An Analysis of Students' Perceptions of Engineering Concepts in a Technology Education Course at North High School

Eau Claire, Wisconsin

By

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ABSTRACT

The purpose of this study was to evaluate students' perceptions of engineering concepts through a pre and post test of students at Eau Claire North High School in the fall of 2006. Students levels of math, science, and technology education courses taken prior to the Principles of Engineering course. The number of courses were compared to see if there was a correlation between increased post test scores and students levels of math, science, and technology education courses taken. Six questions of the research were as follows: What is the relationship between students' math level and related demographics to their prior identification of engineering? What is the relationship between students' science level and related demographics to their prior identification of engineering? What is the relationship between students' technology education level and related demographics to their prior identification of engineering? What is the relationship between students' math level and related demographics to their change in identification of engineering? What is the relationship between students' science level and related demographics to their change in identification of engineering? What is the relationship between students' technology education level and related demographics to their change in identification of engineering?

There was little correlation found between the amount of science, math and technology education courses taken and changes in perceptions of engineering. Many in the student population surveyed took at least two years of science, math and technology education courses prior to taking the principles of engineering class.

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Background of the Problem

The word "engineering" is frequently used in today's society. The degree to which the general public truly understands the duties/qualities of an engineer may not be as common. Sixty-one percent of surveyed adults felt (Discovering Engineering.org, 2006) "not very well" informed about engineering. There may be some ambiguity in society of "what" engineering is and the actual qualities of an engineer are. Engineering, by definition (Webster's, 2004, p. 1), is: "The practical application of science to commerce or industry." Koens' (2004) definition of the engineering method may shed some light on this issue. He felt it is "The engineering method is the use of heuristics to cause the best change in a poorly understood situation within the available resources" (Koen, 2004, p. 2). Engineering has carried a label that only highly successful people in science and math pursue related occupations (Dodge, 2005).

There is a real sense of anxiety in the high tech sector regarding the future of engineering and the replenishment of the field with younger workers based on numbers generated by universities and the other organizations (Beel, 2006). The United States held a world wide ranking of 3rd in terms of engineering degrees completed 30 years ago. Presently, that ranking has fallen to 17th, to indicate a falling trend (Becker, 2005). Projections show that by 2010, more than 90% of the world's scientists and engineers will be living in Asia (Smalley, 2003). Over half of U.S. citizens with an engineering-related degree are 40 years or older (National Science Board, 2004). Data collected since

1990 indicates a 20% decline in math-related bachelor's degrees and the number of engineering degrees has fallen by 9% (Dodge, 2005).

Most science and engineering careers are closely related to the economy and its level of prosperity (Business Roundtable, 2005). Bill Linder-Scholer of ADC Telecommunications believes that the origin of potential engineers is closely linked to the number of students identifying the potential careers in science and engineering in the K-12 school setting (cited in Beel, 2006). There seems to be a real concern about the downward trend of students enrolling in engineering programs. In a recent St. Paul Pioneer Press article, six engineering schools polled in the State of Minnesota indicated that there was a 1.5% decline in junior and senior college engineering students from 1983 to 2003 (Beel, 2006). With 50% of the science and engineering workforce nearing retirement, numbers of students enrolling into engineering-related courses needs to be addressed (Business Roundtable, 2005).

Fifty of the country's top leaders in business and industry have found the need for a federal commitment to fortify science, technology, engineering, and math education. This situation is similar to the late 50's when Russia launched Sputnik into space and subsequent legislation known as the National Defense Education Act of 1958 by the United States (Business Roundtable, 2005). Although the National Defense Education Act had an underlying mission of military strength, the government's outcry was geared toward increasing science education in the classrooms (Kubota, 1997). A 20% decline of engineering candidates, down since 1985, is producing the same Sputnik-like outcry coming from society today in terms of education (Business Roundtable, 2005). The Sputnik challenge caused the United States to invest more money into education and change the conditions of schools (Conti, Ellsasser, & Griffith, 2000). The rational, is that a Sputnik type of challenge is needed to alleviate some of the occupational shortages business and industry faces today.

According to Geoffrey Orsak, School of Engineering Dean at Southern Methodist University, engineering needs some "highly visible heroes, just as the business world has Michael Dell and Bill Gates" (cited in Dodge, 2005, p. 26). These heroes would help change the identity of engineering and so too would parents and other relatives. According to Celeste Baine, the director of engineering education service center for Junior Engineering Technical Society (JET's):

> We need to see math and science as tools to understanding the world and solving problems. Only when our mothers, fathers, sisters, brothers, friends and relatives accept this concept will we, as a society, begin to move forward and graduate more Science, Technology, Engineering and Math (STEM) students. (Baine, 2005, p 2)

While growing up, children demonstrate some of the qualities of an engineer through their activities in play and discovery (Petroski, 2003). Where is the point that children lose the concepts of creativity, design, and innovation as fun and exciting?

"Pre-school students have the prerequisites in their play for appreciating what exactly engineering is: design" (Petroski, 2003, p. 206). Engineering methods and activities are often taught in schools. However, in education, these activities are not being identified as engineering activities (Petroski, 2003). Cognitive development by organizing similar experiences in a child is the definition of schema (Steele, 2005). Creating associations in student's mind, which will develop his/her schema of engineering, will allow for him/her to associate the qualities of engineering back to the days of his/her childhood.

To increase the interest in engineering, the National Science Foundation, NSF, has awarded a grant for development of the National Center for Engineering and Technology Education, NCETE. The main purpose of the NCETE is to deliver engineering, design, and analytical skill building to K-12 schools (National Science Foundation, 2005). The NCETE consists of 9 universities and several public schools located throughout the United States with the aim to develop technology and engineering curriculum, along with teacher professional development. The NCETE mission statement is:

> To infuse engineering design, problem solving and analytical skills into the K-12 schools through technology education in order to increase the quality, quantity, and diversity of engineering and technology educators, and to significantly strengthen the pathways to engineering and technology professions for students. (National Center of Engineering and Technology Education, 2005, p. 1)

There is a 5 year commitment of grant money by the NSF to these centers to infuse engineering design, problem solving, and analytical skills into a K-12 setting (Illinois State University, 2005). The University of Wisconsin-Stout is in partnership with the NCETE project. The NCETE began in 2005 delivering engineering-related concepts to high schools.

Along with the center at the University of Minnesota-Twin Cities, UW-Stout is one of 9 NCETE locations that will, with several high schools, aim to develop potential engineering students in the high school setting. The partners working with UW-Stout include the Wisconsin schools of Eau Claire North High School, Eau Claire, Brillion High School, Brillion, Milwaukee Bradley Tech School, Milwaukee, and Highland Park High School, St. Paul, Minnesota. The intention is to assist these schools in delivering engineering curriculum focusing on manufacturing engineering problems. Technology education teachers were solicited and trained at UW-Stout from these four schools during the summer of 2005.

One of the manufacturing engineering problems used during the fall semester of 2005 was the creation of an individual train car. Technology education students enrolled in an engineering education class were presented the challenge of creating an individual wooden train car. Students were given specifications for the car in order to work together with a six car set. These students produced 50 cars to simulate production methods employed in manufacturing engineering processes. In the upcoming years, partner high schools will continue to develop other curriculum that pose problems and challenge students to develop solutions to engineering-based problems proposed by the NCETE. Solutions will be developed according to curriculums delivered from the partner schools in engineering classes in order to reinforce concepts desired from the NCETE mission.

The NCETE manufacturing engineering treatment is presently being taught in the cooperating member schools by technology education teachers. Many of the concepts that are delivered in this treatment originated from a summer summit that took place at UW-Stout in late June 2005. The three day summit allowed partner teachers to partake in presentations by the professors in the Manufacturing Engineering department about manufacturing methods that are practiced in the industrial world today. Dr. Kenneth Welty and Dr. Brian McAlister presented activities for the teachers involving jig and fixture generation and engineering education delivery methods. Partnership teachers began to construct their own jigs and fixtures that were used in the manufacturing process of the wooden train cars. At the end of the summer summit, teachers created a train engine, coal car, passenger car, tanker, grain car, and caboose that would represent each car in the set. Teachers then took their experiences from the summer summit and applied them to the technology education classroom in the NCETE treatment of manufacturing engineering during the fall 2005 semester.

Statement of the Problem

The importance of developing good engineers from the United States is a priority recognized by the National Science Foundation. Grant money has been provided for the creation of a center for the development of future engineers in the United States. The National Center of Engineering and Technology Education has been developed through a grant from the National Science Foundation with ideals of delivering engineering concepts into the K-12 education setting (National Center of Engineering and Technology Education, 2005). There has been limited evaluation of the NCETE program to determine students' change in perceptions of engineering qualities after an NCETE treatment in a high school Principles of Engineering course.

Purpose of the Study

The relationship between the desired outcome of the NCETE project goals and what students' comprehension is upon exiting the program needs to be evaluated. The goals of this study were to compare students' attitudes in a Principles of Engineering class at Eau Claire North High School during the fall of 2006 through a pre and post survey of the NCETE treatment. A survey measured these students' attitudes towards engineering prior to entering and after the NCETE treatment to identify any changes. The goals of students' comprehension of engineering technology concepts upon exiting the program set forth by National Center for Engineering and Technology Education were evaluated to determine the effectiveness of the center.

Research Questions

The following questions of the study were addressed to determine the students' knowledge of engineering prior to entering and upon exiting the class:

1. What is the relationship between students' math level and related demographics to their prior identification of engineering?
2. What is the relationship between students' science level and related demographics to their prior identification of engineering?
3. What is the relationship between students' technology education level and related demographics to their prior identification of engineering?
4. What is the relationship between students' math level and related demographics to their change in identification of engineering?
5. What is the relationship between students' science level and related demographics to their change in identification of engineering?
6. What is the relationship between students' technology education level and related demographics to their change in identification of engineering?

Importance of Topic

The five identified areas that make this an important topic of study are listed below:

1. With the possibility of the United States only working on less than 10% of the engineering projects in the next 10 years (Finley, 2005), the decline of engineers has to be addressed. Potential engineers within the United States need to develop in our high school and middle school technology education, math, and science courses.

2. Young people create an identification of the concepts of engineering and how they are related between other disciplines. Since many disciplines have become interwoven over time, it is unclear of what engineering is in comparison to what science is or even business (Clough, 2005). The Science, Technology, Engineering, and Mathematics education initiative is striving to bring teachers of each one of these disciplines together to deliver related curriculum (Lipton, 2005). Bringing disciplines together would allow students enrolled in engineering technology education courses the importance that science and math plays in their education.

3. Children experience the concepts of engineering at an early age, but fail to recognize that they are actually performing engineering (Petroski, 2003). The word engineer in a child's schema relates to a train conductor, not to the characteristics of design and problem solving (Petroski, 2003). Children in their early stages of education need to be taught that some of the activities that they participate in are engineering-related. If students have a schema on engineering created in high school, the 61% of adults surveyed as not being familiar to engineering would decline (Discovering Engineering.org, 2006).

4. As stakeholders in the NCETE project, we need to highlight the relationship of design and imagination to high school students and how these relate to some of the same qualities that exist in the engineering community. Students can develop a schema with engineering and their early childhood days of design and creation through a treatment developed from NCETE-based projects.

5. The concept of preserving the field of engineering by increasing the numbers of high school-aged students participating in engineering-related technology education programs is becoming important to the future of engineering. Students will have the opportunities to design and develop products through the use of engineering qualities in technology education courses.

Limitations of the Study

In conducting research, there will be some form of limitation in gathering the precise data needed to make a conclusion. The following five points will serve as possible limitations to the study.

1. Limitation at Eau Claire North may not allow for the Principles of Engineering course to fully address engineering concepts desired from the NCETE goals and mission. Depending on what time, materials, and facilities are available at Eau Claire North, all topics that are on the survey may not be covered.

2. Students enrolled in the class may be junior or seniors, which does not include sophomore or freshman students. Students at a junior or senior level may have a different prior knowledge of engineering compared to a sophomore or freshman level student depending on previous courses taken.

3. A prerequisite may be placed on the class which would not allow any students to enter without a certain level of math or science. This prerequisite may again skew the number of students who have an elevated level in prior knowledge of engineering compared to a general population of high school-aged students.
4. Questions on the survey may be misinterpreted. Students may not have a clear impression of what the question on the survey is actually asking, causing error in the students' answers to the survey.
5. Students may not comprehend what the question is addressing and answer the question with a lower level of sincerity. Based on some different terminology, the survey questions may contain words that are beyond the level of their vocabulary. Not comprehending some terms may cause the students to make assumptions, which would alter the results of the survey.

Definition of Terms

The following terms are listed throughout the chapters of this paper. This portion will serve as a reference for each term.

Engineering - The practical application of science to commerce or industry; the discipline dealing with the art or science of applying scientific knowledge to practical problems (Webster's, 2004).

Heuristic - Is anything that provides direction in the solution of a problem, but is in the final analysis and does not justify a point (Koen, 2004).

National Center for Engineering and Technology Education (NCETE) - Creates a partnership of technology education teachers and engineering educators to build capacity for research; develop teachers in the technology education field, diverse leaders in engineering and technology education; and deliver engineering curriculum, design, and analytical skills into K-12 schools (National Science Foundation, 2005).

National Science Foundation (NSF) - A federal agency created by Congress in 1950 to promote progression in science, national health, prosperity, welfare, and securing the national defense (National Science Foundation, 2005).

Schema - Cognitively developing a child to organize similar experiences so that they can be easily recognized (Steele, 2005).

Chapter II: Literature Review

Introduction

This chapter will include a discussion of the definition of engineering and what society deems as engineering, followed by the purpose of curriculum in pre-engineering courses. In addition, the composition and make-up of students in these pre-engineering classes will be discussed. The chapter will conclude with the recognized methods of learning in pre-engineering.

Definition of Engineering

As stated in chapter one, society does not have a clear definition of engineering in which everyone can place an association. A standard definition of engineering according to Dr. Michael Davis (1996) is:

> An engineer is a person having at least one of the following qualifications: a) a college or university B.S. from an accredited engineering program or an advanced degree from such program; b) membership in a recognized engineering society at a professional level; c) registration or licensure as an engineer by a governmental agency; or d) current or recent employment in a job classification requiring engineering work at a professional level. (p. 13)

It would be very difficult for a young person to identify an engineer at work based solely on the definition from Dr. Davis. An engineer by society's perception is one who has met the following criterion: having a degree from an accredited program or employment in a job requiring engineering at a professional level. Young people would have a difficult time creating an association if they have not seen an engineer at work or have drawn a correlation between activities and engineering.

A child may have a difficult time creating a schema of engineering due to lack of engineering-related experience in school or the real world. Some research was done by the Museum of Science in Boston to measure what children consider is a profession of an engineer. Christine Cunningham, vice president of research for the museum mentioned younger people's schema of an engineer is that "Kids typically think they're construction workers, auto mechanics, or computer technicians. Even younger children think that they drive trains" (cited in Brown, 2005, p. 16). When looking at society, it is very difficult to determine which activities are considered engineering-like unless the engineer would meet selected criteria. Constructivist theory defines learning as a continuous process in which learners take information from their surroundings or environment and construct personal meanings based on prior knowledge and experience (Kozulin, 1998). One should consider looking to the past sources to consider how society constructed the meaning of engineering.

The title of engineering originated during the Middle Ages from the Latin word in generare, which means to create (Wright, 2002). Applications of the word engineer came in the form of war activities or personnel in the army. "The first people to be called engineers were soldiers associated with engines of war (catapults, siege towers, and the like" (Davis, 1996, p. 15). The specialty of a soldier involved with the design and construction of catapults differed from what a person in charge of the designing a siege tower or other war-related equipment. Did this regard to specializing in one area continue to the present day when one would take into consideration the areas of disciplines related to engineering?

With technology and other endeavors of the world expanding beyond previous boundaries, the need for specialization exists. Looking at a construction site, there are many workers, air-condition technicians, welders, carpenters, masons, heavy equipment operators, and engineers working on putting the pieces of an engineering puzzle together (Lewis, 2004). A common theme to this puzzle is applying math and science through the manipulation of materials to benefit human kind. Tammy Richards, Assistant Dean of Engineering at Southern Methodist University, believes the source of a definition is the responsibility of engineers. "Engineers need to clear up the misconception that engineering is about widgets. It is really about solving problems for people" (cited in Brown, 2005, p. 16). The children, according to the previously mentioned Boston Museum of Science study, and the origin of the term engineering, create a wide variety toward what determines the specialization of an engineer.

Purpose of Pre Engineering Curriculum

The variety of what an engineer does has existed from present day throughout the history of engineering. The part of engineering that has seen little change is how engineering is applied. With the first applications of engineering used in war, engineers were concerned with reliability, speed, and practical considerations. Testing materials and construction procedures were recognized as early engineering (Davis, 1996). Looking at the previous components of engineering, an application of science in math to manipulate materials for the benefit of mankind, the first applications of engineering had the same applications. Although it may be difficult to find a benefit for humans in using something engineered for war, those were the times. Early war-like methods of engineering have roots in selecting years of study and ending with a capstone project. To teach soldiers the proper subjects in order to become specialized in a certain war-like application of engineering, the French were the first to create an engineering learning center back in the late 1700's

In 1794, Ecole Polytechnique of France delivered some of the first attempts in engineering curriculum. Classes consisted of lab, drawing, and presentations after each lecture. First year courses consisted of: geometry, trigonometry, physics, fundamentals of chemistry, and practical applications in structural and mechanical engineering. Second and third year classes consisted of more applications in building roads, canals, and fortifications. The last year of the engineer's education was spent at a specialized school in military, artillery, engineering mines, bridges, and roads (Davis, 1996). As with most new trends in the world, other countries had to come up with their own version of Ecole Polytechnique, the United States version was created at West Point.

In the United States, engineering education has seen its origin come from two strands. The original curriculum came from West Point, eight years after Ecole Polytechnique, which evolved into engineering education in the United States. Another strand consisted of experiments with various alternatives from the original West Point curriculum (Davis, 1996). The years went by and methods of engineering were not only specialized to war applications, but other needs that were to benefit human kind. One constant remained with the curriculum of engineering; there was an application of math and science to materials to benefit human kind. Applications of engineering became known as engineering design and benefits of this design method were felt in our learning institutions.

The importance of sound instruction and curricular content in engineering is dependant on the enduring understandings of the profession. Since engineering is an application that has not seen subject boundaries, learning in education relies on the many disciplines for its application. Learning in engineering goes farther than calculations, there are characteristics in design that are important, such as: critiquing, identification of trade-offs, teamwork, and invention (Lewis, 2005). There can be many benefits in an engineering classroom that students and teacher both can observe. Engineering education promises profound changes in the way students learn science. Instead of passively absorbing knowledge from textbooks and packaged laboratory experiments, students use scientific method - learn, hypothesize, test and compare - to create something new (Brown, 2005). The benefit of becoming better at learning science or other subjects may be a benefit of engineering education and engineering may help a student see the whole picture. According to Gene Bottoms, head of the Schools That Work program at the Southern Regional Education Board, "Engineering helps students to see a reason for what they're learning. It deepens their understanding of the academic concepts and increases retention. It shows them that mathematics and science matter" (cited in Brown, 2005, p 16). As the trend in the 1800's was to teach engineering to students other than soldiers, today educators and society look to the high schools to deliver engineering in the form of pre-engineering education.

Applications of math and science, along with the manipulation of materials, are part of the roots of engineering and pre-engineering education. The question would lie in which subject area should deliver pre-engineering education to high school aged students. According to Dr. Theodore Lewis (2005), professor at the University of Minnesota,

> The climate for engagement with engineering is now inviting; technology education is being viewed favorably as a credible means of advancing the goal of technology literacy for all, and a means by which students can gain insights about and interest in engineering careers. (p.37)

Dr. Lewis expressed an interest in collaboration in more than one classroom with delivery of pre-engineering education. Other approaches to engineering education would be the collaborative approach of involving teachers in math and science along with practicing engineers in the role of teaching design (Lewis, 2005).

The collaboration would involve scheduling activities and lectures to coincide with what is presently being taught in each class. An example would be the engineering theme of materials processing within three courses. The science class would talk about molecular make-up and properties, math would discuss calculations of fractions and decimals, and the technology education class would work on a lesson in measurement and/or materials processes. In some schools this scenario may not be feasible, in which case the technology education teacher may have to take the responsibility of teaching engineering classes. Teachers of pre-engineering education would bring a greater amount of academic rigor and relevance to the classroom (Rogers & Rogers, 2005).

Dr. Lewis suggested that "Teachers of engineering classes should have a competency in math and science" (Lewis, 2005, p. 50). Pre-engineering education would require the teachers to apply large amounts of math and science to their classroom. Pre-engineering education can become a broad field of study. As in technology, it is a synthesis of many experiences and draws on a wide range of concepts, not containing subject boundaries. Developing authentic problems and developing solutions are essential in a student's education (Twyford & Jarvinen, 2000). This form of education would be challenging yet beneficial in terms of what the teacher has to learn and deliver to the students.

Although there is a challenge in pre-engineering education, there would be some benefits to this form of education in terms of what students will gain out of a class. According to Rogers and Rogers (2005), "Pre-engineering education focuses on preparing students for careers in engineering and engineering technology, while technology education provides students with general technological literacy applicable to every career field" (p. 89). There have been some misconceptions with technology education in the past. "Unlike the past, when educators said technology meant computers, these courses deliver a true experience" (Brown, 2005, p. 14). Looking at the benefits, students, teachers, and even the discipline of technology education can benefit from pre-engineering education. According to an article written by Steve and George Rogers (2005) in the *Journal of Industrial Teacher Education*, "Technology Education can benefit from the inclusion of pre-engineering education by increasing students' technological literacy, promoting increased academic rigor and relevance, and eliminating the view that technology education is unessential in school curriculum" (p. 88). With pre-engineering education being beneficial to the student, teacher, and the professions of engineering and technology education, the composition of the pre-engineering classroom needs to be determined.

Composition of Students/Classes

Some students may have an interest in participating in a pre-engineering high school level course and not be able to handle the vigorous amounts of math and science that are a part of the curriculum. In some instances, teachers are surprised with the outcome of some academically labeled average students. "This is not an honors class. None of them thought he or she could do it, but they all proved very capable of coming up with unique designs. If I had tried to teach these concepts from a textbook, they wouldn't have absorbed what they meant" (cited in Brown, 2005, p. 14) said Parkview Baptist High School Algebra, Baton Rouge, LA, teacher Sheri Goings. Textbooks may not be the only answer to the pre-engineering curriculum. Educators have to be willing to identify alternative methods of curriculum delivery when searching for success with their students. Problem-based learning is appropriate for beginning level engineering courses by helping students develop skills and a level of confidence in solving problems they have not experienced before (Smith, Sheppard, Johnson, & Johnson, 2005).

Finding alternative methods of curriculum delivery is important in reinforcing pre-engineering education. Teachers, along with students, may find it difficult to apply math and sciences with the use of only a textbook in a technology education classroom. Hands-on projects engage many average students that lectures would normally leave behind (Brown, 2005). Applying and answering questions in a student's mind is important to the educational process, regardless if he/she will go on to college or two year schooling to further his/her education. Richard Blais, executive director of Project Lead the Way, believes that two year college students and higher level students would both succeed in a pre-engineering curriculum. Two questions that need to be answered in the student's mind, "Why do I need to know this? and Where will I ever use it?" (cited in Brown, 2005, p. 19). Identifying how students will apply knowledge from pre-engineering education is important to the development of the student's schema of engineering. A part of the pre-engineering spectrum that is important to educators is determining how students will learn what is being taught.

Methods of Learning

As unique as each individual, the method of which a student is most effective in learning is also unique. According to Richard Blais, Executive Director of Project Lead the Way (cited in Brown, 2005), "Only about 20 percent of students can really learn from lecture-style teaching. A project/problem based teaching approach accommodates a wider range of learning styles" (p. 19). If 80% of students have difficulty learning from a lecture setting, it is important to look at what will keep students engaged in learning. The National Survey of Student Engagement (NSSE) is used to determine levels of engagement of college students. Students' responses to the survey are targeted around five areas (Smith et al., 2005):

1) Level of academic challenge: Schools encourage achievement by setting high expectations and emphasizing importance of student effort.

2) Active and collaborative learning: Students learn more when intensely involved in educational processes and are encouraged to apply their knowledge in many situations.

3) Student faculty interaction: Students able to learn from experts and faculty serve as role models and mentors.

4) Enriching educational experiences: Learning opportunities inside and outside the classroom (diversity, technology, collaboration, internships, community service, capstones) enhance learning.

5) Supportive campus environment: Students are motivated and satisfied at schools that actively promote learning and stimulate social interaction. (p. 87)

With these five areas necessary for engagement, an educator should find methods to apply each one of these areas in his/her classroom. The application of these areas would be difficult for the instructor to initiate on his own. The attempt of meeting these five areas of engagement is necessary to keep a students' level of engagement in the learning environment at a high level.

With the five listed components of engaged learning, number one would be taken care of by the curriculum in a pre-engineering class by applying math and science in search of a solution to a problem or other course work. An educator must strive to make active and collaborative learning, the second statement, part of the classroom environment. This could be done through team teaching with other teachers on a subject or even having the students learn together as a group. There may be some difficulty in finding experts in the field of engineering in high school buildings. Teachers could invite guest speakers to come into the classroom to present information related on the topic. Learning from a practicing engineer on certain topics or applications of engineering would provide more relevance to a student than a text book or a lab activity. To coincide with statement three, statement four would take students out on field trips and/or connect students with guest speaker opportunities, as well to enrich educational experiences. Children increased their technological capabilities and technological knowledge by participating in design and technology-related activities (Foster & Wright, 2001). In the final statement, the campus or high school environment should provide a sense of motivation and accomplishment. Both of these can be done by promoting the students' accomplishments through presentations in front of the school board or principal. Students will need to find meanings to these experiences in the classroom in order to gain an understating of pre-engineering education.

A quality of a professional engineer is to have the skill set of a problem solver and designer. In order to generate the schema of an engineer being a problem solver and/or designer, an educator has to find authentic situations in which the students could learn and demonstrate problem solving and design. In a study by Smith and Carlsson (1985), creativity increased in adolescents 14 to 15 years of age and a larger increase was noticed at age 16. Teachers will have to be aware of the student's level of creativity and drawing conclusions when participating in these activities. Based on a study by Wu, Yim, Ip, and McBride (2005), university level students were significantly more creative in developing and drawing conclusions to real life problem solving activities. In previous discussion, a learner is dependant on taking past experiences and associating them to a current situation in order to make a decision. In a study conducted by Twyford and Jarvinen (2000), children came up with solutions to a technologically-focused problem based on experiences and imagination. In the spirit of problem solving and design, teachers will have to promote creativity and imagination in their students. This promotion will allow students to experience and make associations through problem solving and design necessary in the construction of a definition and schema of the term engineering.

Chapter III: Methodology

Introduction

As courses are being developed in engineering education the need to determine if students are synthesizing the desired information needs to be evaluated. This chapter will discuss the selection and description of the subjects for the evaluation of the NCETE project. In addition, the instrumentation and collection/analysis procedures used in the study to determine if students grasp engineering concepts following a NCETE treatment will be discussed. Finally, limitations that could exist with the delivery and data collection associated with this survey will be identified and discussed.

Subject Selection and Description

The NCETE project at UW-Stout consisted of five partner high schools with the mission to deliver pre-engineering curriculum to technology education students. Working with the technology education staff at Eau Claire North High School through the NCETE project, a couple factors led to the selection of their students for the purpose of this survey. One factor was the size of the class. From 2005-2006 there were 27 students which led to a high number of students surveyed in comparison to other partner schools. Another factor was the diversity that existed in the classroom at North High School in terms of cultural, age, grade, and level of science and math taken. The only pre-requisites for the Principles of Engineering course students in the survey were a suggested semester and a half of science and two years of math. Students participating in the Principles of Engineering course did not have any related engineering courses because this was a prerequisite to other engineering courses at North High. The research questions looked to identify any correlations between math, science, technology course, and related demographics. Based on the five NCETE partner schools, Eau Claire North's fall 2006 class offered the greatest potential for data sampling.

Instrumentation

With the NCETE funded through a grant from the National Science Foundation there were many resources available for potential instruments. Tanna Kincaid, an Information Technology Supervisor for the State Board for Vocational and Technical Education in North Dakota, has been initiating a survey of middle and high school students looking at the idea of engineering. Looking at the survey delivered by her group this researcher obtained permission to use questions from her survey to relate to this research. The survey consisted of 20 questions related to demographics and engineering methodology. Students were directed to make a choice based on what is the best solution to reflect the question. Following a six week treatment of engineering-related curriculum, students took the same test to determine if any changes took place. There have not been measures or documentation of validity or reliability available at this time, since the instrument was designed for the purposes of this study.

Data Collection Procedures

The survey was administered prior to and following an engineering treatment that took place in a Principles of Engineering class at Eau Claire North High School. Ed Jeffers, Principles of Engineering instructor, administered the tests to the students at two set times in the school year; one early in the semester, and the other following the treatment. The first survey was delivered in the Principles of Engineering class during the second week of school in the fall of 2006. The researcher obtained IRB consent along with parental consent, prior to each student's participation. Students were given the option of selecting a choice of one solution to a scenario listed with each question. If a student was absent the day of the administration of the survey, he/she was given the opportunity to take the survey up to three school days following the survey. The surveys were then collected and processed to find any correlations to the level of math, science, technology courses taken, related demographics, and answers to the engineering-related questions.

Data Analysis

Data was processed through the services offered by UW-Stout for responses on the pre and post test. Central tendencies were identified in the pre and post test to find the mode of each question answered and if there were any correlations to related demographics. Chi-squared method was used to test response significance.

Limitations

With the data collected being multiple choice, data may have some limitations in terms of responses. The following five points served as possible limitations to this study.

1. Limitation at Eau Claire North may not allow for the Principles of Engineering course to fully address engineering concepts desired from the NCETE goals and mission. Depending on what time, materials, and facilities were available at Eau Claire North, all topics that were on the survey may not have been covered.
2. Students enrolled in the class may be juniors or seniors, which does not include sophomore and freshman students. Students at a junior or senior level may have different prior knowledge of engineering compared to a sophomore or freshman level student, depending on previous courses taken.

3. A prerequisite may be placed on the class which would not allow any students to enter without a certain level of math or science. This prerequisite may again skew the number of students who have an elevated level in prior knowledge of engineering compared to a general population of high school-aged students.
4. Questions on the survey may be misinterpreted. Students may not have a clear impression of what the question on the survey is actually asking, causing error in the students' answers.
5. Students may not comprehend what the question is addressing and answer the question with a lower level of sincerity. Based on some different terminology, the survey questions may contain words that are beyond the level of their vocabulary. Not comprehending some terms may cause the students to make assumptions, which could alter the results of the survey.

Chapter IV: Results

Introduction

This chapter will include a discussion of participant demographics and responses to the twenty question survey that was presented to Eau Claire North Principles of Engineering students in the fall of 2006. Comparisons will be made between participants pretest and post test responses with supporting data tables. The chapter will conclude with the hypothesis of the results in the survey.

Demographic Information: Results from Questions 1, 2, 17, 18, 19, and 20

The survey was distributed to 16 students, who returned parental permission slips, while enrolled in the Principles of Engineering class at Eau Claire North. Distribution of the pre-test took place in early September prior to the NCETE treatment and post testing took place in late November following the treatment. The first question was used to determine gender demographics. Males represented 87.5 % of the surveyed participants, while females represented 12.5 % of participants.

Table 1: Gender of Survey Population

Gender	Frequency	Percent
Male	14	87.5
Female	2	12.5

Survey question number two was used to determine the students' intentions following the completion of high school. All 16 students surveyed responded that they planned on attending college.

Table 2: Students Intentions After Completion of High School

Do you intend on attending college?	Frequency	Percentage
Yes	16	100
No	0	0

Survey question number 17 was used to determine the grade level of students participating in the survey. Of the students surveyed, one sophomore (6.3%), nine juniors (56.3%), and six seniors (37.5%) participated.

Table 3: Grade Level Distribution

Grade Level	Frequency	Percentage
Sophomore	1	6.3%
Junior	9	56.3 %
Seniors	6	37.5%

Survey questions numbered 18, 19, and 20 were used to determine the number of technology education, math, and science courses taken prior to enrolling in the Principals of Engineering class. Three of sixteen students responded in question 18 that Principles of Engineering was their first technology education class. Two students were taking this as their second technology education class, and eleven students were taking Principles of Engineering as their third or more technology education class.

Table 4 Students Previous Level of Technology Education Courses Taken

Levels of Technology Education	Number of Students
Principles of Engineering as the first Technology Education course taken	3
Principles of Engineering as the second Technology Education course taken.	3
Principles of Engineering as the third Technology Education course taken.	1
Principles of Engineering as fourth or more Technology Education course taken.	9

In question 19, four students indicated that they have taken two math classes; twelve students indicated that they have taken three or more math classes.

Table 5 Students Previous Level of Mathematics Courses Taken

Levels of Mathematics Courses Taken	Number of Students
At least two math courses taken prior to Principles of Engineering	8
Three or more math courses taken prior to Principles of Engineering	8

Only one student indicated in question 20 that he or she has taken only one science class, four students indicated that they have taken two science classes, and eleven students have taken at least three sciences classes. Table 5 on the following page will illustrate the student demographics in relation to science courses.

Table 6 Students Previous Level of Science Courses Taken

Levels of Science Courses Taken	Number of Students
One Science Course taken prior to Principles of Engineering	1
Two Science Course taken prior to Principles of Engineering	6
Three or more Science Course taken prior to Principles of Engineering	9

Item Analysis

Results from Question Number 3

The cross tabulation table on the following page illustrates the results from question 3: What is the main reason for taking Technology Education class? A couple of students' opinions on the main reason for taking this classed changed from pretest to posttest. Having an interest in the subject was the popular response for both pretest and post test. Response A was if the students were recommended to take the class by a teacher or counselor. Three students responded in the post test and two in the pretest that a counselor or teacher recommended the class. No students responded with response B: It was a required to take. One student in the post test responded with response C: Recommended by a friend or wanted to take class with a friend. Eleven students in the pretest responded with D: Thought the class would be interesting and wanted to try it out. One student in the posttest responded with a combination of A and D. Overall, 11 of the students took the class based on being interested or wanting to try it out. Three students took the Principles of Engineering class based on a recommendation from a counselor or teacher.

Table 7: Cross Tabulation of Main Reason for Enrolling in Class

	Recommended by teacher or counselor Post test #	Required class Post test #	Recommended by friend Post test #	Though class would be interesting Post test #	Combination Post test #	Total
Recommended by teacher or counselor Pretest #	2	0	0	2	0	4
Required class Pretest #	0	0	0	0	0	0
Recommended by friend #	0	0	0	0	0	0
Though class would be interesting Pretest #	0	0	1	9	1	11
Combination Pretest #	1	0	0	0	0	1
Totals #	3	0	1	11	1	16

Results from Question Number 4

In question number four, students were asked to identify which subject area they felt where their skills were the strongest. Students were asked to only choose one of the following six subject areas to identify their strongest area: A-Technical Hands-on Classes, B-English Language Arts, C-Science, D-Mathematics, E-Social Studies, or F-Art and Music. Eleven of 16 students in the pretest responded that his/her strength was technical hands-on. One student in the pretest felt that response B, English/ Language Arts was their strongest. Three students in the pretest indicated science to be their strongest subject area. Two students reported math to be their strongest in the pretest. One student in the pretest indicated that social studies was his/her strongest subject. Art was not reported to be their strong subject in either the pre or posttest. No student reported that English or Social Studies was their strongest in the posttest for any of the students.

Table 8: Cross Tabulation of Students Strongest Subject Area

	Technical Hands on Post test #	English Post test #	Science Post test #	Math Post test #	Social Studies Post test #	Art Post test #	Total Post test
Technical Hands on Pretest #	8	0	1	0	0	0	9
English Pretest #	1	0	0	0	0	0	1
Science Pretest #	0	0	1	2	0	0	3
Math Pretest #	1	0	0	1	0	0	2
Social Studies Pretest#	1	0	0	0	0	0	1
Art Pretest #	0	0	0	0	0	0	0
Total Pretest	11	0	2	3	0	0	16

Results from Question 5

Of the choices provided, students, both in the pretest and post test, responded to one answer to Question 5: Which of the following sentences do you think best describes what engineers do? In this question students looked at different qualities to identify if those qualities were what engineers did. All students chose response four: Design new and better ways of making or doing things. This response was felt to be the optimum choice for the question. Other options for question five were as follows: work with science tools to discover new information, work in factories helping to make new products, and operate large, motorized equipment. As stated earlier, students felt that the best statement in what engineers do is designing new and better ways of making things.

Results from Question 6

Only two choices were popular in Question 6: Which definition best fits the word innovation? Statement A described innovation as finding a better way to make or do something. This statement was thought of as the best solution for question 6. Thirteen students in the pretest found this answer to be the best. Fourteen students in the post test found that innovation was finding a better way of doing or making something as the best description. Three students in the pretest and two in the post test found that innovation was described as seeing problems from many different angles. Other possible choices were: creating man-made devices, and learning something new about nature.

Results from Question 7

Similar to the response in question five, students found one answer was suitable in both the pretest and posttest of the following question: Which words describe a good engineering design? All sixteen students in both the pre and post test found that response C, effective/efficient/reliable were words that best described engineering. This statement was thought of as the best choice for Question 7. Other choices were: big/expensive/high tech, fast/cheap/lightweight, and small/complex/reliable.

Results from Question 8

Students were given a scenario of which would they find the best way of telling someone about an idea of a new and improved bicycle. In the pretest, five students found the easiest way of telling somebody about new ideas for a bicycle was to build a full working model of the design. Six students in the post test found building a full working model would be the best method to express new ideas of a bicycle. Eleven students in the pretest felt that making a sketch to show important details was the best method of showing improvements in a bicycle. Ten students in the post test felt that drawings would be the best method for showing innovation. This option, Option D, was felt to be the best way to complete the statement for Question 8. Other options for Question 8 were: write out a long descriptive list, and use an audiotape of yourself describing the details. Listed below is a cross-tabulation table of pre and post test responses to Question 8.

Table 9: Cross-Tabulation of Students Method of Telling Someone about Innovation

	Build Full Model of the Design Posttest # of Students	Make a Sketch/Show Important Details Posttest # of Students	Total
Build Full Working Model of the Design Pretest # of Students	3	2	5
Making a Sketch/Show Important Details Pretest # of Students	3	8	11
Total	6	10	16

Results from Question 9

Fifteen out of 16 students surveyed, in both the pre and post test, found that the best response to Question 9, the reason for brainstorming when trying new ideas, was it is a good way to come up with many ideas quickly. This statement was thought of as the correct statement for Question 9. One student, in both the pre and post test, thought that talking about ideas was much easier than writing them down. Other possible choices for reasons for brainstorming when trying new ideas, it's a lot more fun for students to work together as a group, and we get to use our brains for a little while before using our hands.

Results from Question 10

In comparison to the pretest, students found many answers to be useful in the post test Question 10: Which of the following is the best example of research and development (R&D) in a technology laboratory? Thirteen students in the pretest found that statement two, engineers experimented with different materials to find the best one for the job, would be the best example of research and development in a technology lab. Eleven students found this statement to be true in the post test. This statement was the optimum for Question 10. Three students in the pretest and one in the posttest found that statement four, designers asking clients to select furniture styles, was the best representation of research and development in a technology lab. Three students in the posttest found that statement one, a machine stopped working and the problem had to be found and fixed, was the best representation of R&D in a technology lab. One student each found that testing samples of carbon to find the purest one, statement three, would be the best response to Question 10.

Results from Question 11

Question 11 asked students to identify the best definition of a prototype. Fourteen students in the pretest thought that a prototype was defined by models used to test and improve an idea, Statement 1. Thirteen students found this statement to be the best statement in the posttest. Statement one was the best choice to complete the statement for Question 11. Two students in the pretest found that statement four, 3-d models show size/shape of a product, was the best definition of a prototype. No students in the post test found this statement to be the best option. One student in the post test found that Statement 2; sketches show visual details of design, to be the best definition of a prototype. Two students in the post test found that Statement 3, first "finished product" when design job is done, to be the best definition of the prototype.

Results from Question 12

In Question 12, the process of testing a new design idea or product helps in what ways, fifteen out of sixteen students in both the pre and post test found that all three statements help develop a product or new design. Choosing all of the above was the best response for Question 12. One student found in both the pre and post test that testing only found changes needed to improve a design, Statement 2. Statement One was, we can see if our idea will actually work; Statement 3 was, we can find out whether people will like the product.

Results from Question 13

In both the pretest and post test, thirteen out of sixteen students responded that math/science/computer application were best to address Question 13: In order to become an engineering professional, which of the following type of high school courses would best prepare you? Statement B, math/science/computer application was the best for response for Statement 13. Two students in the pretest and one student in the post test felt that English/business/ foreign language would be the best course to take for a prospective engineering student. Two students in the post test felt that social studies/science/art would be the best choices in courses for a prospective engineering student.

Results from Question 14

Question 14, how are engineering and technology most alike, found 15 out of 16 students in the pre and post indicated that both have similarities using materials/processes/using information to create systems. This statement, Statement A, was thought of the best choice for how engineering and technology were alike. One student in both the pre and post test felt that engineering and technology were similar by the use of computers to create automated production systems.

Results from Question 15

Fifteen of 16 surveyed pretest and 12 out of 16 in the post test found Response B, Identify the problem; gather information; develop and refine a solution; model and test the solution, was the best solution to Question 15: Which of the following most completely reflects the stages commonly found in the engineering design process? Statement B was thought of as the best response to Question 15. One student in the pretest and three in the post test found that the stages commonly found in engineering design process were: define problem, create sketches, refine problem, sketch solution. One student in the post test felt that defining the solution, testing the solution, communicating the solution and getting a patent was the best method of demonstrating the stages commonly found in the engineering design process.

Results from Question 16

Three statements were commonly found in the pre and post test responses to Question 16: One of the ways that mathematical information is useful in the engineering design and communication process is? Three students in the pre test and two in the post test found that math information was useful in generating useful data in determining optimal solutions, Statement 1. Statement 1 was thought of as the correct response to Question 16. Six students in both the pre test and post test found the best statement to Question 16 was Statement 3: numbers provide accurate information not open interpretation. Six students in the pretest and seven in the post test found that Statement 4, math is a language people from any country can understand, was the best representation of math being useful for engineering. The table below illustrates the responses to Question 16.

Table 10: Cross Tabulation of Why Math Information is useful for Engineering

	Generating Data Useful in Determining Optimal Solutions Post Test #	Numbers Provide Accurate Information not Open to Interpretation Post test #	Math is a Language People from any Country can Understand Post Test #	Total
Generating Data Useful in Determining Optimal Solutions Post Test #	1	0	2	3
Numbers Provide Accurate Information not Open to Interpretation Post test #	0	5	1	6
Math is a Language People from any Country can Understand Post Test #	1	1	4	6
One of the ways that mathematical information is useful in the engineering design and communication process: Total	2	6	7	16

Research Questions

Research Question #1: What is the relationship between students' math level and related demographics to their prior identification of engineering? Survey Question 19 was related to the students' level of math taken prior to the Principles of Engineering course. Referring to Table 5, no students were enrolled in Principles of Engineering with less than two high school math courses taken. Eight students enrolled in Principals of Engineering with at least two high school courses taken. Eight students surveyed have taken three or more math classes prior to taking Principles of Engineering.

Research Question #2: What is the relationship between students' science level and related demographics to their prior identification of engineering? Survey Question 20 was related to the students' level of science taken prior to the Principles of Engineering course. Referring to Table 6, only one student took one science course prior to the pretest in Principles of Engineering. Six students responded with taking two sciences courses prior to the Principles of Engineering course, and nine students took three or more science courses prior to the pretest.

Research Question #3: What is the relationship between students' technology education level and related demographics to their prior identification of engineering? Survey Question 18 was related to the students' level of technology education courses taken prior to the Principles of Engineering course. Referring to Table 4, three students were taking Principles of Engineering as their first technology education course. Three students were taking Principles of Engineering as their second technology education course. One student was enrolling in the course as the third technology education course, and nine students were enrolling in Principals of Engineering as their fourth or greater technology education course taken. Listed below, Table 11, are the results from the pretest and comparisons of what students felt was their strongest subject area and the average amount of related courses taken prior to the Principles of Engineering course. The final row in Table 11 is students' answers to the engineering related questions and the subject they felt was their strongest.

Table 11: Results from Pretest and Group Demographics

Results from Pre test	Subject Area Students Skills were strongest in	Number Of Students	Mean
Tech Ed Classes in High School Prior to Principles of Engineering	1 Technical Hands On	9	2.56
	2 Other Academic Subjects	7	1.29
Math Classes in High School Prior to Principles of Engineering	1 Technical Hands On	9	2.44
	2 Other Academic Subjects	7	2.57
Science Classes in High School Prior to Principles of Engineering	1 Technical Hands On	9	2.56
	2 Other Academic Subjects	7	2.43
Total Knowledge Score of Engineering Related Questions	1 Technical Hands On	9	9.00
	2 Other Academic Subjects	7	9.57

Research Question #4: What is the relationship between students' math level and related demographics to their change in identification of engineering? Survey Question 19 was related to the students' level of math courses taken prior or during the Principles of Engineering course. The second row in Table 12 addresses Research Question 4.

Research Question #5: What is the relationship between students' science level and related demographics to their change in identification of engineering? Survey Question 20 was related to the student's level of science courses taken prior or during to the Principles of Engineering course. The third row in Table 12 addresses Research Question 5.

Research Question #6: What is the relationship between students' technology education level and related demographics to their change in identification of engineering? Survey Question 18 was related to the students' level of technology education courses taken prior to the Principles of Engineering course. The fourth row in Table 12 addresses research Question 6.

In the fifth row of Table 12, it addresses the change in engineering related answers in the post test. Students who had indicated a strong skill level in technical hands-on courses noticed a three point improvement in correctly answering questions related to engineering. Students who felt that they were stronger in other academic areas noticed a one point decrease in correctly answering engineering related questions.

Table 12: Results from Post Test and Group Demographics

Results from Post Test	Subject Area Students Skills were strongest in	Number Of Students	Mean
Tech Ed Classes in High School Prior to Principles of Engineering	1 Technical Hands On	9	2.78
	2 Other Academic Subjects	7	1.43
Math Classes in High School Prior to Principles of Engineering	1 Technical Hands On	9	2.67
	2 Other Academic Subjects	7	2.86
Science Classes in High School Prior to Principles of Engineering	1 Technical Hands On	9	2.67
	2 Other Academic Subjects	7	2.57
Total Knowledge Score of Engineering Related Questions	1 Technical Hands On	9	9.33
	2 Other Academic Subjects	7	8.57

In Table 13, a comparison of pre and post test engineering related correctly answered questions and grade level is listed. Groups of sophomores and juniors were compared against seniors. Although juniors noticed a slight improvement in correct answers in the pretest, seniors indicated almost a point drop in correctly answered questions in the post test.

Table 13: Comparison of Pre Test, Post Test, Grade Level and Correct Answers

	Grade Level of Respondent	Number of Students	Mean
Pretest Total Knowledge Score	Sophomore Junior	10	9.40
	Senior	6	9.00
Post Test Total Knowledge Score	Sophomore Junior	10	9.50
	Senior	6	8.17

Table 14 on the following page indicates a cross-tabulation of students' scores in either improvement or decline of correctly answered engineering related questions in the pre and post test. Three students were found to have a two point decline from pretest to post test responses. Three students were found to have a one point lower score from pre to post test in correct responses. Two students were found to have a two correct answer improvement on the post test from the pretest. Two students were found to have a one point improvement on the post test from the pretest. Five students found no improvement or decline in correct answers from pretest to post test.

Table 14: Cross Tabulation Students Correct Engineering Related Responses

	Seven Correct Answers on Post test	Eight Correct Answers on Post Test	Nine Correct Answers on Post Test	Ten Correct Answers on Post Test	Eleven Correct Answers on Post Test	Total
Seven Correct Answers on Pre test	0	0	1	0	0	1
Eight Correct Answers on Pre Test	0	0	1	0	0	1
Nine Correct Answers on Post Test	1	2	3	1	1	8
Ten Correct Answers on Pre Test	0	2	1	2	0	5
Eleven Correct Answers on Pre Test	0	0	0	1	0	1
Total	1	4	6	4	1	16

Table 15 indicates no statistically significant correlations exists between improvement in correctly answered engineering related questions on the post test and levels of technology education, math, or science courses taken.

Table 15 Correlations Pre Test and Post Test Responses Classes Taken

	Correlations	Final Number of Technology Education Courses Taken Prior To Principles Class	Final Number of Math Courses Taken Prior To Principles Class	Final Number of Science Courses Taken Prior To Principles Class
Pre Test Total Knowledge Score	Pearson Correlation	-.266	-.160	-.405
	Sig. (2-Tailed)	.318	.554	.120
	Number	16	16	16
Post Test Total Knowledge Score	Pearson Correlation	.000	-.125	-.204
	Sig. (2-Tailed)	1.000	.645	.448
	Number	16	16	16

Hypotheses

The results of the survey indicated that there was an improvement with a limited number of students. With the senior class indicating a mean close to 9.00 in correct answers related to engineering concepts in the pre test and 8.17 in the post test. The level of improvement in comparison to levels of math, science, and technology to improvement in scores would be irrelevant. Table 13 on page 42 is referring to the improvement in students' correct answers from pre test to post test. The seniors took the highest amount of math, science, and technology courses based on the number of years that they would have been in school. Juniors and sophomores showed a slight improvement from a mean of 9.4 average correct questions answered in the pretest to post test with an average of 9.5.

Chapter V: Discussion, Conclusions, and Recommendations

Introduction

This chapter will include a discussion of the findings that occurred during the data collection, comparing those findings to literature found in chapter 2. The chapter will conclude with recommendations for further research that should take place in the field of engineering and technology education.

Discussion

In evaluation of the grade level of students participating in the survey the seniors indicated a decline in correct answers during the post test in comparison to the pre test. As a possible limitation, the seniors may have misinterpreted the questions. Students may not have a clear impression of what the question on the survey was actually asking, causing error in the students' answers to the survey. This was thought of as a possible limitation prior to initiating the survey. Of the questions on the survey, questions 10, 11, and 15 indicated a decline of correct answers in the post test compared to pre test answers. Question 10 indicated a two participant change in correct responses, question 11 indicating a one answer change, and question 15 had three more incorrect answers on the post test in comparison to the pre test. Question 10 asked students to identify the best examples of research and development, question 11 asked students to define a prototype, and question 15 allowed students to identify the common stages in the engineering process. The three additional incorrect answers in question 15 may indicate that students felt the engineering process was different due to schema acquired during the class. Along with students responding incorrectly to answers on the post test in comparison to the pre test, there were questions that did not find a change in responses from pre test to post test.

Five questions on the survey had no change in pre test to post test responses. Question 7 asked students to identify words that described good engineering design, question 9 had students list the best reason for brainstorming. The process of testing a new design or process was question 12. Question 13 found no change in response to the question of which classes were the best to take for an aspiring engineer, 15 out of 16 students in the pre test and post test found similarities in materials processes and using information to create systems was how engineering and technology were alike. These questions involved students thinking and identifying engineering design and the profession of an engineer. Students could have entered the class with a prior knowledge of the characteristics of the profession of engineering along with brainstorming and thought process of engineering. Although there were questions that did not find an improvement or decline in correct answers in the pre test compared to the post test, three questions found a one respondent improvement from pre test to post test.

Questions 6, 8, and 16 were the three questions that found one correct answer improvement in responses from pre test to post test. Question 6 asked students to identify what words would best define the word innovation. In question 8, students were asked to identify the best way to tell someone about a new and improved bike. Identifying one of the ways that mathematical information is useful in engineering design and communication process was the theme for question 16. With the lack of vast improvement in the pre test to post test, one would have to look at the make up of the students involved in the study.

In review of the limitations, some limitation might have a greater level of impact in the change of students' perceptions of engineering upon exiting the class. From the data complied during the survey of students in the Principles of Engineering class at Eau Claire North High School, it was found that 15 out of 16 students enrolled were junior or seniors. Along with these 15 out of 16 students being junior or senior level, all 16 people felt that they would attend college after high school. All 16 of these students also took at least 2 or more math classes and 15 out of 16 students took at least two or more science classes. These higher levels of math and science classes taken by students surveyed may have been a contributing factor of the limited change in responses from pre testing to post testing.

In the review of literature, students' prior knowledge of engineering concepts were based on levels of science and math that they had previously taken. According to Gene Bottoms, head of the Schools That Work program at the Southern Regional Education Board, "Engineering helps students to see a reason for what they're learning. It deepens their understanding of the academic concepts and increases retention. It shows them that mathematics and science matter" (cited in Brown, 2005, p. 16). This may actually have a reverse effect on the students. Students may have been able to reason with engineering concepts based on their experiences in the two or more math that all 16 students took and 2 or more science classes that 15 out of 16 students took in the past. The survey used in the class possibly did not measure the effectiveness of the students' advancement in knowledge in the field of engineering. In the students' responses there were very little indication of perceptions of engineering improving.

In addition, the literature supported the idea that students take information from their environment and continue to construct meanings to that information. Constructivist theory defines learning as a continuous process in which learners take information from their surroundings or environment and construct personal meanings based on prior knowledge and experience (Kozulin, 1998). One should consider looking to the past sources to consider how society constructed the meaning of engineering. A vast majority of the students in the survey took at least two years of math, science, and technology education. The intent of the survey was to measure perceptions of engineering concepts based on the levels of science, math, and technology education classes taken.

There was very little difference in the student population in the amount of the desired courses taken. The simulation itself may have limited students' abilities to differentiate engineering concepts that were practiced in the field today. Children increased their technological capabilities and technological knowledge by participating in design and technology-related activities (Foster & Wright, 2001). Although certain elements of engineering were highlighted in the simulation, the related survey questions may not have been emphasized during the NCETE simulation. It would be necessary to identify the questions in the survey to determine if there was a correlation between the questions and the activities which took place in the Principles of Engineering class.

Recommendations

Recommendations from the researcher are based on the information acquired during the engineering perceptions survey. Topics for recommendation involve the demographics of those surveyed, level of other classes taken, identification of materials covered in class, and other possibilities of evaluation. Looking at the students surveyed from Eau Claire North, there was very little in variance in student demographics. Fifteen of 16 students surveyed were either junior or senior level students. Along with the junior and senior dominance in the course, 14 out of 16 students were male. Researching a higher percentage of females and sophomore/freshman students may yield a greater indication of change from pre test to post test results. With these students being juniors or seniors, other classes such as math and science levels will be higher based on the number of years that they have been in school.

In the study only one student took one year of math and greater than one year of science. With 15 of 16 students enrolled in at least two math and science classes, there could have been a greater exposure to other methods of problem solving than found in the Principles of Engineering class. Surveying students of lower levels of math and science may have given a greater indication if students' perceptions changed based on levels of science, math, and technology education courses taken. Students' courses taken or how these courses were taught could have a great impact on change in students' identification of engineering concepts. Finding little change from pre test to post test may have reflected the students' high levels of prior knowledge in math, science, and technology education due to previous courses taken. The survey questions may not correlate to what content was covered and synthesized in the Principles of Engineering class, students could have learned about the best response to scenarios in other courses. Another possible recommendation is to list a greater amount of scenarios for students' to determine the best answer that closely matching an engineering method.

Along with the addition of more scenarios greater improvement from pre to post test may have been found at other participating NCETE sites. The make up of the Eau Claire North students may have been quite different than those of Brillion or Bradley Tech High School. That demographic, along with the method of delivery or experience of the teacher, may have also created a change in students' perceptions of engineering. In the future, a suggestion would be to include another school or several schools in the survey to determine if the NCETE project was effective. Another change would be to add questions to be more related to the NCETE project or activities.

Students establishing new schema of engineering could take place during the course or simulation of the NCETE manufacturing project. Prior to the simulation, a base line could be established in how students would respond to a question directly related to the NCETE manufacturing project. At the completion of the manufacturing project, students' knowledge gained from the project could be measured. The questions may have not directly measured what was learned from the manufacturing simulation.

This study should be replicated in order to determine the entire effectiveness of the NCETE project. In this replicated study, all other partner schools should be included for the possibility of adding varying levels of math, science, and technology education taken prior to the class. Along with adding additional schools, questions should be included that are directly related to the manufacturing simulation.

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Appendix A

This research has been approved by the UW-Stout IRB as required by the Code of Federal Regulations Title 45 Part 46.

An Analysis of Students' Perceptions of Engineering Concepts in a Technology Education Course at North High School

Student #____________

1. **Are you a male or female...**
   a. Male b. Female

2. **Do you plan to attend college?**
   a. Yes b. No

3. **What was your main reason for enrolling in this class?**
   a. Recommended by a teacher or guidance counselor
   b. It was required
   c. Recommended by a friend/wanted to be with a friend who was taking it
   d. I am interested in this topic and wanted to try it out

4. **In which of the following subject areas do you think your skills are the strongest? (Select one)**
   a. Technical/Hands-on classes
   b. English/Language Arts
   c. Science
   d. Mathematics
   e. Social Studies
   f. Art or Music

5. **Which of the following sentences do you think best describes what engineers do?**
   a. They work with science tools to discover new information.
   b. They work in factories helping to make new products.
   c. They operate large, motorized equipment.
   d. They design new and better ways of making or doing things.

6. **Which definition best fits the word innovation?**
   a. Finding a better way to do or make something.
   b. Creating a new, man-made device.
   c. Seeing a problem from many different angles.
   d. Learning new things about nature.

7. **Which set of words below would best describe a good engineering design?**
   a. big, expensive, high-tech
   b. fast, cheap, lightweight
   c. effective, efficient, reliable
   d. small, complex, electronic

8. If you wanted to tell someone about your idea for a new, improved type of bicycle, the simplest and best way to do so would probably be to:

a. Write out a long description that has all the details listed.
b. Make an audiotape of yourself describing it to them.
c. Build a full working model of the design.
d. Make a sketch that shows the important details.

9. The reason we often use brainstorming when trying to come up with new ideas is:

a. It's a lot more fun for students to work together as a group.
b. Talking about ideas is much easier than having to write them down
c. It's a good way to come up with a lot of new ideas quickly.
d. We get to use our brains for a little while before using our hands.

10. Which of the following is the best example of research and development (R&D) in a technology laboratory?

a. A machine stopped working and the problem had to be found and fixed.
b. Engineers experimented with different materials to find the best one for the job.
c. A researcher tested samples of carbon to find the purest one.
d. The designers asked their clients to select the furniture style they liked the best.

11. Engineering designers often make prototypes of their design ideas. Prototypes are:

a. Working models that can be used to test and improve a design idea
b. Professional sketches that show all the visual details of a design idea.
c. The first "finished product" made when a design job is done.
d. Three-dimensional (3-D) models that show the size and shape of a product.

12. The process of testing a new design idea or product helps in what ways?

a. We can see if our idea will actually work.
b. We can find out what changes might be needed to improve the design.
c. We can find out whether people will like the product.
d. All of the above.

13. In order to become an engineering professional, which of the following type of high school courses would best prepare you?

a. English, foreign language, mathematics, business education
b. Mathematics, technology education, science, computer applications
c. Social studies, science, English, art
d. Physical education, mathematics, foreign language, social studies

14. In what way are the fields of engineering and technology most alike?

a. Both focus on the use of materials, processes, and information to create systems that benefit humankind.
b. Both require extensive training and licensure prior to employment.
c. Both involve the use of computers to create automated production systems.
d. Both fields are better suited to male employees.

15. The engineering design process involves several stages of activity. Which of the following most completely reflects the stages commonly found in the engineering design process?

a. Define the problem; test alternative solutions; communicate the solution; get a patent
b. Identify the problem; gather information; develop and refine a solution; model and test the solution
c. Identify the problem; create a model or prototype of the solution; gather information;
d. Define the problem; create sketches; refine the problem; sketch the design solution

16. One of the ways that mathematical information is useful in the engineering design and communication process is:

a. It provides a means of generating data that is useful in determining optimal solutions.
b. Numbers provide the only basis for theoretical models that are so critical to engineers.
c. Numbers provide accurate information that is not open to interpretation.
d. Mathematics is a language that people from any country can understand.

17. Please indicate below what grade level you currently are:

a. Freshmen
b. Sophomore
c. Junior
d. Senior

18. Please indicate below how many <u>Technology Education</u> classes you have taken at the high school level prior to this class:

a. 0
b. 1
c. 2
d. 3 or more

19. Please indicate below how many <u>Math</u> classes you have taken at the high school level prior to this class:

a. 0
b. 1
c. 2
d. 3 or more

20. Please indicate below how many <u>Science</u> classes you have taken at the high school level prior to this class:

a. 0
b. 1
c. 2
d. 3 or more

Thank you for participating!

Appendix B

Consent Form

Dear Parent or Guardian,

Your son or daughter is currently enrolled in the Principles of Engineering class at Eau Claire North High School. During their time in the class students will participate in a project in cooperation with the National Center for Engineering and Technology Education (NCETE) at UW-Stout. This project is funded by the National Science Foundation with one goal of conducting research in how students learn technological concepts.

As a graduate assistant serving the NCETE at UW Stout, I would like to conduct research based on the manufacturing engineering unit to take place at Eau Claire North in the near future. A survey, approved by the Institutional Review Board (IRB) from UW Stout, will be administered only to students in the Principles of Engineering class whom have returned the permission form on the next page. The IRB has determined that this study meets the ethical obligations required by federal law and University policies.

This survey will be administered by Mr. Jeffers prior to and following the manufacturing engineering unit in the Principles of Engineering class. The data collected from the survey will be used to gain insight on how students' perceptions of engineering concepts may have changed following the unit. This survey in no way will affect the grade of the student and responses from each student will remain confidential. Results from this research will be used in an attempt to increase the effectiveness of technology and engineering education in the high school setting.

To participate in this survey I would ask that you and your son or daughter sign the permission form on the next page and return to Mr. Jeffers as soon as possible. If there are any questions regarding this survey or the goals or mission of this project feel free to email me at: sullivanje@uwstout.edu.

Thanks for your anticipated participation,

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