ergonomics to engineering design process	2.04	2	1	1.32
Total Group Mean	2.22			

Table G13. Engineering and Human Values Time Per Typical Use

Engineering and Human Values Content	*M*	*Mdn*	Mode	SD
understand how engineers put ethics into practice	1.76	2	1	1.32
are aware of social, economical, and environmental impacts on design solutions	2.21	2	2	1.24
understand that the solution to one problem may create other problems	2.23	2	2	1.30
consider cost, safety, appearance, and consequences of design failures	2.25	2	2	1.33
take human values and limitations into account when designing and solving problems	2.07	2	2	1.31
apply knowledge of basic ergonomics to engineering design process	1.95	2	1	1.35
Total Group Mean	2.08			

Table G14. Engineering Science Frequency of Use

Engineering Science Content	*M*	*Mdn*	Mode	SD
apply math and science to the engineering design process	3.15	3	3	1.26
apply knowledge of basic mechanics to the engineering process	2.88	3	3	1.33
apply knowledge of basic statics and strengths of materials to engineering design process	2.02	2	2	1.28
apply knowledge of dynamics to the engineering design process	1.81	2	1	1.40
use of algebra to solve problems or predict results to design solutions	2.19	2	1	1.47
use geometry to solve problems or predict results to design solutions	2.60	3	3	1.35
use trigonometry to solve problems or predict results to design solutions	1.65	1	1	1.37
apply knowledge of material process to engineering design process	2.37	2	2	1.35
Total Group Mean	2.33			

Table G15. Engineering Science Time per Typical Use

Engineering Science Content	*M*	*Mdn*	Mode	SD
apply math and science to the engineering design process	2.84	3	3	1.24
apply knowledge of basic mechanics to the engineering process	2.69	3	3	1.29
apply knowledge of basic statics and strengths of materials to engineering design process	1.98	2	1	1.32
apply knowledge of dynamics to the engineering design process	1.76	2	1	1.39
use of algebra to solve problems or predict results to design solutions	1.98	2	2	1.35
use geometry to solve problems or predict results to design solutions	2.30	2	2	1.32
use trigonometry to solve problems or predict results to design solutions	1.58	1	1	1.34
apply knowledge of material process to engineering design process	2.19	2	2	1.37
Total Group Mean	2.16			

*Table G16.*Teacher Challenges Infusing Engineering Design into Technology Education

Teacher Challenges	*M*	*Mdn*	Mode	SD
integrating the appropriate levels of math and science into instructional content	2.49	3	3	0.88
locating and learning the appropriate levels of math and science to teach engineering design	2.27	2	2	0.93
locating and learning knowledge of engineering fundamentals (statics, fluid mechanics, dynamics)	2.10	2	2	0.97
locating appropriate textbooks to teach engineering design	2.14	2	2	1.08
locating the appropriate laboratory equipment to teach engineering design	2.40	2	2	1.10
locating the appropriate laboratory layout and space to teach engineering design	2.18	2	3	1.17
acquiring funding to purchase tools and equipment to teach engineering design	2.31	2	3	1.23
acquiring funding to purchase materials to teach engineering design	2.25	2	2	1.21
networking with practicing engineers for consultation	2.04	2	2	1.15
obtaining support from math and science faculty	1.96	2	2	1.08
obtaining support from school administration and school counselors	2.11	2	2	1.16
obtaining support to promote engineering design course by school administration	1.94	2	2	1.22
obtaining community support to implement engineering design courses	1.73	2	2	1.09
obtaining parent support to implement engineering design course	1.73	2	2	1.08