Engineering Outcomes of Grades 10-12 Using Different Pre-Engineering Curriculums: A Case Study

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Cheryl A. Wilhelmsen

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Major Professor: Raymond Dixon, Ph.D.

Authorization to Submit Dissertation

This dissertation of Cheryl Wilhelmsen, submitted for the degree of Philosophy with a major in Education and titled "Engineering Outcomes of Grades 10-12 Using Different Pre-Engineering Curriculums: A Case Study," has been reviewed in final form. Permission, as indicated by the signatures and dates given below, is now granted to submit final copies to the College of Graduate Studies for approval.

Major Professor ______________________ Date 4/18/13
Raymond A. Dixon

Committee Members ______________________ Date 4/18/13
James Gregson

______________________ Date 4/18/13
John G. Cannon

______________________ Date 4/18/13
Lee T. Ostrom

Department Administrator ______________________ Date 4/19/13
Kathy Canfield-Davis

Discipline's College Dean ______________________ Date 5-5-13
Corinne Mantle-Bromley

Final Approval and Acceptance by the College of Graduate Studies

______________________ Date 5/7/13
Jie Chen

Abstract

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The purpose of this study is to identify the important constructs and their key indicators that are to be included on an instrument developed to measure the engineering design process and outcome of students in high schools that use the Project Lead the Way and Engineering by Design curriculums. Several pre-engineering curriculums are used in high schools to prepare students for engineering programs at the college level. How well do these curriculums prepare students for college based engineering programs? What are the critical constructs of a pre-engineering curriculum? Emphasis is placed on Integrative Science, Technology, Engineering, and Mathematics (STEM) education in both high and post-secondary level programs. What implications does this have for the professional development of PTE teachers and college instructors in the development of curricula?

The following research questions guided the study:

1. How are the constructs identified by Childress and Rhodes (2008) ranked in terms of criticality for inclusion on an instrument to measure engineering design outcomes in high school in Idaho?
2. What are the key indicators associated with the constructs identified by Childress and Rhodes (2008) to measure engineering design outcome in high schools in Idaho?
3. Are there differences between constructs for design outcomes as identified in the Project Lead the Way and Engineering by Design content?

A content analysis was conducted on the Project Lead the Way Curriculum used in grades 10-12 and the Engineering by Design curriculum for grades 10-12. Main constructs were established and the key indicators for each construct were included in a survey sent to an expert team consisting of High School educators, University educators, and Engineers in industry. The resulting data from the survey were analyzed.

INDEX WORDS: engineering education, engineering design process, content analysis

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I appreciated the administrative assistance offered by Alice Allen in the Idaho Falls Center. In addition, I want to thank those participants who shared an interest in this study with me.

Most importantly, I would like to thank my Father in Heaven for the blessings, health and perseverance He has given me.

Trust in the Lord with all your heart and

Lean not on your own understanding:

In all your ways acknowledge Him, and

He will make your paths straight.

Proverbs 3:5-6

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Chapter 1: The Problem

There are several curriculums at the high school level that teach engineering design using pedagogical approaches that range from problem-based to experiential and inquiry-based learning (Bottoms & Anthony, 2005; Rhodes & Childress, 2010; Gattie & Wicklein, 2007; Smith & Wicklein, 2007; Asunda & Hill, 2007; "Engineering by Design," 2007). What is noticeably lacking, however, is a common instrument that can assess engineering design process and outcome, despite the curriculum that is in use.

Two of the popular engineering curriculums that are in use in Idaho schools are Project Lead the Way and Engineering by Design. Project Lead the Way (PLTW) was developed by Richard Blais in New York in the 1980s (Blais & Adelson, 1998), and serves over 1250 schools in 44 states (Kelley, 2008a). PLTW courses use problem-based learning, which allows students to learn and apply skills and knowledge in real world situations. In September 1999, High Schools That Work (HSTW) and PLTW collaborated to create a high school pre-engineering path (Bottoms & Anthony, 2005). A subsequent study that was conducted reported some implications for improving the PLTW pre-engineering program. They included the following:

- The need for four years of mathematics and science lab-based courses,
- Integrated workshops and projects among science and math teachers for learning mathematics, science, and technical concepts,
- And training the PLTW teachers in how to integrate, interpret, and analyze technical materials (Bottoms & Anthony, 2005).

The study also indicated the need for consistency in implementing pre-engineering content into the curriculum.

The PLTW curriculum requires schools to make a significant upfront capital investment in laboratory equipment and technology. Because of the inability to come up with this investment, some schools are unable to participate in the PLTW program. Whenever a teacher is selected to teach PLTW courses, he/she must complete the Assessment and Readiness Training, which focuses on mathematics and core training. The teachers are required to attend a two-week professional development summer training for each of the courses they will teach. The training focuses on how to engage students in science and mathematics, and how to engage students in projects. In addition, the teachers have access to the PLTW Virtual Academy during the academic year. Studies show that 71.4% mostly or completely agreed that the training prepared them to teach their new course (Bottoms & Anthony, 2005; Ncube, 2006).

PLTW targets the top 80% of students and requires those students to enroll in a college preparatory math course. The students take end-of-course exams and participate in a capstone exercise. PLTW students completed more science and math classes than the HSTW schools and scored higher on National Assessment of Educational Progress (NAEP) tests. Of the graduates, 80% plan to attend college and 68% plan to enroll in an engineering or engineering technology program (Brophy, Klein, Portsmore, & Rogers, 2008). PLTW curricula are widely used in Texas schools, but there has been little substantive research that demonstrates how it helps students develop the "habits of mind" that the National Academy of Engineering (NAE) identifies as an engineering skill set (2009, p. 5).

Engineering by Design is included in the curriculum in many school districts. Some states have adopted a technology education curriculum model that is pre-engineering in nature. The state of Massachusetts, for instance, has created state standards that contain many of the Standards for Technological Literacy (STL). They focus on materials, tools, machines, and engineering design in grades P-5. They use a progression system that introduces new concepts and aspects of engineering and science each year. Middle and high school learners complete more complex and abstract representations of ecosystems and bioengineering. This requires inductive and deductive logic, as well as content knowledge and skills for processing information and comprehending how systems work. Massachusetts has shown that engineering standards can drive the curriculum design, development, and assessment process.

Engineering requires applying both content knowledge and cognitive processes to design, analyze, and evaluate complex systems for today's needs. Engineers develop new devices. They design manufacturing processes, transportation systems, waste management systems, and our power distribution infrastructure. The numerous sub-systems and functional requirements that are necessary for these systems to function optimally emphasize the complexity of the process to design and build them. Problem complexity is "concerned with how many, how clearly, and how reliably components are represented implicitly or explicitly in the problem" (Jonassen, Strobel, & Lee, 2006, p. 68). Solving these complex design problems requires the application of cognitive processes that are associated with logical, strategic, and systems thinking; case and dilemma analysis; and decision-making.

The cognitive processes employed when solving problems from a particular discipline are regulated by the content knowledge of that discipline (Zuga, 2004). From an engineering perspective, P-12 engineering education may use many hands-on activities with technology to develop a qualitative sense for general problem-solving strategies. (Brophy et al. 2008, p. 371) states, "...one could argue that these forms of knowledge and skills are fundamental to all technical professionals involved in the process of technical design, troubleshooting (diagnosing), and/or analyzing complex systems."

One of the main goals of the National Center for Engineering and Technology Education (NCETE) is to "work with engineering and technology educators to prepare them to introduce engineering design concepts in grades 9-12" (Hailey, Erekson, Becker, & Thomas, 2005, p. 24). NCETE describe the engineering design process as:

1. identify the need
2. define the problem
3. search for solutions
4. identify constraints
5. specify evaluation criteria
6. generate alternative solutions
7. analysis
8. mathematical predictions
9. optimization
10. decision
11. design specifications
12. communication (Eide, Jenmison, Mashaw, & Northrup, 2012).

In our current educational environment, there is a movement to include engineering and technology as core academic subjects alongside science and mathematics. The endeavor is to integrate engineering design as a focal point for technology education. Some technology education leaders believe this will lead to greater technological literacy (Lewis, 2005; NRC, 2002/2006). Curriculum developers are experimenting with various ways to integrate engineering themes, content, and processes in order to bolster the learning of science, technology, and engineering topics (Carr & Strobel, 2011). Pre-college engineering standards are still largely undeveloped when compared to science and mathematics education. The NAE report on engineering standards (2010) argues, however, against stand-alone national engineering; preferring to integrate engineering content into other existing academic standards (Carr, Bennett, & Strobel, 2012).

Statement of the Problem

Technology education is not new and has been taught for generations. However, according to the National Assessment of Education Progress (NAEP) (2012, p. ix) "There are currently no standardized, nationally representative assessments to provide evidence of what students know about technology and engineering; the roles they play in our lives; and the extent to which students can use technologies and understand how engineers design and develop them." Determining the engineering constructs and their key indicators for engineering outcome at the 10-12 grade level is a major step towards consistency in curricula development, and is crucial for developing an assessment tool for validating pre-engineering outcomes in high school pre-engineering curriculums.

A study in engineering in K-12 education concluded "...no national or state-level assessments of student accomplishment have been developed" (Katehi, Pearson, & Feder, 2009, p. 2). From a pedagogical perspective, engineering provides a link that ties together mathematics and science (Katehi, et al., 2009). Various research studies show that the integration of engineering can enhance student learning, boost test scores, and help schools meet education requirements (Baker, 2005; Merrill, Custer, Daughtery, Westick, & Zeng, 2008; Silk, Schunn, & Strand Cary, 2009).

There is not a standardized interpretation and meaning of design within the technology education field (Gattie & Wicklein, 2007). An instrument geared towards assessing engineering design process and outcome could provide a focal point for consistency. It is important to examine these important issues in view of the many different high school pre-engineering programs geared towards engineering design as a focus in the development of technological literacy in K-12 learners (Daughtery, 2005; Lewis, 2005; Kelley, 2008b).

Purpose of the Study

The purpose of this study was to identify the important constructs and their key indicators that are to be included in the development of an instrument to measure the engineering design process and outcome of students in grades 10-12 that use Project Lead the Way and Engineering by Design curriculums.

Research Questions

The following research questions guided the study:

1. How are the constructs identified by Childress and Rhodes (2008) ranked in terms of criticality for inclusion on an instrument to measure engineering design outcomes in high schools in Idaho?

2. What are the key indicators associated with the constructs identified by Childress and Rhodes (2008) to measure engineering design outcome in high schools in Idaho?
3. Are there differences between constructs for design outcomes as identified in the Project Lead the Way and Engineering by Design content?

Conceptual Framework Guiding the Study

The conceptual framework for this study consisted of knowledge obtained from three studies of engineering design that addressed what content should be taught in high school curriculums (Childress & Rhodes, 2008; Smith, 2006, Kelley, 2008b). Two of these studies created a framework to define the engineering design curriculum content (Childress & Rhodes, 2008; Smith, 2006). The framework consisted of seven categories:

1. Engineering Design that emphasizes the importance of creativity in designing engineered solutions to problems, as well as design iterations and tradeoffs
2. Application of Engineering Design that included outcomes relating to design activities, experimentation, prototyping and reverse engineering
3. Engineering Analysis that includes mathematics in optimizing solutions and the use of both science and math in the engineering design process
4. Engineering and Human Values that consists of the interactions between engineering design and society such as safety and the environment versus costs and ethics
5. Engineering Communication that included all sorts of communications important to the engineering design process

6. Engineering Science that includes the traditional sciences such as statics and dynamics as well as material properties, energy, power, etc.
7. Emerging Fields of Engineering that included nanotechnology and genetic engineering (Childress & Rhodes, 2008).

The seven categories were identified through a modified Delphi approach that started with preexisting outcome items from national standards projects, focus groups, and other resources. The modified Delphi study used two phases with three rounds within each phase. The first three rounds asked participants to rate, reword, add items, & provide comments. The second phase selected engineers to group the items into conceptual likeness and name the groupings. During rounds four, five and six, the groups of outcomes were ranked. The complete statistical analysis is available at *www.ncete.org/flash/Outcomes.pdf.*

This research used six of the seven categories. Emerging Fields of Engineering was not used in this research study as it related mainly to nanotechnology. The results of the three studies framed this research by providing criteria, which helped to identify key indicators used in the high school curriculums. The key indicators can be used in the development of an assessment instrument for measuring the engineering design process.

Significance of the Study

This study identified a list of important key indicators for six engineering design constructs that can be used to measure high school students engineering design outcome. The list can enhance efforts in the development of a common assessment tool in measuring pre-engineering design curriculums for preparing students to enter higher education engineering programs. The study contributes to the national effort to teach and assess technological literacy and engineering skills for employment in the new global economy. The findings and recommendations outlined by the researcher will help guide technology and engineering teachers in the teaching of the PLTW and EbD curriculums, and will support ongoing scholarship work in the field of technology/engineering development and education and assessment.

Limitations

This study has several limitations. First, the data used in this study were limited to high school curricula used in the state of Idaho. Currently there are three Idaho high schools that provide PLTW and three high schools that provide EbD curriculums. Because of the purposeful sample, attempts to generalize the findings must be limited to the sample. Secondly, readers should also recognize that the participants, structure, curriculum, etc. might also provide different outcomes. Clearly, this limitation has decreased the generalization of this study's findings to all pre-engineering programs. This study confined itself to high school grades 10-12 curricula in pre-engineering programs.

Definition of Terms

The following operational definitions were used for clarity of several specialized terms used throughout this study.

Assessment. The act of collecting data or evidence that can be used to answer classroom, curricular, or research questions (Rogers & Sandos, 1996).

Engineering. The profession of or work performed by an engineer as they apply engineering design processes to technological problems (National Center for Engineering and Technology Education, 2005).

Engineering by Design (EbD). Standards-based model for grades K-12 that delivers technological literacy. Built on the constructivist model, students participating in the program learn concepts and principles in an authentic, problem-based environment (ITEEA, 2013).

Engineering design. A systematic and often iterative approach to designing objects, processes, and systems to meet human needs and wants (National Research Council, 2011/2012). The engineering community focuses on meeting the needs of society through today's technologies of buildings, computers, multi-media devices, and nearly everything else we encounter daily. It is important for us to understand the technology and engineering of these technologies in order to make responsible decisions.

Engineering education. Activities that involve teaching engineering and technological concepts and principles to spread technological literacy, to prepare future engineers, and increase student interest (Douglas, Iverson, & Kalyandurg, 2004).

Formative Assessment. "A process used by teachers and students during instruction that provides feedback to adjust ongoing teaching and learning to improve students' achievement of intended instructional outcomes" (McManus, 2008, p. 3). The formative assessment evaluates the progress in meeting a project's goals and objectives and can act as a type of diagnostic tool to help evaluate the areas needed for improvement. Formative assessments are considered part of the learning.

Knowledge. "A fluid mix of framed experience, contextual information, values, and expert insight that provides a framework for evaluating and incorporating new experiences and information" (Davenport & Prusak, 1998, p. 5).

Measurement. A collection of quantitative data. A measurement is made by comparing a quantity with a standard unit (Helmenstine, 2012).

Outcome Assessment. The assessment associated with the project's goals and objectives. The *summative assessment* evaluates the project's outcomes and provides the final opportunity for the students to show what they have learned (Stiggins, 2007).

Project Lead the Way (PLTW). Courses, which follows a proven hands-on, real world problem-solving approach to learning (PLTW, 2013).

Technology. Any modification of the natural world done to fulfill human needs or desires (NAEP, 2012).

Technology education. Teaching technological concepts and principles taught in the K-12 continuum. The goal of technology education is technological literacy applicable to every career field.

Technological literacy. Understanding technology that enables effective functioning in today's technological society. Being technologically literate is having the ability to use, manage, assess, and understand technology (International Technology Education Association [ITEA], 2000b/2003/2007/2011).

Validity. How well a test measures what it is purposed to measure.

Chapter 2: Review of the Literature

Building a Competitive Workforce

The need for building a competitive workforce is paramount to our economy. The United States may still be the leader in producing goods and services throughout the world, but China is increasing rapidly; their pace rates higher than any other country (Barden, 2011). In order to maintain our economic supremacy educators, businesses, and manufacturers, need to build a more competitive workforce now and for the future. Our students need to have the desire to become lifelong learners and adapt to our changing workforce. The International Technology Engineering Education Association (ITEEA) states:

> Building a competitive workforce for the 21st century requires the careful alignment of K-12 and university curricula with the skill needs of business and industry. In addition to making students better problem solvers, critical thinkers, and users of technology, academic preparation must instill in them the desire to become lifelong learners, willing and able to adjust to changes in workforce skill requirements resulting from fast-changing global markets (2011, p.1).

The integration of technology and engineering could lead to greater technological literacy and promote engineering as a career choice (Lewis, 2005). Adding engineering content to the high school and middle school curricula helps in creating a technologically literate society (Pinelli, 2010). Technological literacy is the study of the history of technology, the positive attributes and consequences of technology, along with the ability to use, manage, evaluate, and understand technology. Engineers design the technologies that modify the world through a systematic approach to meet human needs and wants (NRC, 2012).

Standards

The creation of national standards has often provoked critical voices. On the other hand, standards have driven innovation in education and can engender the implementation of assessments, teacher training, curriculum, and textbooks (Bybee, 2010; National Academy of Engineering [NAE], 2005). (Brophy et al., 2008, p. 1) suggests, "what gets taught in P-12 classrooms is often a function of what gets emphasized in national and state content standards."

Standards for Technological Literacy (STL): Content for the Study of Technology was developed in 2000. The standards define what students should know, and what they are able to do in order to be technologically literate. In addition, it prescribes what the outcomes of the study of technology in grades K-12 should be. These standards place an emphasis on the following:

- three standards regarding the nature of technology
- four standards regarding the relationship of technology and society
- three standards regarding design
- three standards regarding abilities for a technological world
- seven standards regarding understanding the designed world (ITEA, 2000b).

These standards, twenty in total, should serve as a guide for teachers in developing curriculum. They are recommendations from mathematicians, engineers, educators, scientists and parents about what skills and knowledge should be included in the curricula to help our students become technologically literate (ITEA, 2000). Each standard is broken down into benchmark topics for different grade levels.

Accreditation Board for Engineering and Technology (ABET) changes the way programs are evaluated and the way courses are put together. ABET criteria requires institutions to evaluate and document the quality of their programs and their student learning outcomes. Several different key studies strongly influenced the change in the ABET engineering criteria, including *Systemic Engineering Education Reform: An Action Agenda* (Peden, 1995); *The Green Report: Engineering Education for a Changing World* (ASEE, 1994); *and Engineering Education: Designing an Adaptive System* (National Research Council Board [NRCB], 1995).

ABET is based on nine criterions for Bachelor of Science and Associate degree programs, and two additional criterions for the Master of Science level. The targeted outcomes include the following:

1. Apply the knowledge, techniques, skills, and modern tools of the discipline to broadly defined engineering technology activities.
2. Apply knowledge of STEM to engineering technology problems that require the application of principles and applied procedures or methodologies.
3. Conduct standard tests and measurement; to conduct, analyze, and interpret experiments; and apply experimental results to improve processes.
4. Design systems, components, or processes for broadly defined engineering technology problems appropriate to program ed. objectives.
5. Function effectively as a team member or leader on a tech. team.
6. Identify, analyze, and solve broadly defined engineering tech. problems.

7. Apply written, oral, and graphical communication in both tech and non-tech environments; and identify and use appropriate technical literature.
8. Engage in self-directed continuing professional development.
9. Commitment to address professional and ethical responsibilities including a respect for diversity.
10. Knowledge of the impact of engineering technology solutions in a societal and global context.
11. Commitment to quality, timeliness, and continuous improvement (ABET, 2011).

A study at Pennsylvania State University was conducted with industry leaders, as well as deans, chairs, faculty, leaders of national engineering education societies and ABET. The study showed that, more so now than ten years ago, employers seek students with a broader educational background. For example, one leader stated:

> More and more companies are looking at students who have a broader background of education … in the '60s, '70s, and '80s we hired electrical engineers, mechanical engineers, and chemical engineers. Now more and more employers are saying, "We want an engineer who is capable of stepping across some of the boundaries that were originally set up" (Bjorklund, 2001, p. 16).

The study revealed the curricula must include the largely non-technical items such as the six non-technical items contained in the eleven criteria, number 3, of ABET EC 2000. Some of those items are teamwork, communication skills, leadership abilities, knowledge of ethics and world economy and so on.

Many believe that standards should only focus on outcomes and be used for accountability purposes, while others have seen them as a vision for what is needed to enable all students to become literate in the given subject area (Dugan, & Hernon, 2002).

Engineering Education Curriculum Initiatives

Project Lead the Way was started in the 1980s when faculty at Rensselaer Polytechnic Institute (RPI) in New York aided a teacher at a nearby high school in developing technology based courses. It developed into a national program in 1997. The pre-engineering curriculum established courses in Introduction to Engineering, Digital Electronics, Computer Integrated Manufacturing, Principles of Engineering, and Engineering Design and Development. Instructors received training in the curriculum and received the materials and the student resources. The schools need to have resources and a budget to maintain this curriculum. According to a pamphlet published by PLTW, its mission is to create dynamic partnerships with schools to prepare an increasing and more diverse group of students to be successful in engineering technology programs (PLTW, 2004).

Educators who are preparing or who are teaching in PLTW courses should have extensive backgrounds in math, science, and technology/engineering design courses. College algebra, calculus I and II, trigonometry, and analytical geometry are among the math courses required. Biology, general physics, and college physics are among the science classes required. It is recommended that the instructors of the PLTW curriculum have knowledge of biotechnology and chemistry. General engineering design, mechanical design, engineering design, electricity/electronics, digital electronics, fluid power systems, and materials processes are all courses rated as essential in teaching PLTW (PLTW, 2004).

PLTW is just one of a number of efforts in bringing engineering education into public schools. Texas Instruments, the U. S. Department of Education, and the National Science Foundation created the INFINITY Project in 1999. It was sponsored by the Institute for Engineering Education at Southern Methodist University, Rose-Hulman Institute of Technology, University of Illinois at Urbana-Champaign, Santa Clara University, George Mason University, and Applied Signal Technology, and is established in 58 schools in 14 states (Martin, 2005). The textbook, which is a part of the INFINITY curriculum, covers aspects of modern-day multimedia and information technology/engineering. The topics include the following:

- Definitions and descriptions of digital and analog technology
- The engineering design process
- Mathematical models for technology projections
- Definitions and representations of signals
- Fundamental systems concepts
- The basics of hearing and sight perception relevant to digital audio imaging
- The physics and mathematics of electronic and optical displays
- Information storage, compression, and encryption
- Radios and wireless communications
- Computer networks and the Internet (Orsak et al., 2001).

The INFINITY Project offers high school students an opportunity to learn about engineering design principles in the context of information technology. The curriculum consists of 600 pages of text and 500 pages of figures within 20 chapters, along with an INFINITY Technology Kit that is used in the laboratory exercises (Douglas & Orsak, 2002).

Several university outreach programs in engineering education have also been established 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; Baartmans & Sorby, 2001; Creighton, 2002).

Design in Technology Education

According to Gattie (2007), while more programs are integrating design into technology education, there is inconsistency in the interpretation and meaning of design in the technology education field. Design in technology education as proposed by Wicklein (2006) should follow the engineering design process used in the field of engineering because of the following:

1. engineering design is better understood and valued than technology education
2. engineering design elevates the field of technology education to a higher academic and technological level
3. engineering design provides a defined framework to design and organize curricula
4. engineering design provides an ideal platform for integrating mathematics, science and technology
5. engineering provides a focused career pathway for students

Engineering design is similar to technological design in that both requires creativity, critical thinking, innovation, application of technical knowledge, and also knowledge of how our society and our environment are impacted by design. The design process itself centers on four areas used in describing technological problems or the solutions. These include the following:

1. Semantic – verbal or textual explanation of the problem
2. Analytical – mathematical equations utilized in predicting solutions to technological problems
3. Graphical – technical drawing of an object
4. Physical – constructing technological artifacts or physical models for testing and analyzing (ITEA, 2000).

Several universities have already or are in the process of integrating engineering design into technology education (e.g., University of Georgia, Brigham Young University, Virginia Tech, Virginia State University, and others). One of these, the University of Georgia, conducted a national survey of in-service K-12 technology education teachers who base their curriculum on the Standards for Technological Literacy. Their results were broken into three categories:

1. The current practices of technology teachers in relation to utilizing engineering design practices in the high school classroom
2. The value of an engineering design focus for technology education
3. The instructional needs of high school teachers of technology education as it relates to engineering design

Their findings showed agreement among teachers that an engineering design focus for technology education adds value. However, they agreed that their own academic training and the educational resources were limited. This is a challenge for K-12 educators. According to the University of Massachusetts (UMASS), In a 2007 international assessment of 15-year-old students, the U.S. ranked 28th in math literacy and 24th in science literacy. A shortage of STEM teachers in the United States has been directly linked to the low quality of STEM education in this country. The United States faces a critical shortage of highly qualified math and science teachers—projected to reach 283,000 by 2015 (UMASS, 2008, p. 2).

Gattie (2007) indicated that the majority of teachers (90%) were teaching topics on engineering or engineering design in their classrooms. Infusing engineering design into the K-12 education system provides students the opportunity to realize the usefulness of and need for mathematics and science as they apply them to their lives through technology. Throughout the K-12 education and teacher educator environments, efforts are increasing to prepare teachers and students for both learning and teaching technology education from an engineering design perspective (Gattie, 2007). Different models are being used to deliver technology and engineering programs in high schools.

Oxon Hill High School. The Oxon Hill High School in Oxon Hill, Maryland, has adopted a successful Science and Technology Program (STP) that was established in 1976. Oxon Hill is one of three high schools in Prince George's County that offers this program. The four-year academic program consists of 28 credits in which a minimum of 13 credits are in specific mathematics, pre-engineering technology, research, and science classes. Grades 9 and 10 consist of common experience courses for all students (e.g., English Honors, Math, Biology, U.S. History Honors, Foundation of Engineering 1, PE/Health, and an Elective). In grades 11 and 12, the students must choose their coursework from at least one of four major study areas and they are required to complete three Advanced Science and Technology credits taken during grades 10-12. There are four major study areas:

1. Pre-engineering Technology (PET)
2. Biological Science
3. Physical Science
4. Computer Science

Internships are encouraged as part of the students' program, which helps in establishing cooperative learning and a way to experience real world problems and solutions; however, they are required to link directly to the STP and seek approval by the Science and Technology Center Coordinator. There are 525 students enrolled in the program, which is 23% of the high school's enrollment of 2,300 students. Admission into the program is competitive with up to 2,000 students testing each year for the 500-525 seats. Admittance into the program is a combination of the students' grades and a two-part exam (Pearson, 2012). Improving technological literacy promotes economic advancement.

The curriculum is consistent throughout the four years where the students all progress toward the STP certification criteria as a co-hort. The effectiveness of any program can be improved when appropriate goals are set. These goals provide a pathway of the commitment they have made, and they are all working towards a common goal. Their common goal is to develop an interest in technology and engineering. The students need to maintain a high grade point average and, by setting their personal goals, will be more successful in completing the program. Goals give the students a clear picture of what is expected so they can manage their time and their attention. In addition, goals help the teacher to think critically about the important concepts of the course or program.

This program does not allow all 2,300 high school students the opportunity to develop technological workplace skills. It is limited to those with the higher grade point averages. The program is highly competitive and if the students do not maintain the high grade point average, they are released from the program and they return to the base school. All students should have the opportunity to take a Foundations of Technology/Engineering course as a resource in preparing them to understand and apply important technological concepts. I agree with the opinion that "no one should have to wait until after high school to be exposed to engineering" (Douglas et al., 2004, p. 4). Those students who do pursue engineering degrees do not reflect the diversity of students in the United States, which is a pattern of enrollment that is likely to have a number of negative consequences, both for the successful practice of engineering and for the resolution of broader societal issues (Schunn, 2009).

Florida High School Pre-Engineering Program. The University of West Florida and a Florida High School initiated a high school level pre-engineering program. This was the purpose of the program:

> [To] create a seamless environment for students who think they might be interested in engineering, have the motivation and capability to enter the program in high school, and then after having participated in the program have the qualifications, skills, and motivation to enter a university engineering program and complete the program successfully (Rigby, 2005).

This study describes the various issues that arose such as curriculum development, staffing, finance, etc. These were the goals of the program:

- Increase and enhance awareness of the field of engineering among high school students.
- Develop problem solving skills and critical thinking skills in students.
- Increase hands on experience with real world problems.

Each of the four years builds from the previous year and adds different classes to the curriculum. During their senior year, they are required to combine all of their skills to design, develop, and test a team project. The students have a period of about two weeks where they conduct research and then the teacher conducts lectures, which help clear up some of the questions the students found in their research phase. Following the lecture period, the students are assigned a team hands-on project. They prepare proposals and then present their projects.

Hands-on projects help students learn by doing and by learning from their mistakes. It enhances the student's spatial ability. Most engineering classes are taught from books or whiteboard lectures, which are 2D, but engineering is applied in a 3D world. By working in 3D, it helps them work with more patterns and concepts they will have in their environment and provides more hands on activities to draw from when forming new concepts (Rigby, 2005). The project-based learning increases motivation (Nastu, 2009) and students are in charge of their own learning. Project-based learning requires higher order thinking skills and increases comprehension and retention of materials (Strobel, 2008).

One of the key strengths is the fact the students do not wait until the end of the four years to apply what they have learned; they apply it as they progress through the program. They interact with the design aspects from the beginning and if the design fails, they are able to learn from the failure through additional research and experimentation. If students are only involved with the design aspects at the end of their learning process, they learn little about the design phase. This can also be described as constructivism. Many students bring prior knowledge into a learning situation in which they must comment on and re-evaluate their understanding of it. This process of interpretation, articulation, and re-evaluation is repeated until they can demonstrate their comprehension of the subject. Constructivism often utilizes collaboration and peer criticism as a way of provoking students to reach a new level of understanding. Active practice is the key of any constructivist lesson (Carvin, 2012). Textbooks and research require critical thinking and an opportunity to analyze problems. Homework allows them to experience looking at things in a variety of ways through assignments like code breaking, brainteaser books, or essays where they can argue or debate (Strobel, 2008).

Another strength in this curriculum is teamwork when completing their projects. Teamwork has become an important part of the working culture and many businesses now look at teamwork skills when evaluating a person for employment. Most companies realize that teamwork is important because the complexity of the product requires a team with multiple skills to produce a better product (NDT, 2012).

Innovation is a strong factor in this type of curriculum. We need innovation in the world to provide for new jobs and to progress forward in today's trying economy. Innovation comes from the interaction at the fringes called “the fertile verges” between disciplines (Boorstin, 1980). Educators need innovative ways to teach through integrating not only the general education requirements for students (i.e. english, math, science, etc.), but to include skills and knowledge that helps apply to all of the "required" items.

For example, my son said when he was in high school he learned more about technology and innovation from a one-semester shop class where he learned how internal combustion engines and electrical circuits work, than in four years of physics, chemistry, trigonometry, and calculus. This one class integrated skills and knowledge through application.

Qualified teachers, finance, curriculum development, and the development of instructional materials were among the main weaknesses of the Florida High School program. The program goals were to 1) Expose students to the different types of engineering profession 2) Instruct students on how to become an engineer 3) Provide counsel on where to go to school and how to fund their education. In addition, the goal existed to develop critical thinking skills in students; however, the textbooks far exceeded the mathematical concepts for the students enrolled in this program. Due to this fact, the textbooks were tossed and primary instructional material and basic concepts were tailored to the level of the students' current cognitive skills (Rigby, 2005). This weakness of not setting the right goals ended up becoming a strength of the program.

Dealing with the issues in this high school program, educators learned that careful consideration of program goals and a curriculum that aligns with those goals; faculty selection and preparation; solid, level specific instructional materials and proper delivery of those materials are the first steps in the right direction (Rigby, 2005).

Assessment

How are the different pre-engineering programs throughout the education system assessed? The term assessment can vary from different authors, so for the purpose of this study I used the definition of assessment from Rogers and Sandos (1996), as it refers to the act of collecting data or evidence that can be used to answer classroom, curricular, or research questions. It is more than just measuring the students' scores on exams and homework; assessment is an ongoing process, which aims at understanding and improving student learning. There are various methods used to achieve this process:

- Developing criteria for learning quality
- Making the expectations explicit
- Gathering data for analyzing and interpreting how well the performance matches the standards and expectations and
- Utilizing the data results to document and improve performance

When assessment is implemented effectively, it can help in focusing collective attention and create an academic culture focused on improving the quality of education.

Types of assessments. Two common types of assessments are used in educational settings: formative and summative. *Formative Assessment* can provide feedback on the effectiveness of teaching. This allows the teachers to assess their teaching methods and adjust them to improve student learning. Formative assessment programs are challenging to implement in the classroom as the quality of benchmark testing is scarce and many times the assessments are an afterthought rather than a core element of the materials (Herman & Baker, 2006; Wolf, 1991). Another challenging aspect is the limitations of teachers' capacity to develop quality practices (Heritage & Yeagley, 2005; Stiggins, 2005). According to Phelan, Choi, Vendlinski, Baker, and Herman (2011), formative assessment needs to consist of clear criteria and high-quality feedback, which needs to be delivered at the right time. Timely feedback and communication are key factors of effective assessment; helping students to identify areas where they may need to spend more time and effort in improving their work. Teachers also need to participate in professional development on how to effectively use information from assessments (Phelan, Kang, Niemi, Vendlinski, & Choi, 2009; Phelan et al., 2011).

Techniques, such as teacher's observing students as well as, classroom discussion, help students and teachers gain an understanding of what they know or do not know. Tests and homework can be used formatively if teachers analyze where students are in their learning, and provide specific feedback on the performance and ways to improve. Formative assessment is a collection of practices with common features that lead to improving learning (Black & William, 1998a). Several well-known educational researchers emphasize this point when they describe what is at the heart of formative assessment:

- "Formative assessment, therefore, is essentially feedback, both to the teachers and to the pupil about present understanding and skill development in order to determine the way forward" (Harlen & James, 1997, p. 369).
- "Formative assessment refers to assessment that is specifically intended to provide feedback on performance to improve and accelerate learning" (Sadler, 1998, p. 77).

- "An assessment is formative to the extent that information from the assessment is fed back within the system and actually used to improve the performance of the system in some way" (William & Leahy, 2007, p. 31).
- "Formative assessment is defined as assessment carried out during the instructional process for the purpose of improving teaching or learning. What makes formative assessment formative is that it is immediately used to make adjustments so as to form new learning" (Shepard, 2008, p. 281).
- "Formative assessment using performance-based tasks may involve periodic assessments of a product (e.g., writing sample, drawing) or a process (e.g., giving a speech, operating a machine) with feedback to students concerning strengths and weaknesses" (Gronlund, 1998).

Black and William (1998a) published results of a meta-analysis study on assessment and classroom learning. The findings supported the use of frequent feedback to students about their learning. It also supported the idea that innovations that strengthen the use and practice of formative assessment produce learning gains. They examined the role of formative strategies used by teachers. Their studies showed that the primary user of assessment information to promote and improve learning is the student; however, the student has responded to the current educational system by focusing on "rewards," also known as "grades" or "class ranking," instead of the needs of their learning (Black & William, 1998b). It is important to provide feedback to the students on these types of assessments to help them focus on what areas they need to study. Students need this feedback in order to understand how to improve (Stiggins, 2007). Formative assessments help differentiate instruction and improve student achievement.

Summative assessment provides the final opportunity for the students to show what they have learned. This type of assessment provides evidence of student achievement in making a judgment about the student competence or the effectiveness of the program. This can be accomplished in the form of a final exam or final project. Summative assessment measures the level of proficiency at the end of the course, whether it is in the form of a final exam or an evaluation.

We need to think about what the student needs as far as skills and knowledge in order to compete in the workplace. Next, we need to create tasks and learning opportunities that assess a student's strengths or weaknesses. This is a revolving process that needs constant revision. The importance of a summative assessment lies in its potential to provide evidence to both the instructor and the student that the learning goals has been achieved or has not been achieved. Some formative assessments can be used as summative such as when the evidence indicates that students have attained mastery. In addition, some summative assessments can be used as informative such as, a test that reveals significant problems in learning that needs to be addressed through re-teaching. Summative assessment has a different purpose than formative assessment and that is to report the level of achievement (Chappuis, 2009).

An example of summative assessment may be a state test where a measurement of the level of achievement on the state content standards is used to determine the program effectiveness or a comparison of schools. The same state tests can also be used as formative assessment when developing programs, or interventions for groups or individuals. Classroom assessments can also be used as both summative and formative. As a summative assessment, you measure the level of learning taught to determine final report card grades, and as formative, you diagnose the student strengths or weaknesses, revise the teaching plans, and set goals for additional study (Chappuis, 2009).

Formative and summative evaluations are best understood by Bob Stake's statement, "When the cook tastes the soup, that's formative, when the guests taste the soup, that's summative" (Waters, 1997). Instructors' need to ask several questions when developing assessment tools:

- What are the skills needed by the students to compete in the workforce?
- What form of assessments need to be used to help the student learn the skills?
- How will the assessment tool guide both the instructor and student in improving the quality of the work?

Stiggins and Chappuis (2006) explained assessment for learning as a formative assessment that involves the student in their assessments by giving them clear classroom targets based on state or local standards. The targets are then transformed into dependable and accurate assessments.

Process assessment. Process assessment is associated with the immediate effects of instruction and the curriculum. This process helps improve the curriculum and shows which students have achieved the curriculum objectives. Process assessment reflects on whether the program is operating properly. There are certain questions associated with process assessment, which include the following:

1. How well are learners performing?
2. What is the quality of instructional and support personnel?
3. What are the costs and benefits associated with operating the curriculum?
4. To what extent are students satisfied with their instruction?

5. Which (if any) of the curriculum components are deficient? (Finch & Crunkilton, 1999, p. 277).

The various process assessment measures may include rates of completing certificates, diplomas, degrees, course completion rates, program completion rates, and student achievement on standardized tests (Hoachlander, 1991). The various ways the process assessment data can be gathered include standardized achievement measures, instructor constructed knowledge, performance instruments, instructor rating measures, and instructor behavior measures (Finch & Crunkilton, 1999, p. 276).

Product assessment extends beyond the current student to how the curriculum aided former students. The former students or graduates are the product of any curriculum. Studying those students helps in assessing the worth of the curriculum. Product assessments are usually conducted outside the classroom by gathering information from employers, supervisors, and peers. The questions differ from the process assessment questions because they are seeking answers about how students perform in their employment and how adequately the curriculum prepared the students for employment (Finch & Crunkilton, 1999, p. 276). Measures for gathering product assessment information include surveys, job satisfaction, ethnography, historiography, and biography (Hoachlander, 1991).

Outcome assessment. There is a push for outcome-driven assessment in engineering education although; at present, there is no single-accepted assessment in measuring the quality of high school technology engineering education. As McGourty (1998) stated in his research on developing an assessment program for undergraduate education in engineering, "It is doubtful whether any single measurement system could ever win universal acceptance for long, it does not mitigate the pressure to develop some kind of structure to support performance measurement and continuous improvement" (p. 117).

The vision of the successful outcome must be shared with students through models of success and quality work and/or the use of descriptive rubrics. Assessment processes are used to calibrate performance against professional standards (ABET, 2011). Assessments identify specifically where improvement efforts should focus to improve overall quality and performance.

Defining the critical pre-engineering outcomes for high school is very challenging. Programs are different in scope and content across high school curricula. Assessment should demonstrate the outcomes important to the objectives of the program. Outcomes should focus on the student and answer what the student is expected to be able to think and do (Fowler & Froyd, 2006).

ABET has designated criterion outcomes for accrediting universities and the STL have been developed as standards in assessing K-12 schools. Various research studies in curriculum development have been published that address criterions and standards for assessment, however, the following questions still face educators. Do HS learning outcomes prepare students to enter a college based engineering program? At what level are technology educators incorporating key elements of pre-engineering design in their curriculum? Are the HS curricula following a program such as PLTW, Project Probase, Principles of Engineering, Introduction to Engineering (Dearing & Daugherty, 2004), or any other program? If they are following a program, are they meeting the learning outcomes outlined by that program? The forgoing questions impress the need for an assessment tool that measures the critical pre-engineering outcomes that aligns with both STL and ABET associate degree "Criterion 3" student outcomes:

1. *Problem-solving skills.* Identify and solve problems using critical and creative thinking, engineering design processes, analysis, and application (STL 3, 8-16, 18-20; ABET 3a-c, e).
2. *Technological and environmental literacy.* Effectively utilize science and technology towards safety and the environment (STL 1, 2, 5; ABET 3a-c).
3. *Communication skills.* Communicate effectively utilizing visual, mathematical skills, computer aids in both orally and written modes (STL 9, 17; ABET 3a-c, e, f).
4. *Research skills.* Collect, analyze, organize, and evaluate information (STL 1-20; ABET 3b, c, e, i).
5. *Cultural and aesthetic understanding.* Be sensitive to cultural and aesthetic social contexts (STL 4, 6, 20; ABET 3g, h).
6. *Team building skills.* Work effectively as a team member (STL 8; ABET 3d, i).

There is no perfect assessment methodology; therefore, evaluators often select multiple assessment methodologies to balance their strengths and weaknesses. The choice of the methodology depends on many factors, including the goals and the scope of the evaluation (Prus & Johnson, 1994). Many research studies are available on outcome assessment making it a very open-ended issue as to what is the best methodology (Shaeiwitz, 1996; Scales, Owen, Shiohare, & Leonard, 1998; Briedis, 2002; Koh, Rodriguez-Marek, & Talarico, 2009; Mason & Dragovich, 2010; Gurocak, Chen, Kim, & Jokar, 2009; Das, 2008).

Studies have been developed to help identify some of the critical skills in engineering education (Woods, 2000; Smith & Wicklein, 2007; Kelley, 2008b). Kelley (2008b) conducted a study where he examined engineering design in curriculum content and the assessment practices of secondary technology education. Some student learning outcomes identified by Kelley are:

- Engineering design is an iterative process
- Creativity is important to apply in design
- There are multiple approaches to design
- Knowledge of science and mathematics when designing solutions
- The use of measuring equipment to gather data for troubleshooting, experimentation, analysis
- The use of models to estimate probability and study processes
- Optimization techniques to determine solutions
- Knowledge of manufacturing products
- Identifying problems
- Reverse engineering to analyze product design
- Skills in using, managing, and assessing technology
- Ability to handle open-ended/ill-defined problems
- Skills in the use of tools
- Communication through presentations, graphics, technical reports, drawings, 3D, and portfolios
- Rules of dimensioning
- Rules of manufacturing tolerance

- Computer skills
- Think critically
- Synthesize simple to complex systems
- Systems thinking
- Brainstorming
- Innovation
- Ethics
- Social, economic, and environmental impacts
- Cost, safety, and consequences
- Human values, limitations when designing, and solving problems
- Ergonomics
- Statics and strengths of materials
- Dynamics
- Material process
- Use design criteria such as budget, constraints, criteria, safety, and functionality
- Idea generation strategies
- Use models to optimize, describe, and predict results
- Work on a design team (pp. 182-189).

Kelley (2008a) stated, "A study of this design could provide valuable information about outcomes and competencies achieved by these specific curriculum projects and about curriculum deficiencies" (p. 142).

Another study by Halfin (1973) identified 17 mental processes from 10 high-level engineers and designers. Halfin used a Delphi technique to identify mental processes used by these expert engineers and designers. The cognitive processes are listed below:

- Mental Methods
- Analyzing
- Communicating
- Computing
- Creating
- Defining problem(s)
- Designing
- Experimenting
- Interpreting data
- Managing
- Measuring
- Modeling
- Models/prototypes
- Observing
- Predicting
- Questions/hypotheses
- Testing
- Visualizing

Assessment methods in engineering education. Over the years technology education curriculum has evolved from emphasizing manual and industrial arts to a stronger emphasis of engineering science, and design. A shift occurred from a skills-based approach to more of a focus on problem solving and design with a technological base. In engineering, Problem-Based Learning (PBL) promotes deep learning and problem-solving skills (Woods, 1996).

PBL has proven to be an effective way to learn subject knowledge. Learning teamwork, change management, skills in lifelong learning, conflict resolution, and problem solving are examples of effective ways PBL is used in curriculums. In most PBL programs, "the goal is to empower the students with the task of creating the learning objectives that are important to them" (Woods, 2000, p. 1). If the objectives are clear and published, then assessment is easier.

Students are given a problem and they are not restricted on where they may look for answers. PBL curriculums seek to incorporate a multidisciplinary approach in the solution of problems (Waters, 1997). Assessments should emphasize problem solving, thinking, and reasoning skills. Creating problems that are similar to tasks accomplished in real life industry and organizations are key principles of any PBL assessment. They are considered *authentic tasks*. The results should be repeatable in whatever assessment technique is used. This is very challenging because PBL is subjective in nature and it can be difficult for most educators to create assessments where the results are repeatable over time.

Student assessment seeks to provide a diagnostic tool to ensure students are progressing towards achieving the desired learning goals. PLTW and EbD incorporate PBL in their curriculums through activities and working in teams. Waters (1997) described a PBL example where a senior undergraduate course was assigned to design an interactive system for a specific auction firm. This example allowed the students to perform self-assessment and group assessments throughout the process. The students interviewed the customers of the auction firm and from the information they received, they developed their design and the implementation of the design. They worked in phases and at the end of each phase, they performed the self-assessment and group assessments. The instructor was able to detect any group problems at the end of the group assessment phases and provide any corrective actions needed. The study indicated the requirements phase was the most difficult part in trying to specify exactly what the customers needed. The overall results showed that the student performance improved during the design and implementation phases, but their performance was poor in the requirements phase. The purpose of the study was to design an evaluation of the PBL process that determined whether PBL was more appropriate than the more traditional methods in training software engineers. The study found that technology changes rapidly in this field so using a PBL approach did help, but felt the best evaluation would be to look at their graduates several years after they completed the PBL. In the interim, they chose to use qualitative assessment with questionnaires as part of a formative evaluation, and the summative evaluation compared pre-test scores to post-test scores. Waters (1997) felt the requirement to have authentic tasks conflicted with the requirement for assessments to be repeatable. He believed that authentic tasks are themselves ill structured and difficult to assess completely objectively (Waters, 1997).

The study above and countless other studies (such as Wicklein & Rojewski, 1999; Wicklein, 2005; Gravander, 2004; Kelley, 2008a; Lewis, 2005) indicate there are still areas in assessment that are open issues. Technology educators face these issues or challenges when they seek to implement engineering design into their curriculums. According to Wicklein (1999), technology educators have investigated the possibilities of creating a unifying conceptual framework for technology education curriculum for over a quarter century. Several attempts have been made to determine common goals of technology education curriculum (Zuga, 1989). The common thread throughout the literature was the ability to develop critical thinking and problem-solving skills, which are important to the field and are the primary goals of the ITEA (ITEA, 2000a).

Too often educators associate high cost laboratory equipment, computers, and state of the art industrial machines when teaching technological subjects. Technology changes so rapidly the equipment is obsolete within a short timeframe. A solution to this issue would be to form partnerships with industry and internships, such as with the medical fields. This would lead us to areas of intellectual methods and processes as a means to solve technological problems. Wicklein (1999) states:

> By identifying the basic cognitive strategies employed when solving technology-based problems, technology educators could develop instructional strategies that incorporate these methods in a variety of learning activities. The mental processes are not developed as curriculum per se; however, they may serve as a basis for creating curriculum designs that may yield comprehensive and strategic means of employing critical thinking and problem solving strategies for students. Curriculum that emphasizes technical content tends to be rather short lived and is constantly changing due to the rapid accumulation of knowledge and techniques used in business and industry. In comparison, the mental processes and techniques used in solving technological problems could remain rather consistent over time.

> Thus, regardless of changes in tools or the type of technology, the underlying curriculum goals would remain consistent. Teachers and administrators might value stability in curriculum design and especially students involved in the volatile field of technology (p. 1).

Many institutions are focusing on their student learning outcomes and aligning them with ABET EC2000. We need to use every source we have available to us in order to solve the issues we face today, and to address concerns that echo from the 1983 address *Our Nation is at Risk.* Our once "unchallenged preeminence in commerce, industry, science, and technological innovation is being overtaken by competitors throughout the world" (Goldberg & Harvey, 1983, p. 15).

Assessment studies in technology education. Various studies show that there is still a need for more research that addresses assessment issues in technology education. There is not a defined standard that focuses on a common assessment tool that can be used in various pre-engineering programs in high schools (Waters, 1997; Wicklein & Rojewski, 1999; Wicklein, 2005; Gravander, 2004; Kelley, 2008b; Lewis, 2005).

In 2005-2006, a number of research studies were conducted by NCETE across the five Technology Teacher Education (TTE) sites. They included the following:

1. identification of core engineering concepts
2. production of logic models effective professional development
3. production of successive engineering design challenges
4. development of rubrics to evaluate the integration of engineering design in technology education (Asunda & Hill, 2007; Merrill et al., 2008).

Many research studies address professional development, design development, curriculum development, standards, and guidelines within technology education (Bennet, 1999; Rowell, 1999; Cajas, 2000; Morford & Warner, 2004; Dym, Agogino, Eris, Frey, & Leifer, 2005; Merrill & Daughtery, 2010). However, there are limited studies that assess whether what students are learning is what is needed to continue their education at a college or university in the engineering fields (McGourty, Sebastian, & Swart, 1998; Besterfield-Sacre, et al., 2000).

In a research study by Asunda and Hill, one of their three focus areas included what practical strategies could be used to evaluate the infusion of engineering design into technology education learning. They developed a rubric to evaluate the integration of engineering design. The results indicated the assessment of design products was subjective and difficult to quantify design outcome, however, could be denoted by performance indicators (Asunda & Hill, 2007).

Wicklein (2005) ranked the critical issues and problems in technology education through a survey questionnaire with a 55% completion rate. A total of 347 middle school and high school teachers were randomly selected as well as 132 university leaders in technology teacher education and 55 state and regional supervisors. The results showed a critical problem in the insufficient quantities of qualified technology education teachers in the high schools. The insufficient quantities of qualified pre-engineering education teachers lead back to the need of the development of an instrument to assess design process and outcomes in pre-engineering high school programs. The development of sound evaluation practices and statistical methodology can result in positive and productive change in student achievement. The assessment instrument could prove to be a valuable tool for the improvement of educational outcomes.

Summary

The current research indicates the integration of technology and engineering could lead to greater technological literacy and promote engineering as a career choice (Lewis, 2005). Frameworks such as the Standards for Technological Literacy (STL): Content for the Study of Technology, were developed to define what the students should know and what they are able to do in order to be technologically literate. In addition, they prescribe what the outcomes of the study of technology in grades K-12 should be. ABET changes the way programs are evaluated and the way courses are developed. ABET criteria requires institutions to evaluate and document the quality of their programs and their student learning outcomes.

Engineering design is being implemented into the curriculum for pre-engineering high school programs. It is similar to technological design in that both requires creativity, critical thinking, innovation, application of technical knowledge, and also knowledge of how our society and our environment are impacted by design. Engineering design education can contribute to the K-12 education system by providing students with the opportunity to realize the usefulness of and need for mathematics and science as they apply them to their lives through technology.

Many high schools have implemented programs, which introduce engineering design into their curricula. The Oxon Hill High School located in Oxon Hill, Maryland, has adopted a successful Science and Technology Program (STP) that was established in 1976. Oxon Hill is one of three high schools in Prince George's County that offers this program. The four-year academic program consists of 28 credits in which a minimum of 13 credits are in specific mathematics, pre-engineering technology, research, and science classes. Engineering by design is included in the curriculum in many areas. Some states have adopted technology education curriculum models, which are pre-engineering in nature. The state of Massachusetts has created state standards that contain many of the STL elements. Project Lead the Way (PLTW) was developed by Richard Blais in New York in the 1980s (Blais & Adelson, 1998), and serves over 1,250 schools in 44 states (Kelley, 2008b). PLTW courses use problem-based learning, which allow students to learn and apply skills and knowledge in real world situations.

Various studies show that there is still a need for more research that addresses assessment issues in technology education. There is not a defined standard that focuses on a common assessment tool that can be used in various pre-engineering programs in high schools (Waters, 1997; Wicklein & Rojewski, 1999; Wicklein, 2005; Gravander, 2004; Kelley, 2008b; Lewis, 2005).

There are two common types of assessments that are used in educational settings: formative and summative. *Formative assessment* can provide feedback on the effectiveness of teaching. This allows the teachers to assess their teaching methods and adjust them to improve student learning. *Summative assessment* provides the final opportunity for the students to show what they have learned. Tests covering a large amount of material, such as those covering six months or more of learning, would typically be thought of as summative assessment. This type of assessment provides evidence of student achievement, and allows the teacher to make judgments about the student competence or the effectiveness of the program.

Currently, the most common use of assessment is as a summative measure, which is a measurement at the end of the student learning to determine how many of the intended goals the student has learned. It is an assessment after the learning has stopped. Formative assessment is a process used by teachers and students that helps to provide feedback to the student (McManus, 2008). Summative is an assessment of learning; formative is an assessment to help students continue to learn.

There is a push for outcome-driven assessment in engineering education although at present there is no single-accepted assessment in measuring the quality of high school pre- engineering education. There are studies and projects directed towards this goal. One assessment tool may not be accepted for a long period, but that does not mean there should not be an assessment tool to measure the outcomes.

Many research studies address professional development, design development, curriculum development, standards, and guidelines within technology education (Bennet, 1999; Rowell, 1999; Cajas, 2000; Morford & Warner, 2004; Dym, et al., 2005; Merrill & Daughtery, 2010). However, there are limited studies that address the assessment of those curriculums, design, and standards as to whether what students are learning is what is needed to continue their education at a college or university in the engineering fields (McGourty, et al., 1998; Besterfield-Sacre, et al., 2000).

Chapter 3: Method

The purpose of this study was to identify the important constructs and their key indicators that are to be included in an instrument developed to measure the engineering design outcome of students in high schools that use Project Lead the Way (PLTW) and Engineering by Design (EbD) curriculums. The study utilized a comparative case study method. The following research questions guided the study:

1. How are the constructs identified by Childress and Rhodes (2008) ranked in terms of criticality for inclusion on an instrument to measure engineering design outcomes in high schools in Idaho?
2. What are the key indicators associated with the constructs identified by Childress and Rhodes (2008) to measure engineering design outcome in high schools in Idaho?
3. Are there differences between constructs for design outcomes as identified in the Project Lead the Way and Engineering by Design content?

Research Design

Case study research involves the study of a case within a real-life, contemporary context or setting (Yin, 2009). Stake (2005) states that case study research is not a methodology but a choice of what is to be studied. Others present it as a strategy of inquiry, or a comprehensive research strategy (Denzin & Lincoln, 2005; Merriam, 1998; Yin, 2009). Creswell (2012) states case study research is a qualitative approach where the investigator explores a real-life, bounded case over time using detailed data collection. Through multiple sources of information, a case description and case themes are derived. A single case is referred to as a within-site study (Creswell, 2012).

A case study begins with identifying a specific case such as a relationship, a decision process, or a specific project. Researchers study current, real-life cases that are in progress in order to gather accurate information. An *instrumental case* is a study to understand a specific issue problem or concern. A good qualitative case study presents an in-depth understanding of the case by collecting many forms of qualitative data (Creswell, 2012). Yin (2009) recommends seven types of information to collect:

1. documents
2. archives
3. records
4. interviews
5. direct observations
6. participant observations
7. physical artifacts

The Cases

The study focused on grades 10-12 pre-engineering curriculums from two selected schools within Idaho. Permission was granted by the IRB of the University of Idaho to conduct the study (refer to Appendix A). A letter was sent to the Program Manager for the State of Idaho Engineering and Technology Education Program requesting permission for two Idaho schools' participation in the study. Permission was given and the Program Manager supplied the contact information for the Idaho Schools (Refer to Appendix J for the letters). The researcher contacted the three PLTW instructors and one of the three EbD instructors contacted the researcher before the letter was sent, indicating his willingness to participate. All three PLTW instructors replied and said they would be willing to participate. The researcher chose one of the PLTW instructors to provide the curriculum materials and one of the two remaining PLTW instructors to participate in completing the survey instrument.

Lewiston High School, which uses EbD, participated in the study. Lewiston is currently developing their three-year program. They are taking a little different approach to the curriculum sequence of Engineering by Design. The Fundamentals of Technology class is only one semester at the junior high schools. The Technological Design curriculum cover topics such as Career Search, Sketching, Toy Design (which the instructor uses for teaching shop safety, power tools, and finishing), Logo Design Concept, Mouse Trap Cars, Solid Works for Bridge Building, Co^2 Cars, and an additional Design Problem. The curriculum emphasizes the engineering team concept and tries to encourage creative design for all students.

The Advanced Design Applications Class uses a Material Science Curriculum developed by Energy Concepts Inc. that includes Solid materials, Metals, Polymers, Ceramics, and Composites. The emphasis is on the importance of Materials Engineering to the manufacturing process. The Engineering Design courses include More Solid Works, Robotics, VEX Curriculum, as well as, Total Quality Management, to develop Engineering team skills. The senior projects are integrated into the class.

Columbia High School in the Meridian School District participated in the study. Columbia opened in 2006, the newest of the Nampa's three high schools and they use the PLTW curriculum. Introduction to Engineering is taught in the 9th grade, which focuses on the design process and its application. Principles of Engineering is taught in the 10th grade and introduces major concepts students encounter in post-secondary engineering courses such as mechanisms, statics, materials and kinematics. There are five specialization courses within PLTW, Aerospace Engineering (AE), Biotechnical Engineering (BE), Civil Engineering and Architecture (CEA), Computer Integrated Manufacturing (CIM), and Digital Electronics (DE). Digital Electronics and Aerospace Engineering are taught in the 11th grade at Columbia. Engineering Design and Development (EDD) is taught in the 12th grade. This is the capstone course where the students work in teams to design and develop solutions to a problem by applying the engineering design process.

Procedure

Data collection. Data were collected in two stages. In the first stage, a content analysis was conducted for PLTW and EbB curriculums to identify the key indicators that are associated with six of the constructs identified by Childress and Rhodes (2008). In the second stage, the constructs and key indicators were placed on a survey form and sent to experts for them to rate the key indicators importance and difficulty to assess.

Content analysis of curriculums. A qualitative content analysis of the two pre-engineering curriculums was conducted to identify the constructs key indicators. *Content analysis* is a research tool in which researchers quantify and analyze meanings and relationships of words and concepts within text (Carol, B., et al., 1994-2012). Content analysis enables researchers to sift through large volumes of data with relative ease in a systematic fashion. It is a useful technique for allowing researchers to discover and describe the focus of individual, group, institutional, or social attention (Weber, 1990). It also allows inferences to be made that can then be corroborated using other methods of data collection. Krippendorff (1980) notes that "much content analysis research is motivated by the search for techniques to infer from symbolic data what would be either too costly, no longer possible, or too obtrusive by the use of other techniques" (p. 51).

The curriculum materials that were analyzed from the PLTW and EbD curriculums are displayed in Table 1.

Table 1. Curriculum Materials Analyzed for PLTW and EbD.

PLTW 10th Grade Curriculum Materials	EbD 10th Grade Curriculum Materials
Principles of Engineering Lessons, Activities, Projects, PowerPoint's, Assessments, Teacher Notes, Student Resources, ABET Concepts, National Science Education Standards, Standards for School Mathematics, Standards for the English Language Arts, Standards for Technological Literacy, and Principles of Engineering PLTW textbook.	***Technological Design*** Lessons, Activities, Projects, Assessments, Teacher Notes, and Student Resources.
PLTW 11th Grade Curriculum Materials ***Digital Electronics*** Lessons, Activities, Projects, PowerPoint's, Assessments, Teacher Notes, Student Resources, ABET Concepts, National Science Education Standards, Standards for School Mathematics, Standards for the English Language Arts, Standards for Technological Literacy, and Digital Electronics PLTW textbook.	**EbD 11th Grade Curriculum Materials** ***Advanced Design Applications*** Lessons, Activities, Projects, Assessments, Teacher Notes, Student Resources, and Material Science Textbooks.
Aerospace Lessons, Activities, Projects, PowerPoint's, Assessments, Teacher Notes, Student Resources, ABET Concepts, National Science Education Standards, Standards for School Mathematics, Standards for the English Language Arts, and Standards for Technological Literacy.	
PLTW 12th Grade Curriculum Materials ***Engineering Design & Development*** Lessons, Activities, Projects, PowerPoint's, Assessments, Teacher Notes, Student Resources, ABET Concepts, National Science Education Standards, Standards for School Mathematics, Standards for the English Language Arts, and Standards for Technological Literacy.	**EbD 12th Grade Curriculum Materials** ***Engineering Design & Robotics*** Lessons, Activities, Projects, Assessments, Teacher Notes, Student Resources and Robots program materials by Intelitek.

All of the materials were provided electronically, except for the following textbooks and manuals: Principles of Engineering and Digital Electronics (both PLTW);

and The Material Science Manuals, Solids, Ceramics, Polymers, Metals, & Compounds (all EbD). The following steps were performed in phase one:

Step one: Identify the question. What are the key indicators of constructs to measure engineering design outcome in high schools?

Step two: Choose sample for analysis. The PLTW curriculum materials and the EbD curriculum materials were analyzed. An example of the curriculum materials analyzed for the 10th grade PLTW Principles of Engineering curriculum is presented below.

- Course Overview
- Course Description
- Detailed Outline
- Topical Outline
- Key Terms Glossary
- Teachers Notes for each Lesson
- Lessons 1.1 through 1.4
- Lessons 2.1 through 2.4
- Lessons 3.1 through 3.3
- Lessons 4.1 through 4.2
- Engineering Formulas
- Example Design Process
- DE Equations and Theorems
- Presentation Rationale
- Sample Engineers Notebook Entry

- Assessments
- Activities
- Power Points
- Standards
- Textbooks

Step three: Code for words. The curriculum materials were coded at the simplest level, merely for existence, utilizing the six constructs. Each coder was given a copy of the 10th grade curriculum materials for both PLTW and EbD. The researcher provided instructions to the coders prior to the coding process. The instruction process is displayed in Table 2. In addition, the six constructs identified as the conceptual framework were provided as a reference for the key indicators.

- Engineering Design Concepts
- Application of Engineering Design
- Engineering Analysis
- Engineering Communication
- Engineering & Human Values
- Engineering Science

The coders independently highlighted the words most frequently used within grade10 curriculum materials for both PLTW and EbD and each one presented their findings in Microsoft Word. The coders met to review and discuss their findings. The complete list of words for the 10th grade is included in Appendix B and C. The coders then proceeded to perform a content analysis on the remaining curriculum materials for both PLTW and EbD through grade 12. Many of the same words were found in the 10-12 grades of both EbD and the PLTW curriculums. The table in Appendix B displays all the coders' words found in the 10th grade PLTW curriculum. Only the additional words for each curriculum in grades 10-12 are displayed in Appendices C-G.

Table 2. Coders' Instructions.

Please identify frequently found words relating to engineering related topics as well as, the mental processes identified in several studies (Hill & Wicklein, 1999; Wicklein & Rojewski, 1999; Halfin, 1973). Compile the list using Microsoft Word. Thank you.

Researching	Managing	Creating
Computing	Monitoring/Interpreting Data	Questions/Hypotheses
Values	Establishing need	Communicating
Models/Prototypes	Observing	Visualizing
Innovating	Technology Review	Measuring
Defining Problem(s)	Predicting	Modeling
Analyzing/Analysis	Testing	Designing

The reliability of a content analysis study refers to its *stability*, or the tendency for coders to consistently recode the same data in the same way over a period of time. The tendency for a group of coders to classify categories membership in the same way refers to *reproducibility*. Gottschalk (1995) points out that the issue of reliability may be further complicated by the inescapable human nature of researchers. For this reason, he suggests that coding errors can only be minimized and not eliminated (he shoots for 80% as an acceptable margin for reliability) (Carol, B., et al., 1994-2012, Colorado State University, 2006).

According to Krippendorff (2004), in order to assure that the data under consideration are at least similarly interpretable by two or more coders (as represented by different coders), it is customary to require $\alpha \geq .800$. Where tentative conclusions are still acceptable, $\alpha \geq .667$ is the lowest conceivable limit (Krippendorff, 2004, p. 241). The researchers checked the reliability of the coding. The level of reliability overall was at

87%. Tables 4-9 found in Chapter 4 show the inter-rater reliability percentages for grades 10 -12 of each curriculum.

The comparison of the word frequency count, along with the coders' results produced a summation of 711 words, of which both coders found 618 of those words. Some of the words were a derivative of the same word so they were reduced into a final manageable, qualitative descriptive frequency list. This process was done by including the highest frequency word found within a group of similar words. For example, there was a group of the following words found by the coders: *communicate, communication,* and *communications*. The final word selected was *communication* because of the highest word count and meaning or relationship within the curriculum materials. The final descriptive list is included in Appendix H.

All of the electronic curriculum materials were placed into a software Macro search program. A MACRO was developed where each of the electronic curriculum materials were run through the MACRO, creating a word count. The MACRO was designed to include the words identified by the coders.

The key indicators were derived from the final descriptive frequency list by looking at the word frequency and correlating it to the curriculum materials. These were then included as key indicators within the six main constructs in the survey. This survey was sent to the expert team for verification. A copy of the survey is included in Appendix I.

Step four: Explore the relationships between concepts. After the final frequency list was identified, the text was analyzed for the relationships within the six constructs identified in the conceptual framework using a relational analysis. A relational analysis begins with identifying concepts in a set of texts and then exploring the relationships between the concepts that are identified (Carol, B., et al., 1994-2012, Colorado State University, 2006). Another term for relational analysis is termed *semantic analysis* (Palmquist, Carley, & Dale, 1997). The relational analysis focused on looking for meaningful relationships within the curricula: "Meaning is a product of the relationships among concepts in a text. Carley (1992) asserts that concepts are ideational kernels. These kernels can be thought of as symbols, which acquire meaning through their connections to other symbols (Carol, B., et al., 1994-2012, Colorado State University, 2006).

The coders worked together at this point in determining where the key indicators fit within the six constructs. They looked at the concepts, objectives, lessons, activities, assessments, and standards addressed in each lesson, along with the final frequency list that covered all of the materials in both PLTW and EbD curriculum. For example, PLTW Lesson 1.1 Mechanisms includes sub lessons 1.1-1.1.5 that states, students will gain an understanding of mechanisms through the application of theory-based calculations accompanied by lab experimentation. The concepts and objectives for the lesson include the following:

Concepts

1. Engineers and engineering technologists apply math, science, and discipline-specific skills to solve problems.
2. Engineering and engineering technology careers offer creative job opportunities for individuals with a wide variety of backgrounds and goals.

3. Technical communication can be accomplished in oral, written, and visual forms and must be organized in a clear and concise manner.
4. Most mechanisms are composed of gears, sprockets, pulley systems, and simple machines.
5. Mechanisms are used to redirect energy within a system by manipulating force, speed, and distance.
6. Mechanical advantage ratios mathematically evaluate input work versus output work of mechanisms.

Performance Objectives

It is expected that students will be able to do the following:

- Differentiate between engineering and engineering technology.
- Conduct a professional interview and reflect on it in writing.
- Identify and differentiate among different engineering disciplines.
- Measure forces and distances related to mechanisms.
- Distinguish between the six simple machines, their attributes, and components.
- Calculate mechanical advantage and drive ratios of mechanisms.
- Design, create, and test gear, pulley, and sprocket systems.
- Calculate work and power in mechanical systems.
- Determine efficiency in a mechanical system.
- Design, create, test, and evaluate a compound machine design.

Assessment

Explanation.

- Students will explain the difference between engineering and engineering technology.
- Students will explain the relationship between work and power in a mechanical system.
- Students will explain the processes of calculating mechanical advantage.

Interpretation.

- Students will make journal entries reflecting on their learning experiences.
- Students will explain the importance and relevance of simple machines in everyday life.

Application.

- Students will apply their knowledge of simple machines and calculate mechanical advantage of objects within the lab environment.
- Students will apply their knowledge of system efficiency to calculate efficiency of a mechanical system.
- Students will apply their knowledge of gear, sprocket, and pulley systems to calculate speed, distance, rotational direction, and mechanical advantage.

Perspective.

- Students will select an engineering or engineering technology field of interest and prepare an interview with a professional within the field of interest.
- Students will identify and discuss the role and impact of simple machines, compound machines, and gears, pulleys, and sprockets throughout the development of civilizations.

Self-knowledge.

- Students will be required to reflect on their work in their journals by recording their thoughts and ideas. Ideas and questions students may pose and answer in their journals include the following:
    - Today, the hardest part for me to understand was . . .
    - When I work in a group, I find that . . .
    - When I work by myself, I find that . . .
    - What did I accomplish today?
    - Now that I have done this, what is next?
- Students will conduct formal periodic self-assessments of course knowledge and content.

Standards and Benchmarks Addressed

Standards for technological literacy.

- Standard 2: Students will develop an understanding of the core concepts of technology.
- Standard 3: Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.
- Standard 7: Students will develop an understanding of the influence of technology on history.
- Standard 8: Students will develop an understanding of the attributes of design.
- Standard 11: Students will develop abilities to apply the design process.
- Standard 12: Students will develop the abilities to use and maintain technological products and systems.

- Standard 16: Students will develop an understanding of and be able to select and use energy and power technologies.
- Standard 17: Students will develop an understanding of and be able to select and use information and communication technologies.

Other standards used were the National Science Education Standards, Principles and Standards for School Mathematics, and Standards for the English Language Arts.

Phase Two

Survey development. Because the construct categories used for this research were items from prior studies, one of which was identifying appropriate outcomes using a Delphi study (Childress & Rhodes, 2008) and the other using 1084 high school technology education teachers and members of ITEA (Kelley, 2008b), the final categories have already gone through extensive construct validity. The six main constructs used in the survey included the following:

- Engineering Design Concepts
- Application of Engineering Design
- Engineering Analysis
- Engineering Communication
- Engineering & Human Values
- Engineering Science

The key indicators found from the content analysis were placed under one of the six constructs. An additional comment section for each construct was included. The survey was sent to six experts in the field for verification. The expert team consisted of two engineering and technology education teachers from two high schools in Idaho, two engineers from industry in Idaho, and two engineering education faculty from two universities. The team was chosen for their experience in either teaching engineering or practicing engineering in industry. Table 3 provides the background and experience for each of the members.

Table 3. Expert Team Background.

Expert Team Member	Background
High School Educator #1	M. Ed. in Educational Technology 8 years teaching in the Post Falls School District as the Computer Applications/Media Production/Webpage Design Teacher 7 years' experience as an In-Service Trainer at the University of Idaho 9 years' experience as a Senior Electronics Technician 1 year as an Associate Manufacturing Engineer 10 years as Owner/Operator of an Electronics business
High School Educator #2	BS in Electrical engineering from NDSU 21 years as an engineer for HP <1 year contract engineer MS in Professional Technical Education 3 years elementary computer skills (classified position) 8th year as a certified teacher in HS teaching mostly PTE engineering classes and some math
University Educator #1	Ph.D. from John Hopkins University Director of Engineering Professor of Mechanical Engineering Guest researcher for several laboratories in the U.S. and Canada Associate editor, Journal of Computational & Experimental Biomechanics
University Educator #2	PhD. from the University of Georgia Assistant Professor of Industrial Technology at Purdue University for 5 years Over 46 articles, publications, many of which focus on implementing engineering design in secondary technology education Member of multidisciplinary team researching the use of engineering design to teach science to elementary students that was awarded a 6.7 million dollar National Science Foundation grant.
Engineer in Industry #1	MS in Mechanical Engineering, 30 years of experience in thermal-hydraulic analysis that centers on the safety of commercial nuclear power plants during postulated accident scenarios. All of this work is done using computer simulations. The work requires knowledge of thermodynamics, fluid mechanics, and heat transfer. Thermal-Hydraulic computer codes such as RELAP5 and TRACE are used in the analysis process. These computer codes use first principles of physics and empirical data to simulate the physical behavior of transient situations. Mathematical models of physical facilities are made to represent the geometric configuration.
Engineer in Industry #2	B.S. in Civil Engineering from BYU M.S. in Civil/Structural Engineering at BYU A practicing structural engineer for about 15 years

An *expert* is "a person who has background in the subject area and is recognized by his peers or those conducting the study as qualified to answer questions" (Meyer & Booker, 1990, p. 3). Meyer and Booker (1990) identify several situations when an expert judgment is typically gathered:

1. To provide estimates on new, rare, complex, or otherwise poorly understood phenomena.
2. To forecast future events.
3. To integrate or interpret existing data.
4. To learn an expert's problem-solving process or a group's decision-making processes.
5. To determine what is currently known, what is not known, and what is worth learning in a field of knowledge (Meyer & Booker, 1990, p. 4-5).

Expert judgment is often gathered in a quantitative form (Meyer & Booker, 1990). This study used a modified Delphi method, which is a procedure that "is repeated administration of questionnaires to each member of an expert panel, without face-to-face contact" (Dean & West, 1999, p. 4). This method of research is flexible and lends itself to a broad range of applications.

Content validation procedures were followed as outlined in the educational research literature (Carol, B., et al., 1994-2012). These methods required presenting a list of instrument items; in this case, the identified constructs and their key indicators, to a team of experienced engineering education faculty and engineers for construct and key indicator verification.

The instrument asked participants to rate outcome items on a five point Likert scale (Clark & Weing, 1999). The *Importance of Indicator* category asked them to rate the importance of each key indicator for assessing engineering design process and outcome at the high school level. The *Difficulty to Assess* category asked them to rate the difficulty in assessing the key indicator. The ratings for the frequency category are described below.

1. Strongly Disagree: Not necessary for an engineering high school curriculum
2. Disagree: Less than necessary for an engineering high school curriculum
3. Neutral: No opinion
4. Agree: Necessary to include in an engineering high school curriculum
5. Strongly Agree: Essential for inclusion in an engineering high school curriculum

The ratings for the difficulty category are described below.

1. Strongly Disagree: Not difficult to assess in an engineering high school curriculum
2. Disagree: Somewhat difficult to assess in an engineering high school curriculum
3. Neutral: No opinion
4. Agree: Difficult to assess in an engineering high school curriculum
5. Strongly Agree: Very difficult to assess in an engineering high school curriculum

The criticality indicator of the six constructs was derived by multiplying the importance and the difficulty factors for each key indicator within each construct. The average mean value was a summation of each of the key indicators within the construct, divided by the number of key indicators within each construct.

The team of expert engineers and educators were asked to identify any additional constructs they deemed important for the development of an assessment tool of engineering design content in high schools. The instrument sent to the experts was developed by modifying the scale used by Norton in the task verification process (Norton, 1999).

Chapter 4: Results

The results of this study are based on data from the content analysis conducted of the PLTW and the EbD curriculum materials of two high schools in the State of Idaho, and a survey sent to six experts for them to rate the key indicators of six constructs importance and difficulty to assess. Results are presented first by giving the coding results, and then answering each research question using tables and narrative descriptions.

Coding Results

The percentages are shown for the word counts by both coders in Tables 4-9 for the curriculum in the 3 grades. The overall inter-rater reliability was 87%.

Table 4. Coding Percentage for PLTW 10th Grade Curriculum.

10th Grade PLTW			
Coders	# words found	Same # of words	Total %
Coder 1	327	279	0.853211
Coder 2	318	279	0.877358
Total	645	558	0.865285

Table 5. Coding Percentage for EbD 10th Grade Curriculum Additional Words.

10th Grade EbD			
Coders	# words found	Same # of words	Total %
Coder 1	341	291	0.853372
Coder 2	330	291	0.881818
Total	671	582	0.867595

Table 6. Coding Percentage for PLTW 11th Grade Curriculum Additional Words.

11th Grade PLTW			
Coders	# words found	Same # of words	Total %
Coder 1	356	303	0.851124
Coder 2	342	303	0.885965
Total	698	606	0.868544

Table 7. Coding Percentage for EbD 11th Grade Curriculum Additional Words.

11th Grade EbD			
Coders	# words found	Same # of words	Total %
Coder 1	357	304	0.851541
Coder 2	343	304	0.886297
Total	700	608	0.868919

Table 8. Coding Percentage for PLTW 12th Grade Curriculum Additional Words.

12th Grade PLTW			
Coders	# words found	Same # of words	Total %
Coder 1	361	307	0.850416
Coder 2	346	307	0.887283
Total	707	614	0.868849

Table 9. Coding Percentage for EbD 12th Grade Curriculum Additional Words.

12th Grade EbD			
Coders	# words found	Same # of words	Total %
Coder 1	363	309	0.851240
Coder 2	348	309	0.887931
Total	711	618	0.869585

Research Question One

How are the constructs identified by Childress and Rhodes (2008) ranked in terms of criticality for inclusion on an instrument to measure engineering design outcomes in high schools in Idaho? The six constructs used for this study were derived from research conducted by Childress and Rhodes (2008). Childress and Rhodes framework consisted of seven constructs of which six were used for this study. The criticality index for each construct was derived by multiplying the key indicators' average importance index by the average difficulty index (Norton, 1999). The constructs were then rank ordered from the highest criticality index to the lowest criticality index (see Table 10).

Table 10. Criticality Ranking of the Six Constructs.

Construct Category	*Mf* Importance	*Mf* Difficulty	Indicator of Criticality
Engineering & Human Values	4.2	3.3	13.9
Application of Engineering Design	4.0	3.0	11.9
Engineering Communication	4.1	2.9	11.8
Engineering Design Concepts	4.0	2.9	11.6
Engineering Analysis	3.8	2.7	10.3
Engineering Science	3.5	2.3	8.3

The construct Engineering & Human Values had the highest criticality index ranking. This means that based on the experts perception, this construct is the most important to be included on an instrument that measure students engineering design outcome. Overall, the importance to include this construct on such an instrument is high and so is the difficulty to assess this construct.

The key indicator with the highest importance (4.8) for this construct was *participating in teams*. The importance of functioning effectively as a member of a design team is emphasized by ABET (ABET, 2011). Functioning effectively on a team is a critical skill in engineering and technology education (Woods, 2000; Smith & Wicklein, 2007; Kelley, 2008b). The key indicator with the lowest ranked importance for the construct Engineering & Human Values was *understanding relationships among technologies* (3.8).

The second highest ranked construct was Application of Engineering Design. Overall, this construct had high importance for inclusion on an instrument to measure engineering design outcome. The team, however, indicated a neutral opinion on its difficulty to assess. The three highest ranked key indicators for this construct deals with providing documentation, calculating forces, and performing measurements respectively. The key indicator with the lowest importance was *utilizing flight simulators*.

The third highest ranked construct was Engineering Communication. This construct ranked high in importance for inclusion on an instrument that measures engineering design outcome in high schools. The team indicated it would not be too difficult to assess this construct in a high school engineering curriculum. The seven key indicators with the highest importance for this construct had importance indices ranging from 4.5 - 4.7 and deals with communicating professionally on the design solution process as students are engaged in problem-based learning and project-based learning. The key indicator with the lowest importance for the third construct was *utilizing automation system programming functions*.

The fourth highest ranked construct was Engineering Design Concepts. This construct was perceived as high in importance for inclusion in an instrument to measure design outcome in high schools. The expert team indicated it would not be too difficult to assess this construct in a high school engineering curriculum. The five key indicators with the highest importance involve creativity, documenting in an engineer's notebook, attributes of a design process and models. Their importance ranged from between 4.5 - 4.8 and their difficulty to assess range from 3.0 - 3.3. This indicates the expert team ranked them as being necessary to include in an instrument to measure engineering design outcome, with some difficulty to assess. The indicator with the lowest importance was *justifying discoveries are innovations*. It also had 3.0 score in difficulty to assess.

Engineering Analysis was ranked fifth in criticality. Overall, the experts perceived this construct high in importance for inclusion in an engineering high school assessment tool. The expert team also indicated that overall, it would not be too difficult to assess this construct in an engineering high school curriculum. The top seven ranked key indicators in terms of importance for this construct involved using mathematics in solving problems and understanding the quantitative data. They ranked between 4.5 – 5.0 in importance and 2.3 – 3.5 in difficulty to assess. The key indicator *utilizing mathematics to solve problems* had the highest importance (5.0) for this construct. The key indicator with the lowest importance (2.7) was *evaluate input work of mechanisms*. It also received a score of 2.7 in difficulty to assess.

The construct, Engineering Science, had the lowest (8.3) criticality index ranking. The average importance ranking indicated this construct is important for an instrument that measures engineering design outcome in schools; and the average difficulty to assess ranking indicated that overall this construct would be relatively easy to assess. Calculating mechanical advantage, identifying and calculating material properties, and using computers to organize & communicate data were among the top twelve indicators in this construct, with importance between 4.0 – 4.5. Six of the sixty-one indicators in this construct were viewed as less than necessary for an instrument that assesses engineering design outcome in high schools. Those six dealt mainly with aerospace and material sciences.

Research Question Two

What are the key indicators associated with the constructs identified by Childress and Rhodes (2008) to measure engineering design outcome in high schools in Idaho? The key indicators were identified through a content analysis performed by two individuals who analyzed the PLTW and EbD curriculum materials. A survey consisting of the construct and the related indicators along with two Likert scales, one for "importance" and the other for "difficulty to assess" were developed and sent to the six experts for them to rank.

The category *Engineering & Human Values* had six key indicators (see Table 11). The importance ranking data indicated 83% of the key indicators ranged at 4.0 or above, which means five of the six key indicators were ranked high in importance for inclusion in an engineering design assessment tool. The remaining key indicators ranked 3.8. The difficulty to assess ranked a little higher than the previous key indicators with only one falling below 3.0. The overall mean in difficulty to assess ranked a 3.3, which is the highest difficulty ranking among all six constructs. This indicates these key indicators ranked high in importance but may be more difficult to assess in PLTW and EbD curriculums.

Table 11. Key Indicator Results for Engineering & Human Values.

Engineering & Human Values	M*f* Importance	M*f* Difficulty
Participating in teams	4.8	3
Assess the effect of technology on the environment	4.3	3.7
Understanding/determining ethical implications	4.2	3.7
Determining a product's safety in function	4.2	3.5
Test & apply the relationship between voltage, current, & resistance	4.0	2.7
Understanding relationships among technologies	3.8	3.3
Average Mean Value	4.2	3.3

For the category, *Application of Engineering Design* twelve key indicators were identified (see Table 12). The importance ranking data indicated ninety-two percent of the key indicators ranged at 4.0 or above which means eleven of the twelve key indicators were ranked high in importance for inclusion in an instrument to measure engineering design outcome in high school. *Utilizing flight simulators* may not be as important to include in an assessment instrument as it only ranked a 2.0. The overall difficulty to assess ranked a 3.0. The three most difficult to assess were *effectively troubleshoot errors* (3.5), *modify design* (3.5), and *explore functions & characteristics of systems* (3.5).

Table 12. Key Indicator Results for Application of Engineering Design.

Application of Engineering Design	M*f* Importance	M*f* Difficulty
Provide accurate documentation	4.8	3.0
Determining & calculating forces	4.7	2.7
Understanding measurements	4.7	2.7
Effectively troubleshoot errors	4.3	3.5
Modify design	4.2	3.5
Use experimentation to make decisions	4.2	3.2
Apply constraints	4.2	2.8
Construct/evaluate working prototypes	4.2	2.5
Explore functions & characteristics of systems	4.0	3.5
Participating in activities in learning skills	4.0	3.0
Identify manufacturing processes	4.0	2.7
Utilizing flight simulators	2.0	2.1
Average Mean Value	4.0	3.0

The category *Engineering Communication* had twenty key indicators (see Table 13).

The importance ranking indicated seventy-five percent of the key indicators ranged at 4.0 or above which means fifteen of the twenty key indicators were ranked high in importance for inclusion on an instrument that measures engineering design outcome in high school. The remaining twenty-nine percent ranged 3.0 or above. The difficulty to assess ranked between 1.8 and 4.2. *Utilizing brainstorming methods* was 4.5 for importance but received 4.2 for difficulty. This indicates it had high importance but might be difficult to assess. *Communicating knowledge professionally* and *Utilizing modeling software* were ranked the highest in importance at 4.7 and both were ranked low in terms of difficulty to assess.

Table 13. Key Indicator Results for Engineering Communication.

Engineering Communication	M*f* Importance	M*f* Difficulty
Communicating knowledge professionally	4.7	2.8
Utilizing modeling software	4.7	2.7
Communicate the design solution process	4.5	3.0
Engaging in Problem-based learning	4.5	3.0
Applying standards	4.5	3.0
Utilizing brainstorming methods	4.5	4.2
Engaging in project-based learning	4.5	3.3
Develop skills in using tools	4.3	3.2
Utilizing presentation software	4.3	1.8
Developing sketches	4.3	2.3
Evaluate feedback	4.2	3.3
Solutions to design problems	4.0	3.5
Create/deliver formal presentations	4.0	2.5
Communicating using symbols	4.0	2.3
Understanding the importance of project management	4.0	3.3
Understanding communication technologies	3.8	3.2
Create detailed flow charts	3.5	1.8
Improving design process & outcome	3.3	3.5
Using symbols in communicating processes	3.3	2.5

Utilizing automation system programming functions	3.2	2.3
Average Mean Value	4.1	2.9

For the construct *Engineering Design Concepts*, sixteen key indicators were identified through the content analysis (see Table 14). Eleven of the seventeen key indicators were ranked as being of high importance. These key indicators averaged 2.9 in difficulty. This indicates the experts perceived that the top eleven key indicators for construct *Engineering Design Concepts* are not too difficult to assess. The two key indicators that had the highest ranking for difficulty to assess were *understanding attributes of a design process* (3.5) and *conducting/validating research* (3.5).

Table 14. Key Indicator Results for Engineering Design Concepts.

Engineering Design Concepts	Mf Importance	Mf Difficulty
Using creativity in solving problems	4.8	3.3
Document project's progress in engineering notebook	4.7	2.3
Understanding attributes of a design process	4.5	3.5
Understanding core concepts of technology	4.5	2.5
Develop models	4.5	3.0
Conducting/validating research	4.3	3.5
Creating portfolios in documenting work	4.0	2.3
Understand material & equipment requirements	4.0	2.5
Optimizing design solutions	4.0	3.3
Employ strategies	4.0	2.8
Understanding system energy requirements	4.0	2.5
Use construction technologies	3.8	2.5
Use the method of joints strategy to determine forces in a truss	3.7	2.7
Creating system control programs	3.5	2.8

Create new systems/processes	3.2	3.5
Justifying discoveries are innovations	3.2	3.0
Average Mean Value	4.0	2.9

The next category in the instrument was *Engineering Analysis* and thirty key indicators were identified (see Table 15). The importance ranking indicated forty-seven percent of the key indicators ranged at 4.0 or above which means fourteen of the thirty key indicators were ranked high in importance for including on an instrument to measure engineering design outcome in high school. This category received the highest group mean score (5) on importance for the key indicators, *Utilizing mathematics to solve problems,* which indicates this key indicator is considered essential in an engineering design assessment tool, and only somewhat difficult to assess at a 2.7. Out of the thirty key indicators for importance, two fell below 3.0, which were *Evaluate input work of mechanisms* (2.7) and *Differentiating between matrix & reinforcement in composite materials* (2.8). This indicates those two key indicators are not as important as 28 other key indicators for including in an engineering design assessment tool, within this construct.

Table 15. Key Indicator Results for Engineering Analysis.

Engineering Analysis	M*f* Importance	M*f* Difficulty
Utilizing mathematics to solve problems	5.0	2.7
Utilize mathematical formulas to solve design problems	4.7	2.8
Using mathematical concepts in design	4.7	3.0
Knowledge of calculating a moment	4.5	2.3
Developing solutions to problems	4.5	3.7
Understanding quantitative data	4.5	2.8
Creating solutions to problems	4.5	3.5
Conducting various testing methods	4.3	3.2
Evaluating the design solutions	4.2	3.2
Use assessment techniques	4.0	2.8
Creating/utilizing a decision matrix for design problems	4.0	2.7
Evaluate output work of mechanisms	4.0	2.5
Describing basic logic functions	4.0	2.3
Understanding criteria in assessment rubrics	4.0	3.5
Determining angles	3.8	2.5
Identify magnitude, direction, & sense of a vector	3.8	2.2
Understanding mechanical advantage ratios	3.8	2.3
Calculating mean, median, & mode	3.8	2.0
Calculating gear ratio	3.8	2.0
Weighting of tradeoffs	3.6	3.2
Calculating drive ratios of mechanisms	3.5	2.0
Choose appropriate input devices of technological systems	3.3	3.0
Apply statistics	3.3	2.8
Choose appropriate output devices of technological systems	3.2	3.3
Differentiating flow rate versus flow velocity	3.2	2.5
Calculating probability	3.2	2.2

Perform competitive product analyses	3.0	3.0
Mathematically locate the centroid of structural members	3.0	2.3
Differentiating between matrix & reinforcement in composite materials	2.8	2.0
Evaluate input work of mechanisms	2.7	2.7
Average Mean Value	3.8	2.7

The last category or main construct on the instrument *Engineering Science* had sixty-one key indicators (see Table 16). The importance ranking data indicated twenty percent of the key indicators ranged at 4.0 or above which means twelve of the sixty-one key indicators were ranked high in importance for inclusion in an engineering design assessment tool. Six of the sixty-one key indicators ranked below 3.0 below. The difficulty to assess ranked a little lower than the previous key indicators with only three ranking at 3.0 or above and the overall mean ranked at 2.3. The three least difficult to assess were *Differentiating & calculating velocity* at 1.8 and an importance ranking of 4.0, *Differentiate digital & analog systems* at 1.8 in difficulty and 3.8 in importance and *Calculate circuit resistance, current and voltage* at 1.8 and an importance ranking of 3.7.

Table 16. Key Indicator Results for Engineering Science.

Engineering Science	M*f* Importance	M*f* Difficulty
Calculate mechanical advantage	4.5	2.3
Identify & calculate material properties	4.3	2.5
Using computers to organize & communicate data	4.3	2.3
Understanding static equilibrium of bodies	4.3	2.3
Calculate mechanical efficiency	4.2	2.3
Develop technological knowledge	4.2	3.3
Differentiating & calculating velocity	4.0	1.8

Differentiating & calculating speed	4.0	2.5
Test & apply the relationship between voltage, current & resistance	4.0	2.3
Understanding & testing properties of metals	4.0	2.2
Distinguish between the six simple machines	4.0	2.0
Calculate mass	4.0	2.0
Using scientific concepts in design	3.9	2.8
Understanding characteristics of technology	3.8	3.0
Working knowledge of compound machines	3.8	2.3
Understanding & applying thermodynamics	3.8	2.8
Differentiate the basic properties of materials (electrical, magnetic, etc.)	3.8	2.2
Designing, building, & testing truss designs	3.8	2.2
Differentiate digital & analog systems	3.8	1.8
Calculating material properties using a stress strain curve	3.7	2.3
Differentiate between engineering & engineering technology	3.7	2.3
Constructing simple & compound gear systems	3.7	2.3
Identifying properties of elements	3.7	2.2
Calculating torque ratio	3.7	2.0
Understand characteristics of lever systems	3.7	2.0
Calculating stress	3.7	2.0
Complete calculations for conduction	3.7	2.0
Calculate circuit resistance, current & voltage	3.7	1.8
Identifying science concepts	3.7	2.8
Understanding of electrical circuits	3.7	2.7
Understanding of electrical energy	3.7	2.5
Understanding thermal energy transfer	3.7	2.7
Identify impacts of energy	3.5	2.8
Design, create, & test hydraulic devices	3.5	2.8

Understand the advantages & disadvantages of circuit design	3.5	2.5
Understanding electronics	3.5	2.5
Defining types of power	3.5	2.0
Understanding inclined plane systems	3.5	2.0
Employing kinematics equations	3.3	2.2
Identify properties & characteristics of Solids	3.3	2.2
Identify & categorize energy sources	3.3	2.0
Identify components & functions of fluid power	3.3	2.0
Identify characteristics of composites	3.3	2.3
Identify engineering disciplines	3.3	2.3
Provide technical feasibility	3.2	3.3
Working with electronic assemblies	3.2	2.8
Design, create, & test pneumatic devices	3.2	2.2
Design/create/& test pulley systems	3.2	2.2
Understanding recycling technology	3.2	2.2
Applying tensile testing	3.2	2.2
Understanding fuel cell technology	3.0	2.5
Classify & describe properties of Polymers	3.0	2.5
Use transportation technologies	3.0	2.5
Design/create/& test sprocket systems	3.0	2.0
Experiment with solar hydrogen systems	2.8	2.5
Understanding chemical properties	2.8	2.5
Create a simple airfoil	2.8	2.2
Knowledge of aircraft design	2.7	2.5
Understanding aerospace materials & structures	2.7	2.0
Differentiating ceramic materials in industry	2.5	2.0
Average Mean Value	3.5	2.3

Research Question Three

Are there differences between constructs for design outcomes as identified in the Project Lead the Way and Engineering by Design content? In comparing the two curriculums, I did not see differences in the constructs. What I did see were differences in when the constructs were taught. For example, in PLTW curriculum, the 10th grade Principles of Engineering curriculum includes a course overview, which contains documents with instructions for teachers' for the implementation of the course. Teacher Resources contains documents with instructions for teachers for the implementation of the Principles of Engineering course. Student Resources contains documents students use throughout the course. Assessment contains documents to provide helpful information for implementing authentic assessment and clarity on expectations for the course. Curriculum Support Materials contains documents that explain project-based learning, how to read and use the lessons, activities, projects, problems and rubrics for use in the course. National Standards contains a complete listing of Standards for Technological Literacy, National Science Education Standards, Principles & Standards for School Mathematics, & Standards for the English Language Arts. In addition, a matrix of each of the national standards was provided to show how each standard was addressed in the course. The 11th grade curriculum consisted of two routes, one being the Digital Electronics and the other was Aerospace. The 12th grade curriculum was Engineering Design and Development. Each of the 11th and 12th grade curriculums follows the same outline as the 10th grade curriculum.

EbD 10th grade curriculum used at the Joint School District #2 in Meridian, Idaho was entitled Technological Design. The Tool Safety and tests are used in the

Technological Design class. The instructor has student's grades 10 - 12 in that class. Because the Introduction to Technology class is only one semester at the Junior High and they have no shop facility, the hands on/tools/safety part of that class was taught in the Tech Design Class. The Material Science Classes are for the 11th & 12th grade. Instructor Manuals are used for teaching those classes. There was a separate manual for each unit, Solids, Metals, Polymers, Ceramics, and Composites.

The curriculum contains objectives and activities for each lesson. The instructor is working to integrate Manufacturing Processes into the Materials study, for example Injection Molding into the Polymers section. The instructor indicated that the pre-engineering three full year curriculum is a huge change for him, and he is trying to develop a successful curriculum in order to facilitate a smooth transition upon graduation.

The 10^{th} grade curriculum for both high schools is the foundation and provides the students with a general knowledge of each of the topics. The difference between the 10^{th} grade PLTW and EbD was that EbD also emphasized tool safety, as it was not included in the 9^{th} grade curriculum.

The 11^{th} and 12^{th} grade curriculum provides detailed knowledge of the topics introduced in the 10^{th} grade curriculums for both PLTW and EbD. The 11^{th} grade PLTW has two curriculum choices, which are Aerospace and Digital Electronics. These subjects are covered in the EbD 11^{th} & 12^{th} grade materials. In summary, while there were variations in when the constructs were taught, overall the constructs covered in each curriculum were consistent.

Chapter 5: Discussion

The results from this study ranked constructs in order of criticality and identified important indicators for each construct. These constructs and their key indicators represents what experts perceive should be included in an instrument designed to measure engineering outcome for students in high schools that use the PLTW and EbD curriculums.

Four major conclusions are drawn from the findings:

1. An instrument that measures engineering design outcome in high school curriculum must have constructs that assess students' use of engineering and human values, the application of engineering design process, effective communication of engineering design, understanding of design concepts, engineering analysis and engineering science.
2. Experts perceive students' use of engineering and human values as more critical and students' use of engineering science as least critical for inclusion on an instrument that measure engineering design outcome.
3. More than half the important key indicators for constructs that measure engineering design outcome represent design process and the use of manipulative and cognitive skills.
4. Despite the difference in the structure of the PLTW and EbD they both address the important phases and the cognitive processes that students need to exercise and build their expertise in engineering design.

This chapter will expand on each conclusion. The chapter is organized into two main sections: (a) conclusions and discussions of the findings and (b) recommendations for engineering/technology education to help design an assessment tool in measuring the outcomes of engineering design in high school curriculums.

Conclusions

Conclusion #1: An instrument that measures engineering design outcome in high school curriculum must have constructs that assess students' use of engineering and human values, the application of engineering design process, effective communication of engineering design, understanding of design concepts, engineering analysis and engineering science. The order of criticality reflects what constructs needs to be emphasized when assessing engineering design outcomes in high schools. The indicators ranked high in importance reflects learning opportunities and skills provided in both PLTW and EbD curriculums. These included *participating in teams, using creativity in solving problems*, *communicating the design solution process*, and *engaging in project-based learning*. All of these attributes are necessary job related skills for workers in a global economy. For example, teamwork has become an important part of the working culture and many businesses now look at teamwork skills when evaluating a person for employment. Most companies realize that teamwork is important because the complexity of the product requires teams with multiple skills to produce a superior product (NDT, 2012). This is a valuable outcome in the engineering education curriculums and achieving this will help students to integrate well into industry. The ability to solve problems with a degree of creativity and innovation are essential characteristics for qualified engineering professionals. Engineering and technological design both require innovation and creativity (ITEA, 2000). Innovative ideas can lead to new production opportunity, new job market, and gives companies the edge over their competitors. Innovation comes from the interaction at the fringes called "the fertile verges" between disciplines (Boorstin, 1980).

Many believe that standards should only focus on outcomes and be used for accountability purposes, while others see them merely as a vision for what is needed to enable all students to become literate in the given subject area (Dugan, & Hernon, 2002). The two curriculums that were assessed for this study emphasized the importance of standards and several standards were incorporated in these two curriculums. Standards have driven innovation in education and can engender the implementation of assessments, teacher training, curriculum, and textbooks (Bybee, 2010; National Academy of Engineering [NAE], 2009).

ABET also stresses the important of experimentation. Students should be able to conduct, analyze, and interpret experiments (ABET, 2011). One of the strengths of experimentation is the fact that students do not wait until they graduate to apply what they have learned; they apply it as they progress through the program. They interact with the design aspects from the beginning and if the design fails, they are able to learn from the failure through additional research and experimentation. If students are only involved with the design aspects at the end of their learning process, they learn little about the design phase (Carvin, 2012).

Understanding core-engineering concepts, mathematics, science, and using models are very important aspects in the engineering design solutions process. Engineering education at the K-12 level must provide students with the opportunity to realize the usefulness and need for mathematics and science as they apply them to the solving of technological problems. Both PLTW and EbD curriculums included the

Standards for School Mathematics. Highly ranked key indicators within this study include understanding measurements, utilizing mathematics to solve problems and create solutions to design problems.

Conclusion #2: Experts perceive students' use of engineering and human values as more critical and students' use of engineering science as least critical for inclusion on an instrument that measure engineering design outcome. Engineering and human values ranked as the highest construct by the expert team. The highest ranked key indicators within this construct were *participating in teams*, and *assessing the effect of technology on the environment*. As was mentioned before, the need for teambuilding skills is essential as engineering firms become leaner than ever with a need to achieve more with less, as well as meeting shorter deadlines. A shift from defense to commercial applications in the 1980s left engineering employers dissatisfied. The new graduates were technically prepared but employed poor communication and teamwork skills (McMasters, 2004). Engineering curriculum today also help students develop analytical and decision-making skills needed to make wiser, environmentally sound choices regarding design. The STL (2000, Standards 5 & 13), the National Science Education Standards and the guidelines for environmental education (NAAEE, 2004) echo a responsibility for building students understanding on the impact of technology on the environment.

Although Engineering Science was viewed as having the least criticality for inclusion on an instrument to measure engineering design outcome, this does not mean that it should not be present on such an instrument. Thirty-eight of the indicators within this construct had high importance. These include calculating mechanical efficiencies, velocities, speed, mass and material properties, using computers to organize and communicate data, and using scientific concepts in design. All of these outcomes provide students with an understanding of functionally complex issues and help students to see the importance of analysis and optimization in engineering design.

Understanding aerospace materials, structures, and knowledge of aircraft design were among the lowest ranked indicators in this construct. This might be reflective of the lack of expertise in these areas by the experts who completed the survey. Both the PLTW and EbD curriculums provided topics of aerospace material structures and aircraft design. PLTW provides aerospace as an optional track, therefore, not all engineering students followed this path. Most educators do not have access to the expensive equipment such as simulators to teach aerospace.

Utilizing automation was viewed as low importance in assessing engineering design outcome. Automation engineers use the principles and theories of science and mathematics to solve problems in manufacturing. The experts felt it was somewhat necessary to include in an instrument to measure design outcome in high schools. Companies are implementing technologies, such as robotics, process control, computers and factory automation to enhance their productivity, therefore this key indicator could rank higher as more companies bring their businesses back to the United States. Although ranked the lowest in this construct, it is still an important key indicator in the engineering design process.

Mechanism was taught as a subject in both PLTW and EbD. For example, PLTW Lesson 1.1 on Mechanisms required students to gain an understanding of mechanisms through the application of theory-based calculations accompanied by lab experimentation. Most mechanisms are composed of gears, sprockets, pulley systems, and simple machines. In addition, mechanisms are used to redirect energy within a system by manipulating force, speed, and distance. Although the expert team ranked this indicator low, phrasing it a little differently might have resulted in a different ranking.

Conclusion #3: More than half the important key indicators represent design process and use manipulative and cognitive skills. Engineering requires applying both content knowledge and cognitive processes to design, analyze, and evaluate complex systems for today's needs. Engineers develop new devices such as cars, and electronics. In addition, they develop processes such as food processing and manufacturing, design and build our transportation, waste management, and power distribution infrastructure. The complexities of these processes are attributed to the numerous sub-systems and functional requirements that are necessary for them to function optimally. Solving these complex design problems requires the application of cognitive processes that are associated with logical, strategic, systems thinking; case and dilemma analysis; and decision-making (Jonassen, Strobel, & Lee, 2006).

Conclusion #4: Despite the difference in the structure of the PLTW and EbD they both address the important phases and the cognitive processes that students need to exercise and build their expertise in engineering design. Although the topics covered in PLTW and EbD curriculums do not follow the same sequence, the content was consistent between both curriculums. Both used national science and mathematics standards, Standards for Technological Literacy and ABET. Curriculum developers are experimenting with various ways to integrate engineering themes, content, and processes to bolster the learning of STEM topics (Carr & Strobel, 2011). Both curriculums engaged students in science and math as they solved engineering design problems, at the same time emphasizing the importance of creativity, critical thinking, and innovation. Both curriculums used problem-based learning (PBL), which allowed students to learn and apply skills and knowledge in real world situations. Engineering education should use many hands-on activities with technology to develop a qualitative sense for general problem-solving strategies. Brophy argues (2008) that these forms of knowledge and skills are fundamental to all technical professionals involved in the process of technical design, troubleshooting (diagnosing), and/or analyzing complex systems.

Recommendations for Future Research

This study represented preliminary work in the development of a standardized assessment tool to measure engineering design outcome in schools in Idaho irrespective of the curriculum they used. The following are recommendations for further research:

1. This study can be expanded by including a larger sample of expert engineering educators from high schools, universities, as well as engineers from industry to verify the constructs and their key indicators.
2. Test the validity and reliability of an instrument that uses the constructs and key indicators identified in this study to measure engineering design outcome in high schools.

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Appendix A: IRB Approval Letter

December 12, 2012

University of Idaho
Office of Research Assurances (ORA)
Institutional Review Board (IRB)
PO Box 443010
Moscow ID 83844-3010

Phone: 208-885-6162
Fax: 208-885-5752
irb@uidaho.edu

To: Dixon, Raymond
Cc: Wilhelmsen, Cheryl

From: IRB, University of Idaho Institutional Review Board

Subject: Exempt Certification for IRB project number 11-034

Determination: December 11, 2012
Certified as Exempt under category 1 at 45 CFR 46.101(b)(1)
IRB project number 11-034: Engineering Outcomes of Grades 10-12 Using Different Pre-Engineering Curriculums: A Case Study

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The modification to the protocol has been determined to retain the exempt certification. This study may be conducted according to the protocol described in the Application without further review by the IRB. As specific instruments are developed, each should be forwarded to the ORA, in order to allow the IRB to maintain current records. Every effort should be made to ensure that the project is conducted in a manner consistent with the three fundamental principles identified in the Belmont Report: respect for persons; beneficence; and justice.

It is important to note that certification of exemption is NOT approval by the IRB. Do not include the statement that the UI IRB has reviewed and approved the study for human subject participation. Remove all statements of IRB Approval and IRB contact information from study materials that will be disseminated to participants. Instead please indicate, "The University of Idaho Institutional Review Board has Certified this project as Exempt."

Certification of exemption is not to be construed as authorization to recruit participants or conduct research in schools or other institutions, including on Native Reserved lands or within Native Institutions, which have their own policies that require approvals before Human Subjects Research Projects can begin. This authorization must be obtained from the appropriate Tribal Government (or equivalent) and/or Institutional Administration. This may include independent review by a tribal or institutional IRB or equivalent. It is the investigator's responsibility to obtain all such necessary approvals and provide copies of these approvals to ORA, in order to allow the IRB to maintain current records.

This certification is valid only for the study protocol as it was submitted to the ORA. Studies certified as Exempt are not subject to continuing review (this Certification does not expire). If any changes are made to the study protocol, you must submit the changes to the ORA for determination that the study remains Exempt before implementing the changes. The IRB Modification Request Form is available online at: http://www.uidaho.edu/ora/committees/irb/irbforms

University of Idaho Institutional Review Board: IRB00000843, FWA00005639

Appendix B: Coding Results for PLTW 10th Grade Curriculum

Coder 1 Descriptive Frequency	Coder 2 Descriptive Frequency
accomplish	
accomplished	accomplished
	achieve
activities	activities
activity	activity
addition	addition
	algorithm
analog	analog
analog signals	analog signals
analysis	analysis
analyze	analyze
angles	angles
	application
applications	applications
applied	applied
	applies
apply	apply
assembled	assembled
assembly	
assess	assess
assessment	
assessments	assessments
	attributes
axis	axis
axle	axle
	biomass
biomedical	biomedical
brainstorm	brainstorm
brainstorming	brainstorming
build	build
calculate	calculate
calculated	
calculating	calculating
calculations	calculations
calculators	calculators
calibration	calibration
cantilever	cantilever
centroid	
centroids	centroids
chemical	chemical
circuits	circuits
	civil
code	code
codes	
coefficient	coefficient
communicate	communicate
	communication
communications	communications
compare	

comparison	comparison
components	components
compound	compound
	compresses
compression	compression
compressor	compressor
compute	compute
computer	computer
	computers
computing	
concepts	concepts
conceptual	
conclusion	conclusion
	conclusions
conduction	conduction
conductivity	conductivity
	constitutes
constraints	constraints
construct	construct
constructed	constructed
construction	construction
	constructive
control	control
convert	convert
	converting
correlate	correlate
create	create
	created
	creating
creative	creative
creativity	creativity
data	data
decision	decision
design	design
design process	design process
designed	designed
	designers
designing	designing
designs	
determine	determine
	develop
development	development
diameter	diameter
differentiate	differentiate
	differentiates
digital	digital
dimensions	dimensions
distance	distance
distribute	
divide	divide
dividing	
document	document
document symbol	
documentation	documentation
dynamic load	dynamic load

economic	economic
effective	
effectively	
efficiency	efficiency
efficient	
efficiently	
elasticity	elasticity
electric	electric
electrical	electrical
electrical circuit	electrical circuit
electrical energy	electrical energy
electricity	electricity
electromagnetic	electromagnetic
electron	electron
electronic	
electronics	electronics
elements	elements
energy	energy
engage	
engine	engine
engineer	engineer
engineering	engineering
engineers	engineers
engines	engines
environment	
environmental	environmental
equations	equations
equipment	equipment
estimate	estimate
estimates	
	evaluate
evaluation	evaluation
evidence	evidence
	expectations
experience	
experiment	experiment
experimentation	experimentation
explanation	explanation
	exploration
explore	explore
fabrication	fabrication
feedback	feedback
flight	flight
flow chart	flow chart
flow control	flow
flow rate	flow rate
flow velocity	flow velocity
fluid	fluid
force	force
forces	forces
	formula
formulas	formulas
fractions	fractions
frequencies	frequencies
frequency	

friction	friction
fuels	fuels
fulcrum	fulcrum
	function
functions	functions
gear ratio	gear ratio
gear train	gear train
gears	gears
geothermal	geothermal
graph	graph
	gravitational
guidelines	guidelines
hydraulic	hydraulic
hydraulics	hydraulics
hydrogen	hydrogen
identification	
identifies	identifies
identify	identify
illustrate	illustrate
importance	importance
industrial	industrial
industry	industry
innovation	innovation
input	input
	interpret
interpretation	interpretation
investigate	
investigation	investigation
isometric	isometric
joints	joints
kelvin scale	kelvin scale
kinematics	kinematics
kinetic energy	kinetic energy
knowledge	knowledge
learn	learn
	learned
learning	learning
lever	lever
linear	linear
load	load
machine	machine
machines	machines
machining	
manipulate	manipulate
	manipulating
manipulation	
manufacture	manufacture
manufacturing	manufacturing
mass	mass
material	material
materials	materials
math	math
mathematical	mathematical
mathematically	mathematically
mathematician	

mathematics	mathematics
matrix	matrix
means	means
measurable	measurable
measure	measure
measured	measured
measurement	measurement
	measurements
measures	measures
mechanical	mechanical
mechanical advantage	mechanical advantage
mechanical problems	
mechanically	mechanically
mechanism	mechanism
mechanisms	mechanisms
meter	meter
	method
methods	methods
mining	mining
model	model
modeling	modeling
models	models
modifications	modifications
modify	
moment	moment
motor	
motors	motors
multiplying	multiplying
navigation	navigation
nuclear	nuclear
number	number
	numbers
Ohm's law	Ohm's law
optimization	optimization
orbit	orbit
organisms	organisms
organized	organized
outcome	outcome
output	output
perimeter	
petroleum	petroleum
physics	physics
physiology	physiology
plane	plane
pneumatic	pneumatic
power	power
presentations	presentations
pressure	pressure
probability	probability
problem	problem
problems	
procedure	
procedures	procedures
process	process
process control	process control

process symbol	
processes	processes
processing	processing
processor	processor
	produce
programming	programming
projects	projects
prototype	prototype
	pulley
pulleys	pulleys
quantitative	quantitative
ratio	ratio
ratios	ratios
recycling	recycling
relate	relate
	relating
relations	relations
relationship	relationship
relationships	relationships
reliability	reliability
requirements	requirements
research	research
resistance	resistance
	resource
robot	robot
robotics	robotics
rocket	rocket
rocketry	rocketry
rotational	rotational
rotational speed	
rubric	rubric
rubrics	rubrics
science	science
scientific	scientific
scientific notation	
sensor sprocket	
simulated	simulated
simulator	simulator
sketches	sketches
skills	skills
software	software
solar	solar
solution	
solutions	solutions
solve	solve
solving	solving
specifications	specifications
speed	speed
speed ratio	
sprocket	sprocket
standards	standards
static loads	
statics	statics
strategies	strategies
strategy	

stress	stress
substitute	substitute
	sum
switch	switch
symbols	symbols
system	system
	systematically
systems	systems
teams	teams
technical	technical
techniques	techniques
technological	technological
technologies	technologies
technologists	
technology	technology
temperature	temperature
tensile	tensile
tension	tension
test	test
testing	testing
theory	
thermal	thermal
thermal energy	
thermodynamic	thermodynamic
thermodynamic system	thermodynamic system
torque	torque
torque ratio	
troubleshoot	troubleshoot
truss	truss
	trusses
turbine	turbine
understanding	understanding
	utilize
utilizing	utilizing
value	value
values	values
vector	vector
velocity	velocity
viscosity	
voltage	voltage
weight	
wheel	wheel

Appendix C: Coding Results for EbD 10th Grade Curriculum Additional Words

Coder 1 Descriptive Frequency	Coder 2 Descriptive Frequency
blade	blade
board	board
ceramics	ceramics
clean	
composites	composites
glass	glass
guards	guards
metals	metals
metallurgical	
polymers	polymers
protection	protection
safety	safety
solids	solids
tool	tool

Appendix D: Coding Results for PLTW 11th Grade Curriculum Additional Words

Coder 1 Descriptive Frequency	Coder 2 Descriptive Frequency
aerodynamic	aerodynamic
aerospace	aerospace
aircraft	
airfoil	airfoil
airplane	airplane
astronomer	astronomer
astronautical	
atmosphere	atmosphere
atmospheric	
binary	binary
counter	counter
logic	logic
pitch	pitch
satellite	satellite
space	space

Appendix E: Coding Results for EbD 11th Grade Curriculum Additional Words

Coder 1 Descriptive Frequency	Coder 2 Descriptive Frequency
transportation	transportation

Appendix F: Coding Results for PLTW 12th Grade Curriculum Additional Words

Coder 1 Descriptive Frequency	Coder 2 Descriptive Frequency
gantt	gantt
engineering notebook	engineering notebook
management	
portfolios	portfolios

Appendix G: Coding Results for EbD 12th Grade Curriculum Additional Words

Coder 1 Descriptive Frequency	Coder 2 Descriptive Frequency
injection molding	injection molding
solid works	solid works

Appendix H: Final Frequency List

Descriptive Frequency	Word Frequency
activity	1612
addition	106
aerospace	206
aircraft	285
airfoil	79
airplane	32
analysis	185
analyze	239
angles	106
assessments	197
brainstorming	199
calculate	606
centroid	73
ceramics	112
chemical	113
circuits	360
communication	643
components	460
compound	110
compression	60
composites	273
computer	331
concepts	592
constraints	432
construction	199
control	97
create	707
creativity	172
data	952
decision matrix	165
design	2696
design process	134
digital	49
documentation	484
electrical	304
electricity	169
electronics	157
energy	690
engineering	630
engines	284
engineering notebook	312
environment	324
equipment	278
experiment	123
experimentation	60
feedback	155
flow rate	146
flight	406
fluid	161
force	762

forces	331
formula	358
fuels	95
functions	529
gear ratio	234
gears	275
glider	154
hydraulics	81
innovation	92
input	262
joints	107
kinematics	5
kinetic energy	11
lever	155
machines	385
manufacturing	211
mass	87
material	557
materials	374
mathematics	609
mean	119
measurements	565
mechanical	474
mechanisms	173
metals	176
method	172
models	594
modifications	74
moment	71
motor	248
Ohm's law	47
output	317
pitch	161
plane	55
pneumatic	214
polymers	114
portfolio	70
power	690
presentations	470
probability	76
problem	1183
process	596
processes	640
product	921
projects	1064
prototype	461
pulley	241
quantitative	66
ratios	180
recycling	121
relationships	230
resistance	212
requirements	114
research	510
robotics	104

rocketry	227
rubrics	339
safety	100
science	297
scientific	235
simulation	144
simulator	88
sketches	293
skills	108
software	349
solar hydrogen	64
solids	158
solutions	513
solve	779
space	180
speed	123
sprockets	89
standards	1047
static loads	177
statistics	89
strategies	112
stress	284
substitute	294
sum	15
symbols	93
system	1120
systems	546
teams	696
technical	147
techniques	105
technological	419
technology	818
temperature	94
tensile	102
tension	48
test	441
thermal	118
thermodynamic	56
torque	113
transportation	63
troubleshoot	94
truss	292
value	116
values	38
vector	12
velocity	88
viscosity	2
voltage	305
weight	94
wheel	182

Appendix I: Survey Instrument

Instructions: This survey is being used to determine the constructs and key indicators in pre-engineering design curriculums. There are a total of six construct areas and various key indicators within each construct found in the Project Lead the Way (PLTW) curriculum and Engineering by Design (EbD) curriculum taught in Idaho Schools. Two coders completing a content analysis of lessons, teacher notes, student activities, PowerPoint's, and textbook materials for word frequency generated the final list of key indicators found in the curriculums.

The results of the study are important to the field of engineering education and will provide invaluable insight into the improvement of engineering education.

Please be assured that your responses will be held in strict confidence. Please respond as either an experienced PLTW teacher teaching PLTW curriculum, an experienced EbD teacher teaching EbD curriculum, a post-secondary educator, or an engineer in industry.

Please complete all items in this survey as to the importance of the key indicator in regards to teaching pre-engineering in grades 10-12 and the difficulty in which to assess the key indicator. Please add any additional indicators you feel are important and rate them as well.

Thank you in advance for your prompt return of the survey.

If you need assistance or have questions, please contact:

Cheryl Wilhelmsen
cherylw@uidaho.edu
208-589-5374

Importance Scale and Difficulty to Assess Scale Ratings

1 = strongly disagree
2 = disagree
3 = neutral
4 = agree
5 = strongly agree

Constructs	Key Indicators	Frequency of Occurrence	Importance of Indicator (1-5)	Difficulty to Assess (1-5)
Engineering Design Concepts				
	Creating portfolios in documenting work	70		
	Optimizing design solutions	97		
	Create new systems/processes	640		
	Employ strategies	112		
	Using creativity in solving problems	172		
	Understanding core concepts of technology	592		
	Use construction technologies	199		
	Creating system control programs	97		
	Understanding attributes of a design process	134		
	Document project's progress in engineering notebook	18		
	Justifying discoveries are innovations	92		
	Use the method of joints strategy to determine forces in a truss	107		
	Develop models	84		
	Understand material & equipment requirements	190		
	Understanding system energy requirements	189		
	Conducting/validating research	24		
	Employ strategies	32		
Additional Comments				
Application of Engineering Design				
	Participating in activities in learning skills	135		
	Apply constraints	432		
	Provide accurate documentation	484		
	Understanding measurements	565		
	Explore functions & characteristics of systems	278		
	Use experimentation to make	183		

	decisions	
	Determining & calculating forces	331
	Identify manufacturing processes	211
	Construct/evaluate working prototypes	461
	Utilizing flight simulators	88
	Effectively troubleshoot errors	83
	Modify design	74
Additional Comments		
Engineering Analysis		
	Perform competitive product analyses	129
	Determining angles	106
	Use assessment techniques	297
	Mathematically locate the centroid of structural members	73
	Evaluating the design solutions	212
	Differentiating flow rate versus flow velocity	146
	Describing basic logic functions	251
	Evaluate input work of mechanisms	70
	Choose appropriate input devices of technological system	192
	Using mathematical concepts in design	250
	Utilizing mathematics to solve problems	359
	Creating/utilizing a decision matrix for design problems	165
	Differentiating between matrix & reinforcement in composite materials	84
	Knowledge of calculating a moment	71
	Calculating mean, median, & mode	119
	Evaluate output work of mechanisms	140
	Choose appropriate output devices of technological systems	177
	Calculating probability	76
	Creating solutions to problems	212
	Understanding quantitative data	66
	Calculating gear ratio	234
	Calculate drive ratios of mechanisms	106
	Understanding mechanical advantage ratios	74
	Understanding criteria in assessment rubrics	231
	Developing solutions to	440

	problems	
	Utilize mathematical formulas to solve design problems	358
	Apply statistics	67
	Conducting various testing methods	441
	Identify magnitude, direction, & sense of a vector	29
	Weighting of tradeoffs	67
Additional Comments		
Engineering Communication		
	Develop solutions to design problems	94
	Utilizing brainstorming methods	105
	Communicating knowledge professionally	189
	Communicate the design solution process	171
	Communicating using symbols	96
	Understanding communication technologies	99
	Evaluate feedback	155
	Create detailed flow charts	97
	Engaging in Problem-based learning	472
	Engaging in project-based learning	573
	Understanding the importance of project management	147
	Create/deliver formal presentations	470
	Improving design process & outcome	75
	Utilizing automation system programming functions	99
	Developing sketches	293
	Develop skills in using tools	108
	Utilizing modeling software	169
	Utilizing presentation software	115
	Applying standards	653
	Using symbols in communicating processes	86
Additional Comments		
Engineering & Human Values		
	Assess the effect of technology on the environment	324
	Understanding/determining ethical implications	63
	Test & apply the relationship between voltage, current & resistance	197

	Understanding relationships among technologies	413
	Determining a product's safety in function	118
	Participating in teams	565
Additional Comments		
Engineering Science		
	Knowledge of aircraft design	285
	Understanding aerospace materials and structures	206
	Differentiating ceramic materials in industry	112
	Create a simple airfoil	79
	Identify characteristics of composites	189
	Identifying properties of elements	119
	Understanding chemical properties	113
	Classify & describe properties of Polymers	114
	Identify properties& characteristics of Solids	158
	Calculate circuit resistance, current & voltage	134
	Understanding and testing properties of metals	176
	Understand the advantages & disadvantages of circuit design	296
	Working knowledge of compound machines	110
	Using computers to organize & communicate data	331
	Complete calculations for conduction	164
	Differentiate digital & analog systems	181
	Understanding of electrical circuits	296
	Understanding of electrical energy	304
	Understanding basic electricity	169
	Understanding electronics	83
	Working with electronic assemblies	74
	Identify impacts of energy	210
	Identify & categorize energy sources	291
	Differentiate between engineering & engineering technology	189
	Identify engineering disciplines	441
	Identify components & functions	95

of fluid power	
Understanding fuel cell technology	97
Constructing simple & compound gear systems	274
Design, create, & test hydraulic devices	81
Employing kinematics equations	83
	155
Understand characteristics of lever systems	
Distinguish between the six simple machines	385
Calculate mass	87
Identify & calculate material properties	235
Differentiate the basic properties of materials (electrical, magnetic, mechanical & physical)	374
Calculate mechanical efficiency	252
Calculate mechanical advantage	222
Understanding inclined plane systems	55
Design, create, & test pneumatic devices	214
Defining types of power	690
Design/create/ & test pulley systems	241
Understanding recycling technology	121
Identifying science concepts	297
Using scientific concepts in design	235
Design/create/ & test sprocket systems	89
Experiment with solar hydrogen systems	64
Understanding static equilibrium of bodies	177
Differentiating & calculating speed	123
Calculating material properties using a stress strain curve	139
Provide technical feasibility	74
Develop technological knowledge	297
Understanding characteristics of technology	528
Applying tensile testing	102
Calculating stress	145
Understanding thermal energy transfer	118
Understanding & applying thermodynamics	56

	Calculating torque ratio	67
	Use transportation technologies	57
	Designing, building, & testing truss designs	292
	Differentiating & calculating velocity	88
	Test & apply the relationship between voltage, current & resistance	237
Additional Comments		

Figure 1. Survey Comments.

Under Engineering Design Concepts

"Employ Strategies"

"I don't know what this means? Strategies could be anything."

"Use construction technologies"

"Again, construction is a vague term, do you mean building construction, the art of constructing a prototype?"

"Develop Models"

"What kind of models, some are physical, some are mathematical, others are virtual."

Under Application of Engineering Design

"Modify Design"

"I would call this redesign."

Under Engineering Analysis

"Perform competitive product analyses"

"What does this mean?"

"Depends on type of engineering class that is taught."

"Determining angles"

"Depends on the context"

"Utilizing mathematics to solve problems"

"Again, this depends on the design problem."

"This entire section needs a context, example. I think all of these strategies can be effective but sometimes they are not necessary. In some contexts they could be hard to assess in other contexts they could be difficult. I don't think this survey is going to capture accurate information regarding a construct that requires a context."

Under Engineering & Human Values

"Test & apply the relationship between voltage, current & resistance"

"Seems in the wrong category."

Under Engineering Science

"So many of these should maybe be linked to specific types of engineering. I am not sure if all would be covered. I used 1 for easy to assess based on the topic of the column."

Appendix J: Participation Letters

From: Wilhelmsen, Cheryl [mailto:cherylw@uidaho.edu]

Sent: Monday, October 29, 2012 12:54 PM

To: Steve Rayborn

Subject: Request

Importance: High

Hello Steve,

A few months back I had talked with you about my dissertation and I was not sure at the time what my study would completely entail. Dr. Dixon is my Major Professor and we have completed the initial phase of the study requirements and I defended this morning. You mentioned you might be of help in this area. My study is to:

- The purpose of this study is to identify the important constructs and their key indicators that are to be included in the development of an instrument to measure the engineering design process and outcome of students in grades 10-12 that use Project Lead The Way and Engineering by Design curriculums.

I am actually sending you my proposal defense slides so you understand the full study.

What I would hope you could help me do is to contact the 2 schools in Idaho (Meridian and the one that has signed the state agreement for using engineering by design) to ask for their participation in this study. I would need to have the complete curriculum and materials from the two schools, to conduct the content analysis. I was told that you have the list of the schools that use the PLTW and Engineering by Design Curriculum. At the time of putting my study together I was also told that there was only one district using PLTW and one school using Engineering by Design that had signed the state forms. If I have others to choose from that would be great. I am hoping to complete this content analysis during the month of November and present the results before the Christmas holidays.

I appreciate any help in completing this study.

Cheryl Wilhelmsen

From: Steve Rayborn [mailto:Steve.Rayborn@pte.idaho.gov]

Sent: Mon 10/29/2012 3:13 PM

To: Wilhelmsen, Cheryl

Subject: RE: Request

The Meridian School District and the Nampa School District are currently following the PLTW model very well. I can put you in touch with whomever you would like to talk to for PLTW. The EbD curriculum is in various stages around the state and there is one school that has executed the Network Agreement with ITEEA for the EbD curriculum, but I also believe there are others that might be of assistance as well if you want choices. Even though they haven't executed the Network Agreement, they are delivering the curriculum. Most of the EbD users would be implementing the 11th grade curriculum this semester.

Let me know how many you would like to talk to and I will put you in touch with the best I can.

Steve

From: Steve Rayborn [mailto:Steve.Rayborn@pte.idaho.gov]

Sent: Wednesday, October 31, 2012 2:00 PM

To: Wilhelmsen, Cheryl

Cc: Benjamin Higgs; Will Jones; Emmett Wemp; Joseph Wax; Andrew Smith; Eric Mann

Subject: RE: Request

Cheryl,

I hope these names help out.

PLTW

Emmett Wemp	ewemp@nsd131.org	Nampa School District
Joe Wax	wax.joseph@meridianschools.org	Meridian School District
Andy Smith	smith.andrew@meridianschools.org	Meridian School District

EbD

Eric Mann	eric.mann@lposd.org	Sand Point High School
Ben Higgs	bhiggs@cdaschools.org	Couer d'Alene School District *Network Agreement signed
Will Jones	wjones@lewistonschools.net	Lewiston School District

Hi Emmett,

My name is Cheryl Wilhelmsen and Steve Rayborn gave me your contact information. I am working on my doctorate from the University of Idaho. I live in Idaho Falls and work part time at the Idaho Falls center for the U of I in the Engineering Department. My study is to identify the important constructs and their key indicators that are to be included in the development of an instrument to measure the engineering design process and outcome of students in grades 10-12 that use Project Lead The Way and Engineering by Design curriculums. I understand you follow the PLTW curriculum and am seeking your help with this study.

I do not know if Steve sent you my defense proposal but I would be willing to send it to you so you understand what I am looking for.

If you are willing to help, please let me know, as I need to complete the study by the end of November so I can send the results to an expert panel of educators from various Universities, and engineers in the field for validation.

Thank you,

Cheryl Wilhelmsen