

A Survey of National Engineering Education Initiative Leaders:

What Knowledge Do Students and Technology Education

Teachers Need To Be Successful In An Engineering

Education Curriculum?

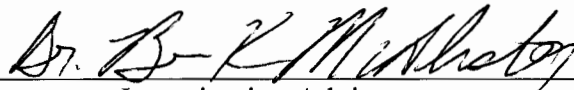
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A handwritten signature in black ink, appearing to read "Dr. B. K. McIntosh", is written over a horizontal line.

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# ABSTRACT

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A Study Of National Engineering Education Leaders: What Knowledge Do Students And Teachers Need To Be Successful In An Engineering Education Curriculum?			
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The purpose of the study was to determine the courses that students need to be successful in high school engineering classes and the knowledge teachers should have in order to properly teach a high school engineering education curriculum. Research was conducted through a survey instrument distributed to leaders of several engineering education curriculum initiatives and engineering education outreach programs.

The findings of this study indicate that leaders of engineering curriculum projects and outreach programs suggest:

- High school students' background in math should follow a path from general math to algebra to advanced algebra to trigonometry to pre-calculus.
- High school students' preparation in science should include physical science and physics.

- Technology education teachers' background in math should include college algebra, along with trigonometry and analytical geometry, and two levels of calculus.
- Technology education teachers' preparation in science should include general physics, college physics, and chemistry.
- Technology education teachers' training in technology/engineering design should consist of engineering design, general engineering design, electricity/electronics, and materials and processes.

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## Chapter I – Introduction

### Background to the Problem

Technology education is a subject that is stamped by change (Adamson & Gloeckner, 1996). The change has been evidenced by the previous names of the subject: manual arts, manual training, industrial arts, industrial education, and technology education. There is a current movement in the United States to infuse technology education curriculum with engineering. Several universities and independent foundations have developed engineering curriculum that has been implemented by schools throughout the United States. Recently, the Wisconsin Department of Public Instruction (DPI) changed the name of its technology education division to engineering and technology education. As the nation progresses into the 21<sup>st</sup> century, industry leaders, educational experts, and frustrated students agree that America is simply not doing enough to instruct and inspire the next generation of scientists and engineers (Haden, 2004). Some technology education, science, and math departments within schools have already taken the initiative and have included engineering education in their curriculum.

Engineering education has been introduced to K-12 education through several outreach projects supported by leading universities and programs established by business and industry, which needs well-educated engineers. Engineering schools representing colleges and universities such as the University of Washington, the University of Colorado, Michigan Tech University, and The Ohio State University send graduate and undergraduate students to work with teachers and students in nearby schools. This follows recommendations by the Glenn Commission on Mathematics and Science Teaching for the 21<sup>st</sup> Century. In its report published in the fall of 2000, Before It's Too

Late, the commission advised colleges and universities to work with local school districts to establish a system of recruiting and advising those who are interested in becoming teachers. (Sanoff, 2001) The objective of these students placed into the schools is two-fold: to excite students about math and science, which may spark their interest in engineering as a career, and provide teachers with knowledge about engineering, so they can inform students accurately about engineering as a career. Several universities also sponsor summer and weekend workshops for teachers to gain experience in engineering education. Schools such as the University of Wisconsin, Tufts University in Massachusetts, Carnegie Mellon University in Pennsylvania, and Stanford University invite K-12 educators onto their campuses to learn about engineering. The faculty at these colleges and universities work with the K-12 instructors to teach them about various fields within engineering and what they do. K-12 instructors also have the opportunity to learn through hands-on experiences and can take these ideas back to their classrooms and enlighten students about engineering.

Project Lead the Way was started in the 1980's when faculty at Rensselaer Polytechnic Institute (RPI) in New York aided a teacher at a nearby high school in developing technology-based courses. It was further developed into a national program in 1997. With the help of corporate funding, Project Lead the Way was able to establish a pre-engineering curriculum with courses in Introduction to Engineering, Digital Electronics, Computer Integrated Manufacturing, Principles of Engineering and Engineering Design and Development. Instructors are able to receive training in the curriculum and receive the curriculum materials, student resources, with mentoring and feedback upon its implementation. Schools involved in the project do need to have the

technology to begin implementation as well as the budget to maintain it. According to a pamphlet published by Project Lead the Way, its mission “is to create dynamic partnerships with our nation’s schools to prepare an increasing and more diverse group of students to be successful in engineering and engineering technology programs.” (Project Lead the Way [PLTW], 2004) Other programs offered to schools include Adventure Engineering, which was launched in 1999 with the support of the National Science Foundation. Adventure Engineering is a curriculum that combines math and science towards engineering that looks to stimulate student interest in those subjects as well as to provide hands-on experiences that apply what they have learned. Recently, the Infinity Project was started in Texas and has started to spread across the country. Backed by grants from business and industry and Southern Methodist University, the Infinity Project provides a curriculum kit developed by engineering faculty that can be implemented with a limited amount of background and training. These programs and initiatives show that business and industry and universities are willing to help K-12 education.

Completing an engineering experience means that the student has a knowledge of math and science that allows them to calculate forces, ratios, etc, when working on a design or solution. However, the levels of achievement and interest in math and science among our nation’s students lag behind other industrialized nations. As a result, business and industry are bemoaning the fact that there are not enough engineers prepared to meet the needs of society. With programs such as Project Lead the Way, Adventure Engineering, and the Infinity Project, business and industry has begun to channel their resources toward engineering education. As previously discussed, a number of colleges and universities, through outreach programs and workshops, have also made strides in

emphasizing engineering, math and science. What knowledge do students need to have to succeed in engineering education courses? What will it take for technology education teachers to provide instruction in engineering education?

### Statement of the Problem

A number of projects have been designed to infuse technology education curriculum with engineering content. Business and industry have stated their demand for engineers that are prepared to work with advancing technology. Corporations have put their funds into these engineering curriculum projects to show their support. Colleges and universities have offered outreach programs and workshops. They deliver curriculum to teachers, which they can use to instruct their students. While these initiatives may exist, little research has been done to determine if technology education teachers are adequately prepared to teach engineering curriculum. More importantly, consensus has not been reached regarding what level of math, science, and engineering design that students and technology education teachers should have in order to either participate or instruct students in an engineering curriculum.

The purpose of the study was two-fold. What classes should students be taking in order to be successful in engineering education courses? Second, what knowledge should technology education instructors have to instruct students in engineering curriculum? In order to find more answers regarding the levels of knowledge students and teachers should have, research was completed with the thoughts of those involved in engineering, math and science on the career and collegiate levels. Further research was accomplished by surveying the leaders of the engineering curriculum initiatives and teacher workshops

across the nation. These surveys were completed to gain insight into the following questions.

#### Research Questions

- 1) What minimum levels of math preparation should students have to participate in high school engineering curriculum?
- 2) What minimum levels of science preparation should students have to participate in high school engineering curriculum?
- 3) What minimum levels of math preparation should technology education teachers have to instruct students in an engineering curriculum?
- 4) What minimum levels of science preparation should technology education teachers have to instruct students in an engineering curriculum?
- 5) What minimum levels of engineering design preparation should technology education teachers have to instruct students in an engineering curriculum?

## Chapter II – Review of Literature

### History of Technology Education

The educational field currently known as technology education has been characterized by several shifts in philosophy. These changes have often been related to advances in our society. As Americans have moved from an agrarian-based economy to an industrial/commercial economy, technology education has progressed as well. These changes have taken place over several hundred years, tracing all the way back to ancient Greeks and Egyptians.

In ancient civilizations, apprenticeship was the most common form of education. Ideas were passed along from father to son or from employer to worker. Apprenticeship became the primary educational institution available to youths of the working class (Martin & Luetkemeyer, 1979). During the Renaissance, educational programs were the focus of reform. Amos Comenius advocated “methods of the arts” and he desired students to “learn by acquaintance” with actual objects (Cochran, 1970). Johann Pestalozzi furthered these ideas and desired to improve the plight of the poor. He taught the use of hand tools with the use of natural objects and models. Called “the father of manual training,” Pestalozzi used the models as aids in instruction when he was unable to have children gain firsthand experience working in fields or workshops (Hostetter, 1974).

### Instruction through Manual Training

Manual training was an early sign of the industrial education movement. Two systems for teaching manual training were the choice of most educators, the Russian System and the Sloyd System. The Russian System, developed by Victor Della Vos,

taught engineering students the necessary tool skills for their occupations. The Russian System was a two-step sequence: the analysis of tools, processes, trades and materials into their elements and the arrangement of these elements into courses of instruction (Martin & Luetkemeyer, 1979). The students who learned in the Russian System would first complete exercises related to the tool skills. After completing the laboratory portion of their work, the students proceeded to work in construction shops connected to the school. Exhibited through a series of exercise pieces in wood and metal at the Philadelphia Centennial Exposition in 1876, it helped to spark the manual training movement in the United States (Phillips, 1985).

Also shown at the Centennial Exposition were elements of the Sloyd System, developed in Sweden. The Sloyd System was a modified version of the Russian System developed by educators such as Otto Salomon and Uno Cyznaeus, leaders in primary schools in Scandinavia. The changes made by Salomon and Cyznaeus emphasized manual dexterity rather than production of skills as a craftsman, to develop an individual's capacities and to provide an outlet for children to put their ideas into external form (Hostetter, 1974). The Sloyd System improved the objects made in the Russian System and produced useful projects. In providing something that students could actually use, the Sloyd System infused manual training into the education of school children. By 1900, the Sloyd System was in many U.S. schools and influenced the creation of specialty schools, such as the Sloyd Training School in Boston.

### The Manual Arts Movement

At about the same time that manual training was becoming a part of public school education, a movement to incorporate arts and crafts into manual training was on the rise.



Those behind the manual arts movement were concerned over a lack of aesthetics and correlated design instruction in manual training programs (Cochran, 1970). Leaders of the manual arts movement, including Charles Leland and J. Liberty Tadd, spread this idea through educational venues throughout the United States. It would be one of the early examples of cross-curricular instruction, combining shop work and art instruction. It would also mark one of many changes in the field.

### The Transformation to Industrial Arts

Into the 20<sup>th</sup> century, the nation moved from an agricultural-based economy towards one based on manufacturing and industry. Educational leaders believed that a course should be established in schools to reflect the change in society. From this came the idea of industrial arts education. James Russell, one of the leaders of the movement, believed an industrial arts course should deal with the stages of production, distribution and consumption of such raw materials as foods, metals, textiles, and woods (Cochran, 1970). These materials were at the center of production during the ongoing industrial boom and were transformed through means of manufacturing and production for human use. Part of the curriculum developed by Russell and Frederick Bonser also reflected the set-up of factories. The organization of school shops was changed from one activity experiences to those where students could participate in various activities with a wide array of tools, machines, and materials.

As the United States became involved in World War I, the need for skilled labor in manufacturing grew. This would be the impetus for teaching industrial arts in public schools, and the decline of manual arts. The manual training programs were not set in their future direction, while the federal government supported industrial arts in schools

and the vocational training it provided for students. The passage of the Smith-Hughes Act of 1917-18 provided for federal dollars to be used for instructors of subjects such as agriculture, home economics, and industrial arts (Martin & Luetkemeyer, 1979). This helped to establish industrial arts in schools, but the subject was not without problems.

Since manual training and manual arts schools were still in operation, many high schools followed the curriculum from these movements. Other school used industrial arts as its means of instruction. This diversity caused conflict across the nation as to what should be taught. The different programs in use also had different definitions and purposes, leading to confusion. Another problem was the attempt by the two groups representing the field to clarify its role and function in the schools (Martin & Luetkemeyer, 1979). These groups were the National Society for Vocational Education (NSVE) and the American Vocational Association (AVA). Each group published standards and guidelines for industrial education. However, in the years leading up to World War II, the term industrial arts was being used more and more frequently. The United States Bureau of Education published Industrial Arts: Its Interpretation in American Schools. Educational leaders formed the American Industrial Arts Association (AIAA), and in the ultimate sign of change in the field, the Manual Arts Conference published Industrial Arts in Modern Education. This not only signaled its establishment of educational standards, but also the realization that industrial arts had become the focus in educating students.

The momentum that the industrial arts movement had gained experienced a lull during World War II. Following the war, however, began an era of growth and development for industrial arts education (Martin & Luetkemeyer, 1979). Many leaders

in the field published their ideas relative to methods of its instruction. The most prominent of these was Industrial Arts in General Education, by Gordon O. Wilber. It was used as a text at many universities and provided what would be the widely accepted definition for industrial arts. Wilber believed industrial arts was the area of general education that deals with industry – from its organization, to the various processes, and ultimately its products – and the problems that arise from the industrial and technological nature of society. (Martin & Luetkemeyer, 1979). Another publication that was an important advancement in the industrial arts movement was developed by a group of graduate students, along with their instructor, William E. Warner, at Ohio State University. Their concept, A Curriculum to Reflect Technology, would establish the curriculum areas that would be used for years to come: communication, construction, power, transportation, and manufacturing. This would lead to Delmar Olson's publication, Technology and the Industrial Arts, which was written under the guidance of William E. Warner. In his writings, Olson recommended that the subject matter for industrial arts be derived from a study of technology as represented in industry (Miller & Smalley, 1963). To further reflect industry, Olson added more categories to Warner's classifications: electronics, research, services, and management. Olson also suggested an industrial arts curriculum that included laboratories to reflect each of the areas of technology, with research and experimentation as a part of the learning process. It not only reflected mass production within industry, but also foreshadowed the use of the modular method in today's technology education.

Changes would come about in the 1950's and 1960's. The United States and the Soviet Union were engaged in the Cold War. One of the first blows was struck by the

Soviets with the launch of Sputnik. Sputnik created an urgency and forum for leaders to discuss ways to improve industrial arts education (Welty, 1989). The first of the reforms was to integrate other curriculum, such as math and science, into industrial arts. Donald Maley of the University of Maryland was a leader in the effort, proposing student activities centered on investigation, exploration, analysis, testing and the use of tools and materials (Phillips, 1985). Another change came with the creation of the Industrial Arts Curriculum Project (IACP), developed at Ohio State University. The primary result of this curriculum was the courses it created: The World of Construction and the World of Manufacturing. Many schools adopted this curriculum for their industrial arts departments.

#### Preparing Students to be a Part of a Technological Society

Industrial arts, as a field of study, remained largely unchanged through the 1970's. As the decade came to a close, however, "technology" had become the buzzword (Welty, 1989). Certainly a subject called industrial arts did not reflect the latest instruction in technology, at least in the view of the general public. A change was needed as American society headed into a technology-driven era. In 1979, leaders in industrial arts curriculum met in Jackson's Mill, West Virginia. Two of their primary goals were to reform the curriculum to establish a way to structure the knowledge of technology (Wright, 1992) and to bring what had become a diverse curriculum together. Industrial arts educators had gone in several directions with their curriculum and lacked focus. One group could be characterized as the technology camp. Another group was the industry group, while another wished to be child-centered (Wright, 1992). What resulted from Jackson's Mill was a compromise. The curriculum that was written used the name

technology education. This was one of the first signals in a shift away from industrial arts. A second was the shift from a strictly manufacturing/construction core to one that also included communications and transportation. These fields would also be studied in a different manner. Rather than activity based, it would be based on the systems model. Each of these disciplines would be examined through inputs, processes, outputs, and feedback. The curriculum innovators believed that these reforms would result in a more comprehensive field of study and a better structure for educating students.

The 1980's were to be the time for the shift from industrial arts to technology education. Recommendations were in place to reform instruction to include more math and science, as well as a more comprehensive view of technology through the use of the systems model. Some elements of progress came about with various pieces of curriculum. Another step forward came with a simple name change. In 1984, the AIAA, being a leader in the industrial arts field, moved forward by becoming the International Technology Education Association (ITEA). It would take the ITEA, and states including Wisconsin several years to develop curriculum and instructional standards that fit the instruction of technology education. The first step that the ITEA took was its Technology for All Americans Project. Their intent was to improve the technological literacy of students. According to the ITEA web site ([www.iteaaww.org](http://www.iteaaww.org)), technological literacy is the ability to use, manage, assess, and understand technology (2003). The goal of instruction was for instructors to teach beyond the tools of technology and to apply the systems model for students to realize how these tools affected society as a whole. With the publication of Standards for Technological Literacy: Content for the Study of Technology in the year 2000, the ITEA established standards that would help instruct

students in technology with a comprehensive study rather than in career or vocational skills. “The standards were meant to ensure that technology education addresses what students should know and be able to do, rather than merely teaching them about technology” (Starkweather, 1996, pg. 7).

Wisconsin published its own set of standards in 1998. Wisconsin's Model Academic Standards for Technology Education was divided into four sections: Content Standards, Systems, Human Ingenuity, and Impacts. Much like the ITEA standards, they were meant to provide a broader view of the technology field for student study. The standards did not focus strictly on the machines and tools of technology, but on how they work and their contribution to advancements in society. The publication of standards signaled the effort to move forward. Many states and their instructors had not been able to agree on what to teach. As far back as can be reasonably traced, several versions of formal industrial and technological education have existed simultaneously, often in competition with each other (Foster & Wright, 1996). This resulted in a rift in the field that was difficult to overcome. Now that curriculum and standards had been established by many organizations, it should have brought the two groups together. However, it did not. How would teachers present this new technology education curriculum? Some teachers continued to instruct students as they had previously. Others moved toward a more student-centered approach and used the modular approach to technology education.

#### A Shift Towards Student-Centered Instruction

The modular approach to technology education was not a new idea. From manual training through industrial arts to the early era of technology education, it could be argued that a modular approach was used to instruct students. It was often impossible to

have an entire class of students work on the same lab activity. Some instructors would assign students to different activities within the shop or lab. Instructors would rotate their students through the different activities or responsibilities in order to allow students to learn a little about everything. Students could work on recoding an audio or video program, develop a plastic boat hull, or complete an electronic circuit, all within the same class or lab. The modular approach would gain a great deal of momentum in the early 1990's. With the modular approach, schools' technology education facilities also improved, either getting a makeover or having new facilities built. What would be used to instruct students in these facilities? With the change in facilities came a corresponding change in curriculum as schools adopted a modular approach to instruction (deGraw & Smallwood, 1997). School districts, making a financial commitment with the new facilities, took the next step and purchased modular technology labs.

Such companies as Hearlihy, Paxton Patterson, and Pitsco have developed the modular technology lab, consisting of computers, equipment, and instructional materials for student use, for purchasing schools. According to the Hearlihy web site ([www.hearlihy.org](http://www.hearlihy.org)), their modular technology lab is a teaching system that divides the classroom into multiple learning stations. Writers, editors, and production personnel, who work along with professional educators to develop the curriculum, compose the modules (2003). Paxton Patterson and Pitsco produce their modular technology labs in the same manner. The goal of the modular lab, according to Pitsco founder and CEO Harvey Dean, is "not to teach students to be technicians. We're trying to teach them to be problem solvers and work as a team" (Tress, 1998, p. 24). The "problem solvers" part of Dean's comment was an indicator of where technology education was headed.

Teacher-centered instruction was becoming less evident in favor of student-centered instruction.

The modular technology lab featured individualized instructional materials (IIMs) such as CD – ROM's, videotapes, readings and assessments. With the curriculum established by the companies, it was up to the students to follow the instructions and take more of a role in their learning. What were the impacts? Some were provided by Tsai (1994) in a study of technology education programs.

Tsai (1994) stated that teaching strategies and teacher's roles were changing with the move from industrial arts to technology education. The addition of modular technology labs to many schools across the United States helped to push this change. Tsai studied the impact of modular technology labs based on a number of variables, including teaching strategies, instructional media and types of lab activities. He found was that the changes in technology education were rapid and significant.

How teachers provided information to students showed a great deal of change. The primary characteristics of teacher-centered instruction, such as lecture, discussion and demonstration, were used less by teachers in Tsai's study. In addition, materials such as transparencies were used less often in favor of computer-aided instruction software (Tsai, 1994). These changes led to more of the curriculum in technology education to become student-centered. Teachers used more projects that required student inquiry and processes of problem solving (Tsai, 1994). With modular technology labs, technology education had taken a step towards giving students more responsibility and presenting interesting subject matter. However, with the curriculum provided by companies such as Hearlihy, Paxton Patterson and Pitsco, instruction could only go so far. Goals listed in



Tsai's (1994) study such as math and science concepts and skills, solving problems and analysis would need to be met by introducing new subject matter to technology education.

### History of Engineering Education

While the inclusion of engineering education as a part of a K-12 curriculum seems like a new idea, it really is not. In some way, shape or form, engineering education has been a part of educating our nation's students. However, its emphasis has been minimized. After World War II, the focus of engineering in public education was engineering science activities. The Grinter Report was published in 1955 to suggest the means for engineering education. One part was to emphasize engineering science for students who wished to move on to careers in research and development. The other part aimed for students who wanted to pursue engineering design activities within industry (Coe, Magelby, Red, & Todd, 2001). The idea of design, with the United States in the midst of the space race, was quickly pushed to the side. The best and brightest minds were used to provide research for new ideas, but yet not to apply those ideas. This is where the United States began to encounter problems.

### Addressing Shortages in the Engineering Field

While colleges in the U.S. were more concerned with research and publication of ideas, other industrialized nations, such as Japan, took their ideas one step further and applied them. With businesses and products lost to other nations, the nation's economy suffered. By the 1990's, an increasing amount of complaints came from industry about the lack of preparation of engineering graduates entering the workforce (Felder, 2004). The first step was taken by some of the nation's leading engineering colleges, who at the

request of industry, added programs in various engineering fields, such as manufacturing, mechanical and industrial, civil, and electrical. One problem remained. The demand for workers who were prepared to produce with ever-changing technologies outpaced the supply graduated by these schools. Engineering can be defined as the science and art of applying scientific and mathematical principles, experience, judgment and common sense to design things that benefit society ([www.engr.washington.edu/score/engineers.html](http://www.engr.washington.edu/score/engineers.html)).

According to the National Science Foundation, the nation's universities awarded 37 percent fewer degrees in computer science, 24 percent fewer in math, 16 percent fewer in engineering and two percent fewer in physical sciences in 1998 as compared to 1988 (Laubach, Mooney, & Nicholas, 2002). The problem was that fewer students were interested in these disciplines, and the trouble began long before students walked onto a university campus. According to Lester Rubinfeld, a math professor at Rensselaer Polytechnic Institute (RPI) in New York,

“We have thought a lot about how to really get kids interested in math and science and decided that you can't go in at the high school level. You have to go back further in time and get kids interested when they are about to lose interest, somewhere between the 4<sup>th</sup> and 7<sup>th</sup> grades.” (Sanoff, no page number listed)

Several entities went about sparking these students' interest and hopefully, revitalize engineering education in our nation's schools.

#### Curriculum Initiatives in Engineering Education

The re-entry of engineering education into the K-12 curriculum had its start in the 1980's. A teacher in the state of New York looked to nearby Rensselaer Polytechnic Institute for some assistance in establishing technology-oriented courses. Their efforts led

to the development of Project Lead The Way (Sanoff, 2001). The program has now grown into a national effort. Project Lead the Way has established five courses, including introduction to engineering design, digital electronics, computer-integrated manufacturing, principles of engineering and engineering design and development. According to the program's website ([www.pltw.org](http://www.pltw.org)), over 1000 schools nationwide have been able to implement Project Lead the Way with the benefits of corporate grants through a foundation established by the project. Once a school is able to gather funding and support, training is provided by Project Lead the Way to instruct teachers in the curriculum. In addition, the project also offers mentors for students, career shadowing and college credits for qualifying students (Johnson, 2003). Project Lead the Way is just one of a number of efforts in bringing engineering education into public schools.

Adventure Engineering was developed in 1998 with funding from the National Science Foundation. In a joint effort, students from the University of Oklahoma and the Colorado School of Mines develop the curriculum that has been implemented in several schools in those respective states. The focus of the program is to improve middle school students' interest and learning in math, science and engineering leading to more hands-on engineering experiences (Laubach et. al., 2002). The curriculum is four weeks in length and takes students on various excursions. These adventures are filled with challenges that require students to use math and science concepts leading to the understanding of engineering design principles. The curriculum has been written in a manner that students need to use inquiry and problem solving in order to achieve success. Other means include the establishment of relationships between schools and nearby universities.

The Infinity Project was created in 1999 by several entities, including Texas Instruments, the U.S. Department of Education and the National Science Foundation. It is also one of several programs sponsored by The Institute for Engineering Education at Southern Methodist University, which was created to facilitate partnerships among universities, K-12 education and corporate entities to address the issues related to the shortfall in engineering and technical talent expected in the coming years. From its beginnings, the Infinity Project now is established in 58 schools in 14 states from Connecticut to Hawaii. Prerequisites for high school students taking the course include Algebra II (or its equivalent) and one science course. The yearlong curriculum uses math and science to guide students in creativity and design projects related to recently developed technologies such as cell phones and digital video.

#### University Outreach Programs in Engineering Education

In a Glenn Commission report issued in 2000, one of its recommendations included a call for the nation's colleges and universities to work with local school districts to develop a system of recruiting and advising people who would be interested in teaching the subjects of math, science, and technology (Sanoff, 2001). There are many examples of colleges and universities that have reached out to its area school districts. Michigan Tech works with primary and secondary schools in the Copper Country Intermediate School District, sending out graduate and advanced undergraduate students as fellows to work with local teachers. Goals of the program include establishing math and science labs to enable students to actively engage in doing and learning the subject matter as well to improve and develop math and science instruction as well as the school programs (Baartmans & Sorby, 2001).

The Bridges for Engineering Education program is another effort funded by the National Science Foundation (NSF) and includes partnerships with several universities that extend it to K-12 schools nationwide. The program provides planning grants to schools that will further develop the teaching of math, science and engineering. The goal of Bridges for Engineering Education is not only to see improvement in these academic areas where the United States has fallen behind its global competitors, but to also enhance the development of the nation's science and engineering workforce. Schools such as the University of Georgia, Virginia Tech University, the University of South Carolina, and Arizona State University have been leaders in Bridges for Engineering Education and have extended their efforts to improve engineering content in K-12 education.

Mathematics Engineering Science Achievement (MESA) is a program established in the state of Washington with the cooperation of the University of Washington, Washington State University and Pacific Lutheran University. The MESA program also uses partnerships with business and industry, government, and K-12 education, to provide fiscal and instructional resources. The MESA program looks to enrich minority, or underrepresented, students that will have the skills needed to succeed in math, engineering and science. The skills that the students learn in this secondary level program are intended for students to be prepared for studies in science or technology related university programs.

The Ohio State University operates the Center for the Accelerated Maturation of Materials (CAMM), which is a multi-institutional effort focused on materials development. Driven by industry demand, CAMM performs research and

experimentation in the development of high performance structural materials. Support for the research comes from leading industries such as Lockheed Martin, Ford, Phillips, and General Electric. CAMM has established a network of universities and labs that stretch from coast to coast that share computational models and predictions based in theory. The center also is active in outreach programs, lending the ideas gained in its research to K-12 instructors. The intent of these workshops is to improve engineering education at the pre-college level.

Tufts University in Massachusetts has established a similar outreach program, with a primary focus on engineering concepts. The curriculum is then established in math, science and social studies classes, supporting teachers with professional development and graduate students in classrooms as well as one-on-one contact with students (Creighton, 2002). The School Of Engineering has also established a website as a resource for K-12 educators looking to integrate engineering into their classrooms. Workshops are also conducted for K-12 instructors at schools including Stanford University, the University of Wisconsin, and Carnegie-Mellon University. While these initiatives have benefited some schools, there are problems that linger. The most relevant of these is the lack of education our nation's students receive in math and science, which they need as a base for engineering education to be successful.

#### Issues in the Instruction of Students

The Educational Testing Service (ETS) develops the Scholastic Aptitude Test (SAT) as well as other achievement-based tests. In 2002, the ETS published the report, Meeting the Need for Scientists, Engineers, and Educated Citizenry in a Technological Society. The report addressed the growing concern regarding the lack of achievement of

U.S. students in math and science as they entered middle school and high school. It also identified weaknesses in the preparation of elementary and secondary students in science and mathematics (Barton, 2002).

### Concerns in Mathematics Instruction

Concerns developed in the instruction of the students. Estimates show that 28 percent of math teachers nationwide were neither trained nor certified to teach math in public schools (Loftus, 2004). Public school systems are losing college graduates trained as teachers to other fields, where they are often compensated with higher wages or salary. Having uncertified teachers already puts math at a disadvantage when instructing students. This in turn, leads to those students losing interest in math and not pursuing it as a part of their chosen profession. Southeastern Consortium for Minorities in Engineering executive director Yvonne Freeman believes that corporate and government funding needs to be aimed at the training of teachers in math and science (Loftus, 2004). The lack of certified and trained teachers leads to students not reaching expected levels of achievement when it comes to testing and becoming a part of the technology workforce.

As with many other academic fields, mathematics standards were established to provide an outline of what concepts teachers were to provide to their students. Two publications came to the forefront. One was Curriculum and Evaluation Standards, published by the National Council of Teachers of Mathematics. It marked the beginning of current educational reform and the development of standards in other fields of study (Anagnostopoulos, Gorham, Newberry, Stoler, & Sechrist, 2001). Another was the Principles and Standards for School Mathematics. The belief stated is that all students should learn important mathematical concepts and processes with understanding

(Laubach et. al., 2001). How do we know that students understand? According to the ETS, this means reaching a level of Proficient on a variety of achievement tests. Established by the National Assessment of Educational Progress (NAEP), twelfth-grade students performing at the Proficient level should consistently integrate mathematical concepts and procedures into the solutions of more complex problems of the five NAEP content strands. Students should also demonstrate an understanding of algebraic, statistical and spatial reasoning. They should be able to perform algebraic operations involving polynomials, justify geometric relationships, and judge and defend their answers as applied to real-world situations. These students should be able to interpret and analyze data in tabular and graphic form; understand and use elements of the function concept in symbolic, graphical and tabular form; and make conjectures, defend ideas, and give supporting examples (Barton, 2002). This statement discusses some of what is expected of high school students to be successful in math. Students need to be able to go beyond simple adding and subtracting. Of course, problem solving is necessary, but inquiry and analysis are also expected. Having these skills can lead to student success in real world situations and applications such as engineering. Though the ETS report states there is no way to determine just what mathematics score on a NAEP test is needed to successfully pursue majors in college leading to entry into science professions, having reached the requirements of Proficient on achievement tests would provide a good base for the prospective engineering student (Barton, 2002).

#### Concerns in Science Instruction

Science faced the same dilemma as math. About 20 percent of science teachers are not certified or trained in the field (Loftus, 2004). The field is experiencing similar



problems in bringing trained educators into the profession or keeping them after their early years in teaching. These issues lead to struggling when it comes to achievement testing in science. Tests and studies have shown that students don't understand what matter is, let alone how atoms and molecules explain the properties of matter. They don't understand that air is a substance, or that light travels from one place to another, or what force is (Budiansky, 2001). Much like math, leaders in the science field went about reform.

The American Association for the Advancement of Science (AAAS), published Science for All Americans in 1989, calling for scientific literacy for all students and providing a foundation for future science standards (Anagnostopoulos et. al., 2001). Science for All Americans resulted from Project 2061, which was established by the AAAS as a science and math curriculum reform initiative (Budiansky, 2001). Project 2061 also examined what information textbooks were providing, often finding it to be rote memorization and the defining of terms. Science needed to go beyond these simplistic concepts and challenge student minds. With the National Science Education Standards, teachers were recommended to plan inquiry-based science programs, guide and facilitate learning, engage in ongoing assessment of their teaching, and continue with planning and development of the school science program (Laubach et. al., 2001). The elements of engineering education were evident in the wishes of science educators: inquiry and problem solving, student-centered instruction and the continuing involvement of teachers.

Science is not just facts to be memorized or terms to learn, but a process for building up a picture and explanation of the world from evidence (Budiansky, 2001).

There was a wide breadth on what was being taught, but very little depth. Definitions and labels related to scientific phenomena were what students received in their instruction. Students were not provided the concepts behind these phenomena, and the average to below-average student had only scratched the surface in what they could learn. Some assistance came in the form of relationships of public education with universities, such as Michigan State. The university established a science curriculum leading students through a logical chain of evidence, showing them a variety of phenomena, which can be explained by the same basic principle, and of providing students with a chance to put to use the ideas they have learned (Budiansky, 2001).

#### Concerns in Engineering Education

Engineering education in public schools is where many universities are looking for help. As mentioned, until recently, very little or no curriculum was established in K-12 education to provide students with a background upon entering college. Many K-12 teachers do not know what an engineer does or what the different engineering disciplines are. In turn, teachers are unsure of instructing those students who wish to pursue engineering as a career (Hein & Sorby, 2001). It leads to a trickle-down effect, where the students do not pursue engineering degrees and then industry points the finger at education for not being able to sufficiently fill their needs. The traditional school of thought holds that engineering education should provide students with basic scientific tools: heat transfer equations, understanding loads in buildings, and principles of electronics. The new school believes that engineering is creative and applies those scientific principles, and an engineering education without real coursework in how to be creative does a disservice to students and the profession (McGraw, 2004). The idea of

creativity and application of knowledge is parallel with the ITEA's publication of Standards of Technological Literacy.

Although the standards were meant for technology education as a whole, a number of the standards were written with an emphasis on engineering. Standard number eight states "Students will develop an understanding of the attributes of design." Standard number nine asserts, "Students will develop an understanding of engineering design." Standard number eleven declares, "Students will develop the abilities to apply the design process." (Anagnostopoulos et. al., 2001) The Accreditation Board for Engineering and Technology (ABET) established its Engineering Criteria 2000 in 1997. Within these measures, there were items that could be connected to the Standards for Technological Literacy. These included understanding and use of math, science and technology, understanding about engineering and technology in society, understanding and use of abilities in engineering and design and identifying, formulating, solving engineering problems. With the expectations that technology education teachers meet the Standards for Technological Literacy, how could they include engineering education within their curriculum?

#### Where Teachers Can Look to for Engineering Curriculum

As previously mentioned, programs such as Project Lead the Way and Adventure Engineering have been implemented with some success into K-12 curriculum. In both programs, teachers receive training and curriculum in order to allow them to instruct their students. Many more teachers are taking advantage of workshops provided by universities. Michigan Tech University works with teachers to increase the understanding and appreciation that math and science teachers have for the engineering

profession and to work with secondary teachers in the development of “engineering” exercises suitable for delivery to pre – college students (Baartmans & Sorby, 2001). The workshop was also designed to give teachers a bachelor’s degree level knowledge of the disciplines. In exploring various engineering disciplines, the teachers were given depth that they could take back to their students and be confident in the information they were giving. That confidence was the primary evidence that teachers took something away from the workshop and to be able to guide their students when it came to career choices (Hein & Sorby, 2001). Teachers also have a number of resources to choose from in order to expand their curriculum. Journals such as Prism feature current issues in engineering education and the Journal of Engineering Education, which contains articles on instructional methods. A website, TeachEngineering.com, is a searchable digital library of K-12 curriculum, developed by Tufts University in Massachusetts. With all of this information at hand, teacher’s jobs are a bit easier when it comes to engineering education, but what does it mean for their students?

### Implementing Engineering Education

When should engineering education begin? According to Jackie Sullivan of Colorado College of Engineering, it should be third grade at the latest. Those students love hands-on learning and it provides the ideal outlet for making math and science relate in their world (Creighton, 2002). Some of the outreach programs provided by universities have placed students into the elementary levels, which helps to facilitate engineering education and its content. The projects that teachers learn at workshops need to be broken down by students into the engineering design process. This includes: gathering research and brainstorming solutions, evaluating the ideas, selecting materials,

building a prototype, testing the design, and retesting (Cyr, Gravel, Prouty, & Rushton, 2002). These are ideas brought forth, beginning with the use of IIMs and continuing with the establishment of engineering education. The instruction is student-centered and the students are challenged, giving them more of a stake in their education and preparing them for post-secondary education, hopefully in an engineering discipline. Engineering education, while starting to gain a foothold in K-12 curriculum, can benefit both teachers and students.

### Chapter III – Methodology

The study gathered information through a survey instrument that was distributed to the leaders of several university-based engineering education workshops and program initiatives across the nation. The survey instrument consisted of 35 items, many of which were rated on a three point Likert-type scale, followed by open-ended questions that allowed for the subjects to add information that may not have been addressed in previous items. In addition to the survey, subjects were also asked to complete an implied consent statement that discussed the purpose of the study, its risks and benefits, and their confidentiality. A self-addressed stamped envelope was provided for subjects to return the survey instrument and the implied consent statement.

#### Subjects

The subjects that participated in the survey were leaders in various engineering education workshops and program initiatives across the nation. These subjects were chosen based on their development of engineering curriculum projects and engineering education workshops. Participants in the survey were asked what specific courses they believed were necessary for students to be prepared to participate in high school engineering education courses. In addition, these leaders were asked to specify courses technology education teachers needed to successfully deliver an engineering curriculum. A total of 11 surveys were distributed.

#### Instrument

The purpose of the survey was to solicit opinions of engineering curriculum project leaders to determine the math, science, and engineering design courses students

and technology education teachers need to in order to be prepared for an engineering curriculum.

The first section of the survey instrument addressed demographic information related to the programs represented by the subjects. Items in this section dealt with the number of years that the project or initiative has been offered to schools, the grade levels targeted by the curriculum, and the number of school districts and students that have participated in the offered programs. In the survey itself, the first part was directed towards the math, science, and engineering design courses that the subjects believed high school students should have to succeed in their curriculums. The second part of the survey addressed the math, science, and engineering courses at the university level the survey subjects believed that teachers should have in order to properly deliver their curriculum.

The survey was used to ask participants to indicate whether respective math, science and technology classes were nonessential, recommended, or essential. Open-ended questions were provided at the end of each section for subjects to add any math, science, and engineering design courses offered in the survey. The survey instrument was reviewed for validity by a panel of experts including university engineering and technology education faculty. With suggested revisions, a final draft of the survey was constructed. A sample copy of the survey mailed to project leaders is included in Appendix A.

### Procedures

Surveys were distributed in the fall of 2004. A cover letter discussing the purpose of the study and the selection of subjects was mailed with each survey. A sample of this

letter is included, as Appendix B. Follow up was conducted with an e-mail asking those who had not completed surveys to please do so as soon as they could. A letter of consent was also sent to possible subjects to discuss the risks and benefits of their participation in the study. This form is included as Appendix C.

### Limitations

Subjects for the study were chosen because of the success of their given engineering education curriculum workshops and projects. A small sample size resulted because of the limited number of identified projects. While the small sample size affected the generalizability of the findings, the data does represent the opinions of the participants. One could also use the information provided in this study to inform the design of more comprehensive studies in the future.

The reliability of the items in the survey was reviewed by faculty in university engineering education and technology education. The courses provided in the survey items were restricted to what high school students needed to be successful in an engineering curriculum. This could cause confusion among subjects whose projects were not developed strictly for the high school level. It may also result in the elimination of information provided by some of the subjects.



## Chapter IV – Results of the Study

### Rate of Response

The purpose of the study was to determine the knowledge needed by students to succeed in engineering education courses, and what their instructors need to know in order to educate their students in an engineering education curriculum. Surveys were mailed to the leaders of several curriculum initiatives and outreach programs in engineering education. A total of eleven surveys were distributed. There were eight surveys returned, calculating a response rate of 72.7 percent. One survey was eliminated from consideration as the subject's curriculum project was developed strictly for university level students. One survey was returned with roughly half of the items completed, while another was returned with two items incomplete. These answers are included in the data analysis.

### Demographics

Demographic information was collected from subjects in the first section of the survey instrument. The items were based on the number of years their program or initiative has been offered, the grade levels targeted by their curriculum, along with the number of school districts and students that are participating. The first item measured how long these programs and initiatives have been offered to schools and teachers interested in implementing the curriculum. The great majority of the programs have been established less than ten years, reflecting the recent time period that engineering education has been emphasized across the nation. The table displaying the results from this item is on the following page.

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Table 1 – How many years has your program been offered to teachers?

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Option	Responses	Percentage
0-4 Years	3	42.9
5-9 Years	2	28.6
10-14 Years	1	14.3
15 or more years	1	14.3

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The second demographic item asked subjects for what grade levels their curriculum was written. Multiple answers were allowed and the responses reflected a wide range for which engineering curriculum was created. A couple of the programs and initiatives have curriculum that can be used with kindergarten students. Most have developed curriculum for the middle and high school levels.

The third item of the demographic section of the survey asked subjects the approximate number of school districts that have participated or are participating in their program or initiative. Several options were provided for subjects to respond to, yet a majority of the responses showed that the given curriculum had been implemented in less than 25 school districts. This may be another reflection of the recent emphasis on engineering education in school. Table two presents the responses to this item.

Table 2 – Please indicate the approximate number of school districts that have participated or are participating in your program or initiative.

Number of School Districts	Responses	Percentage
Less than 25	4	57.1
25	0	0.0
50	1	14.3
75	0	0.0
100	0	0.0
125	1	14.3
150	0	0.0
175	0	0.0
200	0	0.0
More than 200 (Approximately 400)	1	14.3

The final item of the demographic section asked subjects to provide the number of students that have participated or are participating in their program or initiative. Again, subjects were provided with a number of possible options and the responses were clustered, representing a majority. Many of these programs and initiatives have seen hundreds of students participate. Table three exhibits the responses provided by the subjects.

Table 3 – Approximately how many school-aged students have participated or are participating in your program or initiative?

Number of Students	Responses	Percentage
Under 100	1	14.3
101 – 200	0	0.0
201 – 300	1	14.3
More than 300	5	71.4
(500, 1500, 2000, 5000, 10000)		

#### Engineering Education Curriculum Initiatives - Project Lead the Way

Project Lead the Way had its beginnings in the late 1980's as a joint effort by a teacher from the state of New York and Rensselaer Polytechnic Institute. What began as technology-oriented courses has now grown into a pre-engineering curriculum that stretches across the nation. Project Lead the Way has developed six courses for the high school level, including principles of engineering, introduction to engineering design, engineering design and development, civil and architectural engineering, digital electronics, and computer-integrated manufacturing. Project Lead the Way has also created curriculum at the middle school level that serves as a pathway to their high school courses.

The growth of Project Lead the Way has been rapid, as the engineering curriculum they have written has been in place less than ten years. In that short time frame, however, Project Lead the Way has been implemented in middle schools and high schools in approximately 400

school districts across the nation. In total, over 10,000 students have participated in Project Lead the Way at the middle school or high school level.

High school students' preparation for the Project Lead the way curriculum should include a strong math and science background. In their response to the survey, general math, algebra, advanced algebra, geometry, functions and statistics, trigonometry and pre-calculus were regarded as essential. A calculus course was recommended for high school students. In the subject of science, courses in physical science, physics and biotechnology were rated as essential. Studies in biology and physics were recommended for students

Educators preparing to instruct students in Project Lead the Way courses are suggested to have extensive backgrounds in math, science and technology/engineering design courses at the university level. In math, courses in college algebra, trigonometry & analytical geometry, probability and statistical analysis and calculus I were considered essential. Studies in a calculus II course were recommended. Science courses considered essential at the university level were biology, general physics, and college physics. It was recommended that prospective teachers acquire knowledge in biotechnology and chemistry. In the area of technology/engineering design, the response was the more knowledge, the more prepared the teacher will be to instruct students. All courses were rated as essential, including general engineering design, mechanical design, engineering design, electricity/electronics, digital electronics, fluid power systems, and materials and processes.

#### Engineering Education Curriculum Initiatives - Adventure Engineering

The Adventure Engineering program started in 1998 as a joint effort of the University of Oklahoma and the Colorado School of Mines, with funding provided by the National Science Foundation. The curriculum has been written by students at each of these schools and

implemented at several schools across Oklahoma and Colorado. The program contains adventures for students to use math and science concepts that lead to an understanding of engineering design principles. Inquiry and problem solving by the students are other key characteristics of the Adventure Engineering program.

Adventure Engineering has been established less than ten years, but is already having an effect in schools across Oklahoma and Colorado. Mostly focused at the high elementary and middle school levels, the program also includes curriculum for ninth grade students. Since it is limited to the two states for the time being, it has not had the wide-ranging affect of Project Lead the Way, with the number of schools being involved estimated in the dozens. In those schools however, around 2000 students have participated and learned from the Adventure Engineering curriculum.

The responses to the survey items regarding high school students' preparation for Adventure Engineering leaned more toward general courses in math and science. This is reflective of the curriculum concluding at the ninth grade level. The general math course was rated as essential, and algebra was recommended for high school students. In ninth grade, students are not likely to have taken advanced algebra, geometry, functions and statistics, trigonometry, pre-calculus, or calculus, and for Adventure Engineering, were considered not essential. The results were similar for students' science preparation. Physical science was the only class considered as essential. Again, courses ninth graders are not likely to have taken, including, biology, chemistry, physics, and biotechnology were regarded as not essential for students in Adventure Engineering.

Backgrounds for teachers in math and science need to be a little more wide-ranging, according to the response. At the university level in math, college algebra, trigonometry &

analytical geometry, and probability and statistical analysis were considered essential. The other courses listed in the survey, calculus I and calculus II, were regarded as not essential. Science knowledge at the university level should center on biology, chemistry, and general physics, as they were rated as essential. Biotechnology and college physics were considered as not essential. In technology/engineering design, an engineering design course was the only course to be recommended. The other courses listed in the survey, electricity/electronics, digital electronics, fluid power systems, and materials and processes received not essential responses. The items on general engineering design and mechanical design were not answered by the respondent.

#### Engineering Education Curriculum Initiatives - The Infinity Project

The Infinity Project is a joint effort among many entities, including Texas Instruments, the U.S. Department of Education, and the National Science Foundation. The Institute for Engineering Education was established at Southern Methodist University in Dallas to facilitate partnerships among universities, K-12 education and industry to aid the Infinity Project and work with the aforementioned groups to address expected shortages in engineering and technical talent in the near future. Much like Project Lead the Way, the Infinity Project has started to take hold in schools across the nation. The curriculum of the Infinity Project features math and science concepts used by students to create and design projects in newer technologies that students will use, such as cell phones.

Although the Infinity Project has been in place a relatively short time (about five years), it has been able to be placed in schools across the nation at the eleventh and twelfth grade levels. According the response returned, the Infinity Project is in place in around 125 schools. In total, approximately 500 students have been involved in some level of the Infinity Project.

Responses regarding the Infinity Project, as it is written for high school upperclassmen, reflected focus on higher level courses. Studies in advanced algebra, trigonometry, pre-calculus, and calculus were seen as essential for high school students. Algebra and geometry were recommended for students, as were AP courses in math. This answer was received in item nine, asking for other courses that students should take. General math was considered to be not essential. In science, a wider range of responses was reflected. The section saw answers in the non-essential, recommended, and essential categories. Physics was the one course that received a response of essential. Biotechnology was seen as not essential to students' knowledge. Courses in physical science, biology, and chemistry were recommended in students' preparation.

The background in math for teachers is to be strongly emphasized at the university level, according to the responses provided. College algebra and calculus I were seen as essential for their knowledge. The other courses in this section were recommended, including trigonometry & analytical geometry, probability and statistical analysis, and calculus II. The knowledge base in science focused on general physics, considered as essential, and chemistry and college physics, which were recommended. Biology and biotechnology courses were viewed as not essential. Strength in the area of technology/engineering design is not a requirement of the Infinity project, according to the responses provided. Engineering design was the only course to be recommended, while all other courses received a reply of not essential. These courses included general engineering design, mechanical design, electricity/electronics, digital electronics, fluid power systems, and materials and processes.

#### University Outreach Programs – Michigan Tech University

Michigan Tech University works with primary and secondary schools in the Copper County Intermediate School District to establish math and science labs that look to engage



students in the subject matter as well as to improve skills in those subjects. Success in math and science is essential for students to do well in engineering courses. Michigan Tech graduate and advance undergraduate students work as fellows with the teachers in these schools to develop a curriculum that will be beneficial to students.

The outreach program at Michigan Tech is in its beginning stages, having been offered to school districts for less than five years. Other signs that the program is in its infancy are that less than 25 school districts have participated in the outreach program, involving fewer than 100 students. At this time, the primary targets of the outreach program are high school teachers, but as been mentioned, Michigan Tech works with schools at the primary level as well.

A strong background in math is expected of high school students affiliated with the Michigan Tech outreach program. Each course in this section was seen as essential, including general math, algebra, advanced algebra, geometry, functions and statistics, trigonometry, pre-calculus, and calculus. Responses toward science were a little more varied. Physical science, chemistry and physics were seen as essential, and biology and biotechnology were regarded as not essential in high school students' preparation.

Math knowledge is expected to be a strength of teachers linked with the Michigan Tech outreach program. College algebra, trigonometry & analytical geometry, probability and statistical analysis, calculus I and calculus II were rated as essential at the university level for teachers. Science knowledge focused in chemistry, general physics and physics, seen as essential. Courses in biology and biotechnology were regarded as not essential. A focus was also evident in university level technology/engineering design for teachers. General engineering design, mechanical design, engineering design, electricity/electronics, and materials and

processes were rated as essential. Digital electronics and fluid power systems received responses of not essential for instructors' knowledge.

#### University Outreach Programs – MESA

Mathematics Engineering Science Achievement (MESA) is a cooperative effort among the University of Washington, Washington State University and Pacific Lutheran University. This program has established relationships among these universities along with business and industry, government, and K-12 education. The objective of MESA is to enrich minority or underrepresented students that will have the skills to succeed in math, engineering, and science. It is hoped that the skills learned by students in the program will propel them to success in science or technology related university programs.

The Mathematics Engineering Science Achievement program has been established longer than any of the other programs that responded to the survey, currently at fifteen years. In turn, MESA has been able to gain a foothold throughout K-12 education in the state of Washington. Schools that participate in the program currently stand at around fifty, with the largest affect seen in the number of students that participate. There are approximately 5000 students that benefit from the MESA program each year, which is fairly constant in its core group of schools.

Math knowledge for high school students in the MESA program is suggested to be wide-ranging. Courses recommended, according to the survey response, include algebra, advanced algebra, geometry, trigonometry, pre-calculus, and calculus. Responses were not received for the items on general math and functions and statistics. Science knowledge for students was recommended in courses including physical science, biology, chemistry, and physics. No response was given for biotechnology. The respondent commented in item sixteen, which was

open ended, that MESA provided many integrated math and science projects for students within its curriculum.

The knowledge requirements for teachers at the university level in math centered in college algebra, which was the only item in this section to receive a response. It was recommended by the respondent. Science courses at the university level in biology, chemistry and general physics were recommended for teachers' preparation. The other science courses, including biotechnology and college physics, did not receive responses. In the area of technology/engineering design, no responses were received in relation to any of the courses listed. This may be evidence that the technology/engineering knowledge needed for instructors is provided in workshops for the MESA curriculum.

#### University Outreach Programs – The Ohio State University

At The Ohio State University, the Center for the Accelerated Maturation of Materials (CAMM) is a multi-institutional effort centered on materials development. With industry demand as the driving force behind CAMM, the program conducts research and experimentation in the development of high performance structural materials. Some of the industries that provide support include Lockheed Martin, Ford, Phillips, and General Electric. CAMM has been able to build up a network of universities and labs from coast to coast that share models and predictions based in theory. The center also offers outreach programs to K-12 instructors that allow them to share in this research. The purpose of the teacher workshops is to improve engineering education at the pre-college level.

The Center for the Accelerated Maturation of Materials (CAMM) has been established for over ten years and has had an effect on schools within the proximity of The Ohio State University. Teachers that have participated in the workshops have typically come from two

groups, at the fourth through sixth grade level and at the ninth through eleventh grade level.

Although less than 25 school districts have had teachers involved, they have been able to take their knowledge back to over 200 students, providing them with a background that can aid their future.

The knowledge in math for high school students in the CAMM outreach program focuses on lower-level high school courses, with some advanced courses recommended. General math and algebra received responses of essential in the survey. Geometry and functions and statistics were recommended by the respondent, while the other courses in this section were rated as not essential. These included advanced algebra, trigonometry, pre-calculus, and calculus. Student studies in science again leaned toward lower-level courses, with physical science the only course considered essential. Biology, chemistry, and biotechnology were recommended for student knowledge, while physics was regarded as not essential.

Teachers participating in the CAMM outreach program need to have a strong knowledge base in math, according to the responses received. All of the courses in this section, including, college algebra, trigonometry & analytical geometry, probability and statistical analysis, calculus I and calculus II, were rated as essential. The same held true for university level science courses. Biology, biotechnology, chemistry, general physics, and college physics were viewed as essential for teachers. In technology/engineering design, a general engineering design course was the only course seen as essential in teachers' preparation. The knowledge base could be expanded in mechanical design, engineering design, electricity/electronics, and materials and processes, as they were recommended by the respondent. Digital electronics and fluid power systems were considered as not essential.

### University Outreach Programs – Tufts University

Tufts University in Massachusetts has also developed an outreach program that focuses on engineering concepts. Tufts University has its curriculum placed into math, science and social studies classes, providing teachers with professional development in the process. The program at Tufts also uses graduate students to work in the classrooms of these teachers and make contact with the students to enhance their learning. The Tufts School of Engineering also has a website that teachers can use as a resource to integrate engineering into their classrooms.

The Tufts outreach program is another that is just starting to get a foothold. In place less than five years, the program has been implemented in just a few (less than 25) school districts, but has already seen around 1500 students become involved and further their understanding of engineering concepts. Teachers throughout K-12 education have participated in the workshops and have taken what they have learned back to their students.

The math knowledge suggested for high school students in the Tufts outreach program focused on early high school courses, with advanced courses recommended. General math and algebra received essential responses, with the other courses recommended by the respondent. These included advanced algebra, geometry, functions and statistics, trigonometry, calculus I and calculus II. In science, study in biology, physics, and biotechnology was seen as essential for students. Biology and chemistry received responses recommending the courses for students.

At the university level, teacher's knowledge in math needs to be strong, according to the responses. College algebra, trigonometry & analytical geometry, calculus I and calculus II were considered essential for their preparation. Probability and statistical analysis was recommended for prospective teachers. For science, study should focus on physics. The two courses listed in the survey, general physics and college physics, received essential responses. The other courses

in the section, biology, biotechnology, and chemistry, were recommended for teachers at the university level. Knowledge in technology/engineering design should be focused on engineering design and electricity/electronics, considered essential by the respondent. The other courses in this area were recommended. These include general engineering design, mechanical design, digital electronics, fluid power systems, and materials and processes.

#### Summary of Data Received from Responses

The following section summarizes the findings across all subjects or programs. Each section of the survey is analyzed, focusing on items that showed high levels of agreement or those that had a range of disagreement. The analysis concludes with a table displaying the results of survey responses to each item.

#### Beliefs Regarding Math Preparation for Students

In order to calculate the formulas presented by many engineering problems, students need a base of knowledge in math. Items one through nine of the survey allowed the subjects to state what they thought students need to be prepared. These items are connected to the first research question, what minimum levels of math preparation should students have to participate in an engineering curriculum? Among the respondents to the survey, the highest level of agreement was in regards to item two, algebra. All seven subjects replied that it was recommended or essential for students to have completed an algebra course. (See Table 4)

Consensus was also exhibited among many other math courses. Four of the subjects felt it was essential that students' preparation included general math. The answers toward advanced algebra, trigonometry, geometry and pre-calculus were similar. Each item had five responses

reflecting that it was recommended or essential for students to complete these courses in preparation for study in engineering education.

The least agreement was with item five, asking if students should have completed a functions and statistics course. Three of the respondents did not believe it was essential for students to have completed the course, while only two felt it was essential. Item nine was an open-ended question, asking respondents for any other math courses that students should take. One subject recommended that advanced placement (AP) courses should be taken by students in preparation for engineering education. Results for all items of this section of the survey are below.

Table 4 - What minimum levels of math preparation should high school students have to participate in an engineering curriculum?

Item	Not Essential		Recommended		Essential	
	Responses	%	Responses	%	Responses	%
1) General Math	1	16.7	1	16.7	4	66.7
2) Algebra	0	0.0	3	42.9	4	57.1
3) Advanced Algebra	2	28.6	2	28.6	3	42.9
4) Geometry	1	14.3	4	57.1	2	28.6
5) Functions and Statistics	3	42.9	2	28.6	2	28.6
6) Trigonometry	2	28.6	2	28.6	3	42.9
7) Pre-Calculus	2	28.6	2	28.6	3	42.9
8) Calculus	2	28.6	3	42.9	2	28.6

#### Beliefs Regarding Science Preparation for Students

Science is integral in engineering, as the use of theory and judgment are important in the completion of many design problems. The science knowledge that students need is requested of respondents in items ten through fifteen and is related to the second research question, what minimum levels of science preparation should students have to participate in an engineering curriculum? All seven subjects replied that a physical science course was recommended or essential of students' preparation. Another item that showed a high level of agreement was



number thirteen, physics, as four subjects who believed that the course was essential. The five essential responses toward physics equaled those of physical science for the course that respondents believed was essential in high school students' preparation for study in engineering education.

All other items in this section reflected lower levels of agreement. Results for items eleven (biology) and twelve (chemistry) each received five responses recommending the course for students. Item fourteen (biotechnology) exhibited some difference among the subjects, reflected in the three responses feeling the course was not essential, but two others believing it was essential. Item fifteen asked subjects for any other science courses students should take in preparation for engineering education. One subject stated that AP courses in science should be recommended for those students. Item sixteen was an open-ended question that asked for any additional comments related to what students needed to be successful in engineering education. No replies were provided. Results for all items of this section of the survey are below.

Table 5 - What minimum levels of science preparation should high school students have to participate in an engineering curriculum?

Item	Not Essential		Recommended		Essential	
	Responses	%	Responses	%	Responses	%
10) Physical Science	0	0.0	2	28.6	5	71.4
11) Biology	2	28.6	5	71.4	0	0.0
12) Chemistry	1	14.3	5	71.4	1	14.3
13) Physics	2	28.6	1	14.3	4	57.1
14) Biotechnology	3	50.0	1	16.7	2	33.3

#### Beliefs Regarding Math Preparation for Teachers in Engineering Education

Prospective teachers need to do a great deal of studying and research in order to properly instruct their students in any subject. With the rigor required of instructing students in engineering education, teachers need to have a good knowledge base in mathematics in order present examples of formulas and calculations. The knowledge that teachers need is addressed in items seventeen through twenty-two of the survey and connects to the third research question, what minimum levels of math preparation should technology education teachers have to instruct students in an engineering curriculum? The greatest agreement by respondents was on item seventeen, college algebra. (See Table 6) Six of the seven subjects indicated that it was essential for prospective teachers to have completed a college algebra course. Similar results were seen with item eighteen, trigonometry and analytical geometry. Responses toward this item

were identical to item seventeen, except that five of the subjects believed that the course was essential for teachers, and one subject not providing a response.

All of the other items in this section exhibited average or above average results. Item twenty, Calculus I, received five responses that the course was essential for prospective teachers, yet one subject believed that it was not essential. Item nineteen on probability and statistical analysis received two recommended and four essential responses. Item number twenty-one, Calculus II, had a wide distribution of responses, with one subject believing that it was not essential, two subjects recommending the course, and three subjects feeling that it was essential in teachers' preparation. Item twenty-two asked for any other university level math courses prospective teachers should have and no replies were received. The results for the responses to items seventeen through twenty-one are reported in the table below.

Table 6 – What minimum levels of math preparation should technology education teachers have to instruct students in an engineering curriculum?

Item	Not Essential		Recommended		Essential	
	Responses	%	Responses	%	Responses	%
17) College Algebra	0	0.0	1	14.3	6	85.7
18) Trigonometry & Analytical Geometry	0	0.0	1	16.7	5	83.3
19) Probability & Statistical Analysis	0	0.0	2	33.3	4	66.7
20) Calculus I	1	16.7	0	0.0	5	83.3
21) Calculus II	1	16.7	2	33.3	3	50.0

#### Beliefs Regarding Science Preparation for Teachers in Engineering Education

Much like students, prospective teachers need a solid background in science in order to successfully deliver an engineering education curriculum. Items twenty-three through twenty-eight in the survey addressed the fourth research question, what minimum levels of science preparation should technology education teachers have to instruct students in an engineering curriculum? Item twenty-six, which asked subjects if teachers should have taken a general physics course, exhibited the most agreement of any item in this section. Six of the respondents believed the course was essential in teachers' preparation. (See Table 7) Other university level

science courses, such as college physics (Item 27), chemistry (Item 25), and biology (Item 23), also exhibited above average responses.

The least agreement was with item twenty-four, biotechnology. Two respondents believed the course was not essential in teachers' preparation and three respondents recommended it. Item twenty-eight asked respondents to add any other university level courses they believe teachers should have, and no replies were given. Results for all items of this section of the survey are below.

Table 7 - What minimum levels of science preparation should technology education teachers have to instruct students in an engineering curriculum?

Item	Not Essential		Recommended		Essential	
	Responses	%	Responses	%	Responses	%
23) Biology	2	28.6	2	28.6	3	42.9
24) Biotechnology	2	33.3	3	50.0	1	16.7
25) Chemistry	0	0.0	4	57.1	3	42.9
26) General Physics	0	0.0	1	14.3	6	85.7
27) College Physics	1	16.7	1	16.7	4	66.7

#### Beliefs Regarding Technology/Engineering Design Preparation for Teachers in Engineering Education

If a teacher is going to instruct students in engineering education, developing a background in technology/engineering design courses is integral. The last section of the survey,

items twenty-nine through thirty-four, addressed this issue and relates the research question, what minimum levels of engineering design preparation should technology education teachers have to instruct students in an engineering curriculum? The most agreement was with item thirty-one, engineering design. Three respondents stated that an engineering design course was recommended and three respondents stated that the course was essential in a teachers' preparation. The next highest recommended courses were general engineering design (Item 29), electricity/electronics (Item 32), materials and processes. (Item 35)

The least agreement was with two items in this section. Item thirty-three, digital electronics, received four responses of not being essential for teachers' preparation. The same held true for fluid power systems, also with four not essential responses. Item thirty-six asked subjects if any other university level courses in this area should be included in prospective teachers' programs. No responses were given. In addition, item thirty-seven was an open-ended question asking for any additional comments related to what prospective teachers needed to successfully instruct students in an engineering education curriculum. No responses were provided here. Results for all items of this section of the survey are below.

Table 8 - What minimum levels of engineering design preparation should technology education teachers have to instruct students in an engineering curriculum?

Item	Not Essential		Recommended		Essential	
	Responses	%	Responses	%	Responses	%
29) General Engineering Design	2	33.3	1	16.7	3	50.0
30) Mechanical Design	1	20.0	2	40.0	2	40.0
31) Engineering Design	0	0.0	3	50.0	3	50.0
32) Electricity/Electronics	2	33.3	1	16.7	3	50.0
33) Digital Electronics	4	66.7	1	16.7	1	16.7
34) Fluid Power Systems	4	66.7	1	16.7	1	16.7
35) Materials and Processes	2	33.3	2	33.3	2	33.3

## Chapter V – Discussion

### Summary

What are the beliefs of leaders in engineering education curriculum projects regarding the knowledge necessary for students and teachers to achieve success in an engineering education curriculum? According to the responses received from the survey instrument, both students and teachers should have a wide base of knowledge across math, science, and technology/engineering design. Some of the responses reflected a great emphasis on particular courses in each of these subjects.

In examining the math courses offered to high school students, participants in the survey felt strongest that students should have a background in algebra. All who responded at least recommended the course, which focuses on algebraic concepts along with reasoning, measurement, probability, statistics, discrete mathematics, and functions. The ideas of algebraic concepts and formulas, measurement and probability are mathematics principles that are integral to the study and application of engineering concepts.

Algebra ranked ahead of general math in the study and is typically taken by students who are not ready for an algebra course. Participants in the survey may have assumed students will have taken this course and believed it was less important in their replies. Advanced algebra, which enhances the concepts learned by students in an algebra course, was also strongly supported by participants. This further stresses the need for a strong knowledge base in algebraic concepts for students. Trigonometry was another course that received strong support from participants. In addition to examining trigonometric functions, students also learn the relationships between the sides and angles of triangles and their respective functions. Much like general math, geometry did not receive as strong of a response, as it is typically required of



students before enrolling in a trigonometry course. Being able to apply these mathematics concepts to engineering problems will aid the students in their studies.

The science courses offered to students resulted in two distinct disciplines that survey subjects believed were necessary for students. Physical science elicited the strongest response as all who responded at least recommended the course, which usually deals with matter and measurement, motion and its cause, energy and power, and sources of electric current. These are ideas that are used in solving and applying problems encountered in engineering. Specialized study in some of those areas also led to a good response for students to take a physics course. It would allow the students to advance their knowledge in matter, energy, and electricity. Similar to advanced algebra for math courses, it seems that more knowledge means better preparation for the student and a greater chance at success. Some courses, such as biotechnology, did not receive as strong of a response from the subjects. This could reflect the lack of emphasis on fields such as genetic engineering in the programs' curriculum, with more focus placed on mechanical and civil engineering.

Whatever their chosen field may be, teachers need a solid background in order to properly instruct their students. Preparing to instruct students in an engineering education curriculum requires a great deal of study in a wide array of courses in academic areas related to the field. In math, survey subjects felt strongest that teachers needed to have a background in a college algebra course. Skills such as factoring, rational expressions, linear equations, systems of equations and quadratic equations are the basis of study in the course. These skills are important for teachers instruct their students and being able to lead them to answers to various engineering problems.

Among other university level math courses that received solid support, trigonometry and

analytical geometry aids teachers' preparation in expanding their knowledge in graphs and their applications, along with right triangle trigonometry. Study in a Calculus I course was also highly suggested in order to build knowledge of functions and sets, as well as logarithmic, trigonometric and inverse functions. Rounding out math courses was the belief that perspective teachers should take a probability and statistical analysis course to acquire knowledge in areas including estimation and hypothesis testing and reliability. Each of these skills is characteristic of problems encountered in engineering and will help the teachers of an engineering education curriculum better instruct their students.

The studies of perspective teachers in university level science courses had distinct disciplines identified by participants in the survey. General physics received the strongest response, often including algebra and trigonometry in its study. College physics courses were also suggested, where calculus and a study of thermodynamics further knowledge in areas that are related to engineering. Biology was another course believed to be helpful towards teachers' preparation.

In the area of technology/engineering design, emphasis on a wide array of courses was not evident in the responses of the participants. The participants favored engineering design, focusing on design concepts and drafting techniques. General engineering design ranked behind it among the course offerings. It is the type of course that introduces design principles and provides an introduction to computer-aided design. (CAD) Courses in electricity/electronics and materials and processes also received attention from the participants, as these are fields that are open to potential engineers.

With engineering education beginning to gain prominence in technology education programs, as well as other education curriculums, teachers are acquiring new information

everyday, often trying to stay a step ahead of the students. A comparison of the courses suggested by the participants in the survey provides some interesting similarities. Among mathematics courses, algebra and trigonometry received the strong response for both groups. In the science curriculum, participants for both groups held physics in high regard. Some of these curriculum initiatives require that students take these courses before enrolling in the engineering education program. The developers of these initiatives realize what the students need in order to be able to be successful. The preparation of teachers allows them to enhance their knowledge in these areas and be further ahead than students. It is then the teacher's responsibility to use this knowledge to establish lessons and problems, deliver the engineering education curriculum, and provide the answers necessary for students' inquiries.

### Conclusions

Engineering education is the next step in the evolution of technology education. Technology education, upon its introduction in the 1980's, provided new ways to solve problems and the means to create those solutions. It introduced the use of computers and other advancements for a number of lessons within the curriculum. The introduction of technology education brought the curriculum into a modern era and away from the shop. It also began to change the dynamic of students who were enrolling in the courses. More females and other curious students enrolled in technology education courses, as they offered the chance to improve hands-on skills and for students to use their creativity. However, reflecting how society quickly changes, so does technology education. Initiatives such as Project Lead the Way, Adventure Engineering, and the Infinity Project are growing. These initiatives are attractive to schools, as corporate sponsors back them and provide funding to schools wishing to implement them. Some schools are developing their own engineering education curriculums, with the help of

universities in their area. Engineering education is beginning to gain a foothold in technology education as well as in other areas of schools. The two groups who can aid the field in its endeavors, students and teachers, each have their responsibilities to satisfy this need. Students must acquire the necessary knowledge that will prepare them for the rigors of engineering education, and eventually, the engineering profession itself. Teachers must also acquire knowledge, as their studies in preparing to teach, often do not lead them to the courses most often mentioned in the survey. As engineering education is implemented across the nation, it is imperative that teachers remain committed to lifelong learning and benefit their students who want more.

### Recommendations

Engineering education represents the next step forward for schools in technology education. Schools also need to make sure that students and teachers achieve success in engineering education for the full benefits of these initiatives and programs to be realized. Students preparing to enter courses in an engineering education courses should be aware of the expectations of them. If students, upon entering high school, wish to enroll in engineering education courses, advice from their counselors as to what academic courses to enroll in will be beneficial. Engineering education requires a strong background in math and science. Specifically, courses such as algebra, advanced algebra, physical science, and physics should be a part of their plan. The content taught in these courses will allow students to use their concepts in solving engineering problems. The willingness of students to take courses that are considered advanced shows that they will also be able to handle the rigors of an engineering education curriculum.

If students are to have high expectations set for them, teachers should as well. It becomes harder and harder every day for teachers to reach students, as the students' outside influences and responsibilities increase. Teachers work diligently to provide their students a quality education. Part of that includes lifelong learning by the teacher. No teacher can survive strictly on what they learned prior to entering the profession. In addition to classroom management, student-teacher relations and professional collegiality, the curriculum can change in an instant. In a field such as technology education, this is especially true, as technology itself continues to advance with great speed. Preparing to deliver engineering education content will require the teacher to gain additional knowledge, as their university preparation likely did not cover what will be required of them. Courses beyond algebra often are not required. Adding trigonometry and calculus to their background will be necessary. University level physics may be another area where the teachers are lacking. Knowledge in the technology/engineering design discipline should include engineering design, along with some work in electricity/electronics and materials and processes. There are a couple of means of acquiring this knowledge. One is taking courses at a nearby university or technical college. Another is participation in the workshops sponsored by universities in engineering education, often held in the summer or on school breaks, when teachers can easily attend. The larger programs, including Project Lead the Way, offer summer training for their teachers that not only discuss course curriculum, but also provide opportunities to apply or learn the knowledge needed to deliver it. In any method, the teacher must commit to being a lifelong learner in order to prepare for the rigor required of them in delivering engineering education content.

### Recommendations for Further Study

In this study, subjects were asked what courses they believed students and teachers should take in order to be successful in their engineering education programs and initiatives. These responses leave open possibilities for further study. One such possibility may be the development of a recommended four year plan for high school students that would include courses related to their curriculum, including math and science courses that would fully prepare the student for engineering education, in high school and perhaps beyond. Another possible study could break down various math, science, and technology/engineering design courses and discuss the key ideas from each that are essential to what students and teachers need to be successful in an engineering education curriculum.

In reflection, I believe the questions that were asked of the subjects provided a good idea of the preparation that students and teachers need to be successful in an engineering curriculum. The subjects were presented with a wide range of courses to choose from and could rate them based whether they felt the course was non-essential, recommended or essential. The data exhibited the beliefs of leading programs and initiatives across the United States, and showed how engineering education is becoming a growing part of our student's education. While the data was strong and provided a good basis for discussion, what may have made it even stronger was to open the survey to a wider population. Including representatives from universities that offer engineering programs would be one option, as would involving some of the teachers who have participated in the selected programs. This would increase the survey population and could offer even more data that could be analyzed, resulting in a stronger study. However, much like the implementation of engineering education, this study has just scratched the surface, providing an idea of things to come.

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## Appendix A

### Engineering Education Survey

Please return to: Larry Martin  
727 Ellis Avenue  
Baraboo, WI. 53913

Directions: Please read and answer the following statements to the best of your knowledge.

#### Demographic Information

A. How many years has your program or initiative been offered to teachers?

0-4 years                      5-9 years                      10-14 years                      15 or more years

B. For what grade level(s) was your curriculum developed? (Circle all that apply)

Grades:      9      10      11      12      Other: \_\_\_\_\_

Please indicate the approximate number of school districts that have participated or are participating in your program or initiative.

Less than 25	25	50	75	100	125	150	175	200
1	1	1	1	1	1	1	1	1

If more please est.: \_\_\_\_\_

Approximately how many school-aged students have participated or are participating in your program or initiative?

Under 100                      101 – 200                      201 – 300      if more please est.: \_\_\_\_\_

Directions: Please indicate which high school courses high school students should take to be successful using the curriculum provided by your project by circling  
 NE = Not Essential (1); REC = Recommended (2); ESS = Essential (3).

### High School Students – Math

1. General Math: A course designed to improved student ability with basic mathematics concepts. It is typically offered for those students that are not ready for Algebra I.

NE REC ESS

2. Algebra: The focus of the course is primarily on algebraic concepts; however, topics focusing on logical, reasoning, measurement, probability, statistics, discrete mathematics, and functions are often included.

NE REC ESS

3. Advanced Algebra: Students will work with advanced algebraic concepts; in addition instruction in logical, reasoning, measurement, probability, statistics, discrete mathematics, and functions are typically included.

NE REC ESS

4. Geometry: Students will learn the logical arrangement of thought processes, geometric rules, and their applications. Students also study triangle trigonometry, vectors and 3D figures.

NE REC ESS

5. Functions and Statistics: Emphasis is placed on functions and graphing, along with statistics and the use of statistical reasoning.

NE REC ESS

6. Trigonometry: A study of trigonometric functions, including relationships between the sides and angles of triangles and their respective calculations.

NE REC ESS

7. Pre-calculus: Students will be introduced to calculus concepts, including logic, statistical work and graph theory.

NE REC ESS

8. Calculus: Emphasis will be placed on topics such as properties and functions of graphs, limits, continuity, differential calculus and integral calculus.

NE REC ESS

9. Other high school math courses:

\_\_\_\_\_ NE REC ESS

\_\_\_\_\_ NE REC ESS

## High School Students – Science

10. Physical Science: Students will focus on the following areas: matter and measurement, motion and its cause, using force and motion, forces in solids, liquids and gases, work, energy and power, sources of electric current, currents and circuits, and magnetism and electromagnetism.

NE REC ESS

11. Biology: The study of all living systems emphasizes cells, chemistry, genetics and the animal kingdom.

NE REC ESS

12. Chemistry: The course deals with the structure, composition and properties of matter and the changes that take place when matter becomes involved with energy.

NE REC ESS

13. Physics: The course is a study of the physical laws governing matter and energy in the areas of heat, wave energy, electricity and magnetism.

NE REC ESS

14. Biotechnology: Students will apply ideas such as genetic engineering, monoclonal antibodies, or recombinant DNA products in hands-on labs to see how they are being used by industries such as agriculture and medicine.

NE REC ESS

15. Other high school science courses:

\_\_\_\_\_ NE REC ESS

\_\_\_\_\_ NE REC ESS

16. Any additional comments related to what high school students need to be successful in learning an engineering education curriculum?

Directions: Please indicate which university level courses you would recommend a teacher have completed to successfully teach your project's curriculum by circling NE = Not Essential (1); REC = Recommended (2); ESS = Essential (3).

### University Level - Mathematics

17. College Algebra: Students will apply the following basic algebraic skills: factoring, exponents, rational expressions, linear equations and inequalities, systems of equations, and quadratic equations. An introduction to functions will conclude the course.

NE REC ESS

18. Trigonometry & Analytical Geometry: Examination of circular functions, their graphs, inverses, identities and applications. Students will study right triangle trigonometry and applications. Applications of calculus for rational, algebraic, circular, exponential and trigonometric functions; formal integration will be included in course content.

NE REC ESS

19. Probability and Statistical Analysis: The course will introduce students to the following: exploratory data analysis; basic probability, probability distributions, mathematical expectation, sampling distributions; basic statistical inference (estimation and hypothesis testing); topics in reliability.

NE REC ESS

20. Calculus I: The following topics will be presented: functions, limits, continuity, bounds, sets; the derivative of functions and applications; exponential, logarithmic, trigonometric and inverse functions.

NE REC ESS

21. Calculus II: The course will build from the topics in Calculus I and proceed into: antiderivatives; integration theory and techniques, applications; parametric equations, vectors.

NE REC ESS

22. Other university level math courses:

\_\_\_\_\_ NE REC ESS

\_\_\_\_\_ NE REC ESS

### University Level - Science

23. Biology: Students will be introduced to life processes, cell biology, genetics, molecular biology, evolution, ecology, plant and animal diversity. Life systems are viewed from the sub-cell to the community level, emphasizing the variety, functions and interaction of whole organisms.

NE REC ESS

24. Biotechnology: Students will be introduced to theory and lab experience in recombinant DNA techniques and their applications in the biotechnology field.

NE REC ESS

25. Chemistry: Students will be presented with fundamental principles of chemistry with applications in the composition and structure of matter, formation and naming of compounds, mole concepts, writing and balancing chemical equations, states of matter, equilibrium, solutions, and acids and bases.

NE REC ESS

26. General Physics: Algebra and trigonometry based general physics course. Students will focus on the study of mechanics and sound with required laboratory.

NE REC ESS

27. College Physics: Calculus-based general physics course: students will focus on the study of mechanics with thermodynamics with required laboratory.

NE REC ESS

28. Other university level science courses:

\_\_\_\_\_NE REC ESS

\_\_\_\_\_NE REC ESS

### University Level - Technology/Engineering Design Courses

29. General Engineering Design: Students will be introduced to drafting principles, concepts, and the language necessary to present technical information on industrial drawings through sketching, traditional drafting and computer (CAD) techniques.

NE REC ESS

30. Mechanical Design: Course content will include the analysis and design of machine elements: gearing bearings, shafting and friction devices. Design principles will be used to solve problems related to these products.

NE REC ESS

31. Engineering Design: Design concepts and drafting techniques. Freehand sketching, problem solving, and drafting procedures will be used to communicate design intent. Emphasis on special visualization, conceptualization, and graphic communication.

NE REC ESS

32. Electricity/Electronics: Students will be presented with concepts and analysis techniques in DC and AC circuit analysis including: current, voltage, resistance, capacitance, inductance, impedance, loop and node equations, transients, network theorems, real, reactive and apparent power in AC circuits. These ideas will also be applied to mathematical functions related to the field.

NE REC ESS

33. Digital Electronics: Students will acquire theory and lab knowledge in junction and field effect transistors as switches, basic digital and switching circuits, bipolar and Mosfet logic families, digital integrated circuit schemes and building blocks, multi-vibrators, memory elements, digital to analog and analog to digital converters.

NE REC ESS

34. Fluid Power Systems: Topics to be covered include: basic fluid mechanics, pneumatics, hydraulics, control systems and common industrial circuits.

NE REC ESS

35. Materials and Processes: Students will learn various manufacturing processes, material properties and their selection for products. Structure and characteristics of metals, polymer/wood, ceramic and composite materials will be analyzed.

NE REC ESS

36. Other recommended university level technology/engineering design courses:

\_\_\_\_\_ NE REC ESS

\_\_\_\_\_ NE REC ESS

37. Any additional comments related to what prospective technology education teachers need to successfully instruct students in and engineering curriculum?



APPENDIX B (Cover Letter)

Larry Martin  
University of Wisconsin – Stout  
727 Ellis Avenue  
Baraboo, Wisconsin 53913  
Phone: (608) 355 - 9973  
E-mail: [lmartin@uwstout.edu](mailto:lmartin@uwstout.edu)

Mr. John Doe, College of Technology, Engineering and Management  
Sample High School  
123 Sample Street  
Sample, Wisconsin 45678

Dear Mr. Doe:

I am a technology education teacher at Wisconsin Dells High School. In addition, I am currently pursuing my Master's degree at UW-Stout in the area of technology education. As a part of the master's program, I am developing my research paper as a discussion of what level of knowledge in math, science and engineering design technology education teachers and students need in order for engineering education to become a part of the technology education curriculum. I realize that this is an issue within the field that needs to be addressed in order to better prepare students for their post-secondary years.

Fortifying the preliminary research that I have already completed on this topic will be the results of the survey that I have mailed to you. I hope to gain more perspective on engineering education with the results of this survey. Your information is of the greatest importance to my research. Confidentiality of singular responses is ensured, as they are collected solely for this study.

I have included a self-addressed stamped envelope for you to return the survey. I would like to receive your input by November 3, 2004. Not only will this provide ample time to complete the survey, it will allow me time to compile the answers you have provided in anticipation of completing my work in the fall semester of 2004. If you have any questions in regards to this survey, feel free to email or phone at the locations listed above. Thank you for your time and participation.

Larry Martin

Technology Education

Wisconsin Dells High School

### Appendix C (Letter of Consent)

#### UW-Stout Implied Consent Statement for Research Involving Human Subjects

##### Consent to Participate In UW-Stout Approved Research

**Title:** How Can Engineering Education Become A Part Of The Technology Education Curriculum?

**Investigator:**

Larry Martin  
Wisconsin Dells High School  
520 Race Street  
Wisconsin Dells, WI. 53965  
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**Research Sponsor:**

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**Description:**

Engineering education is gaining prominence in a number of K-12 curriculums. In Wisconsin, the Department of Public Instruction (DPI) has initiated a name change in technology education to reflect this: Engineering and Technology Education. In addition, industry has directed the impetus toward our nation's schools to better educate students in the field of engineering. Some steps have been taken, including the programs Project Lead the Way, Adventure Engineering, the Infinity Project, and Bridges to Engineering. Many leading universities have also established outreach programs to help local schools implement engineering education. A logical route for engineering education is to be included in the technology education curriculum. What will students need to be successful learners? What will teachers need to be effective instructors?

**Risks and Benefits:**

No risks are evident are evident in the application survey. The potential benefits include the information gained from the study will allow future students research information on this topic. In addition, it can provide school districts that are looking into engineering education with the knowledge of leaders throughout the nation. It will also provide information to school districts that are writing program plans and curriculum in the development of their technology education department.

**Special Populations:**

No special populations will be asked to participate in the survey.

**Time Commitment and Payment:**

I gratefully thank each person who voluntarily participates in the survey. It will help guide my research and aid in my learning as a student and a teacher.

**Confidentiality:**

Your name will not be included on any documents. We do not believe that you can be identified from any of this information. This informed consent will not be kept with any of the other documents completed with this project.

**Right to Withdraw:**

Your participation in this study is entirely voluntary. You may choose not to participate without any adverse consequences to you. Should you choose to participate and later wish to withdraw from the study, you may discontinue your participation at this time without incurring adverse consequences.

**IRB Approval:**

This study has been reviewed and approved by The University of Wisconsin-Stout's Institutional Review Board (IRB). The IRB has determined that this study meets the ethical obligations required by federal law and University policies. If you have questions or concerns regarding this study please contact the Investigator or Advisor. If you have any questions, concerns, or reports regarding your rights as a research subject, please contact the IRB Administrator.

Investigator: Larry Martin  
(608) 253 -1461 (ext.1026)  
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Sue Foxwell, Director, Research Services  
152 Vocational Rehabilitation Bldg.  
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**Statement of Consent:**

By signing this consent form you agree to participate in the project entitled, How Can Engineering Education Become A Part Of The Technology Education Curriculum?

Signature \_\_\_\_\_

Date .....

