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The acronym STEM (science, technology, engineering, and mathematics) has surfaced to prominence in both secondary and higher education. Of these four disciplines, only three are components of the nation's secondary educational system, science, technology, and mathematics. Engineering is only a post-secondary discipline. However, Kupa (1999) noted that using engineering as a framework can provide opportunities to engage secondary students in science, technology, and mathematics. McVearry (2003) stated the secondary schools are developing a favorable attitude towards engineering and that consequently more schools are attempting to infuse engineering into their K-12 curricula.

As secondary education disciplines, science, technology, and mathematics have K-12 learning standards developed and published by their respective professional societies. These standards include: *National science education standards,* (National Committee on Science Education Standards, 1999), *Standards for technological literacy: Content for the study of technology* (STL) (International Technology Education Association [ITEA], 2000), and *Principles and standards for school mathematics,* (National Council of Teachers of Mathematics, 1999). According to Thomas (2003) since engineering is not a recognized K-12 school discipline, engineering has been infused into current technology education programs with the support of the engineering and technology professions.

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The STL (ITEA, 2000) established both standards and benchmarks for core areas of K-12 technology education. Two of these standards for technology education are directly linked to engineering. STL Standard Nine stated that, "students will develop an understanding of engineering design" (ITEA, p. 99). In addition, STL Standard 10 indicated that "students will develop an understanding of the role troubleshooting, research and development, invention and innovation, and experimentation in problem solving" (ITEA, p. 106). Numerous other STL (ITEA) standards and benchmarks also indicate a strong relationship to engineering. Grimsley (2002) went on to note that "engineering content and concepts are intertwined in every aspect of the STL" (p. 1). "This is not surprising given that ITEA sought input from the National Academy of Engineering (NAE) on the standards, and later, submitted the standards to an intensive quality-review process at the National Research Council (NRC)" (Pearson, 2003, p. 1).

Since it appears that engineering is a component of K-12 technology education, are the competencies indicated in the STL (ITEA, 2000) the same competencies that the post-secondary engineering profession desires developed in its entering students? Or has the focus on STEM and its engineering component exposed a void in the current K-12 learning standards?

Purpose of the Study

The central purpose of this study was to expand upon previous research in relation to competencies that are desired by university engineering faculty in their incoming freshman. The results of this study should assist teachers in understanding what qualities and competencies high school students should possess upon entering into freshman engineering programs.

Research Questions

The following research questions were addressed by this study.

1. What competencies related to engineering do university engineering faculty indicate should be developed by high school students in a K-12 engineering/technology education class?
2. Are these identified engineering-related competencies already included in existing K-12 standards for science, technology, and/or mathematics?

Methodology

This study used a Delphi technique as noted by Paige, Dugger, and Wolansky (1996) and Wicklein (1993) to identify and analyze what secondary education competencies should be developed in a K-12 engineering program as indicated by engineering faculty. Similar to the rationale used by Scott, Washer, and Wright (2006), "the primary purpose for choosing the Delphi technique was to obtain a consensus of opinion from experts knowledgeable in engineering. The Delphi exhibited three distinct characteristics useful for this study: anonymity, interaction with controlled feedback, and statistical group response" (p. 46). According to Farmer (1995) using the Delphi technique is "the most appropriate method for attaining consensus in a national panel" (p. 2).

Both Farmer (1995) and Akers, Vaughn, and Haygood (2003) noted the first round should consist of open-ended data collection. Through open-ended listings, the participants in round one were instructed to identify the basic competencies that they foresee a secondary student needing to be successful in their college-level engineering or engineering technology program. Additionally, in round one Delphi panel members were asked via a cover letter and survey information section to provide demographic data; field of engineering, age, gender, highest degree earned, if they were a professional engineer (PE), years of industry experience, and years in higher education. The open-ended lists of competences were requested in four sections; engineering/technology related, mathematic related, science related, and other.

The Delphi panel for this study consisted of engineering and engineering technology professors from South Carolina State

University, Clemson University, Purdue University, plus Project Lead The Way (PLTW) affiliate professors. Faculty from Clemson University and Purdue University were selected because of the strong engineering and engineering technology programs at those land-grant institutions. South Carolina State University was selected based upon its engineering technology program and to insure faculty from underrepresented groups were included. These universities were additionally selected based upon the breath of the engineering and engineering technology programs, therefore insuring a wide range of engineering disciplines.

Scott, Washer, and Wright (2006) indicated that the section of panelists should insure "individuals actively engaged in the field" (p. 47). Therefore PLTW affiliate professors were selected based on their demonstrated commitment to infuse engineering competencies into secondary education. According to McVearry (2003), PLTW is the nation's premier program in providing high schools with pre-engineering curriculum and linkage to college-level engineering and engineering technology programs. PLTW has grown from 11 high schools, mostly in upstate New York, in 1997 to a current total of over 1800 schools in 46 states, plus Great Britain (Hughes, 2006).

From this population of professors a group of 16 professors agreed to participate as the panel of this Delphi study. The panel covered a range of engineering fields including civil engineering (18.75%), electrical or computer engineering (18.75%), mechanical or industrial engineering (25.0%), plus professors of engineering technology (37.5%). Professors from research-intensive or land-grant universities comprised 43.75% (n = 7) of the panel, while professors from smaller state colleges, technical institutes, or community colleges comprised 56.25% (n = 9) of the panel. The demographic description of the first round panelists can be viewed in Table 1.

Table 1.

Demographic Descriptions of Delphi Panel

	N = 16	
Gender		
Female	1	(6.2%)
Male	15	(93.8%)
Age level		
40 years or less	2	(12.5%)
41 to 50 years of age	6	(37.5%)
Over 51 years of age	8	(50.0%)
Educational level		
Master's	11	(68.8%)
PhD	5	(31.3%)
Years in higher education		
Less than 10 years	3	(18.8%)
11 to 15 years	3	(18.8%)
16 to 20 years	5	(31.3%)
Over 21 years	5	(31.3%)
Field of engineering		
Civil	3	(18.8%)
Electrical/Computer	3	(18.8%)
Mechanical/Industrial	4	(25.0%)
Engineering Technology	6	(37.5%)
Type of institution		
Research-intensive/ Land- grant	7	(43.8%)
State/Community College	9	(56.2%)

Round two of the Delphi survey for this study consisted of asking participants whether the competencies that emerged from round one should be included as a component of high school pre-engineering education. A four-point Likert-type scale was used for this rating, with 4 = strongly agree, 3 = agree, 2= disagree, and 1 = strongly disagree. Using the Likert-type scale was suggested for the second round of this type of study by Farmer (1999), Zargari (1996), and McCall (2001). McCall noted that "the words of the Likert scale are converted in meaningful way to an interval scale that gives the researcher the ability to use totals or to calculate numerical averages"

(p. 2). Nine of the panelist from round one participated in the second round survey of this study. This provided a response rate of 56.3%. The demographic characteristics of the second round panelists were consistent with the demographic characteristics of round one panelists.

Based on the results of the second round, competencies with a mean rating of less than 3.00 were eliminated from the list of competencies. These items were removed due to the fact that any rating under 3.00 would be classified as only “moderate”. In order to validate the secondary round findings, during the third round of the survey panelists were asked to give their professional opinion as to whether they agreed or disagreed that the competency was relevant for a high school pre-engineering program. Participants were given a list of the 41 competencies from round two and were then asked to indicate yes, if they believed the competency was relevant and should be a component of a high school program, or no, if they did not believe the competency was relevant and should not be a component of a high school pre-engineering program. Of the 41 competencies, 38 were confirmed by 75% of the panelists. These 38 competencies were deemed to represent the Delphi panel’s agreement of what competencies related to engineering university engineering faculty believe should be developed by high school students. The 38 competencies validated by these nine third round panelists provided the data for this study.

Findings

The Delphi panel participants noted three competencies at a mean of 3.89 (SD = 0.33). Those competencies included one from the mathematics-related area, one from the science-related list, and one from other-related competencies. In general, competencies associated with basic and interpersonal skills were rated higher than competencies with technical skills.

Table 2.

Engineering Competency Ratings

Competency	N	M	SD
Engineering/Technology			
Students should be able to perform deductive reasoning	9	3.44	0.73
Students should be able to sketch designs	9	3.33	0.50
Students should be able to operate fabrication equipment in a safe manner	9	3.33	0.50
Students should possess basic knowledge of engineering and the fields of engineering	9	3.22	0.44
Students should be able to apply the engineering design process	9	3.22	0.44
Students should be able to design solutions to engineering problems	9	3.11	0.33
Students should possess a basic knowledge of technology education	9	3.00	0.50
Students should be able to disassemble an object and analyze its components	9	3.00	0.50
Students should be able to perform basic 2-D mechanical drafting	9	3.00	0.71
Students should be able to apply geometric constraints	9	3.00	0.50
Students should possess basic electrical circuit theory	9	3.00	0.50

Table 2. (continued)

Mathematics			
Students should possess a high level of competency in algebra	9	3.89	0.33
Students should possess a high level of competency in trigonometry	9	3.78	0.44
Students should possess basic computation skills	9	3.78	0.44
Students should possess a high level of competency in geometry	9	3.67	0.50
Students should have graphing skills	9	3.67	0.50
Students should be able to perform basic statistics	9	3.22	0.44
Students should have exposure to calculus	9	3.11	0.33
Students should be able to perform basic Boolean mathematics	9	3.11	0.33

Table 2. (continued)

Science			
Students should be able to read meters, scales, and other instrumentation	9	3.89	0.33
Students should be able to relate science to mathematical concepts	9	3.78	0.44
Students should possess a high level of competency in physics	9	3.11	0.33

Other Related			
Students should be able to communicate effectively through writing (proper grammar)	9	3.89	0.33
Students should possess a high level of reading comprehension.	9	3.78	0.44
Students should demonstrate honesty	9	3.78	0.44
Students should possess a willingness to learn	9	3.78	0.44
Students should be open-minded to new concepts and ideas	9	3.78	0.44
Students should demonstrate problem solving skills	9	3.78	0.44
Students should be able to follow directions.	9	3.78	0.44

Table 2. (continued)

Students should be able to communicate effectively through speech (public speaking)	9	3.67	0.50
Students should demonstrate a strong work ethic.	9	3.67	0.50
Students should demonstrate effective interpersonal communication skills	9	3.56	0.53
Students should possess a high level of organizational skills	9	3.56	0.53
Students should be able to effectively communicate technical data	9	3.44	0.53
Students should possess a high level of computer literacy	9	3.44	0.53
Students should have a basic understanding of technical terminology	9	3.33	0.50
Students should understand aspects of group dynamics	9	3.22	0.44
Students should be able to perform basic research	9	3.00	0.53

The highest rated engineering/technology related competencies were the students' ability to sketch designs (M = 3.33, SD = 0.50) and the students' ability to operate fabrication equipment in a safe manner (M = 3.33, SD = 0.50.). The next highest rated engineering related competencies were the basic knowledge of engineering and the fields of engineering (M = 3.22, SD = 0.44) and the students' ability to apply the engineering/technology design process (M = 3.22, SD = 0.44).

Students possessing a high level of competency in algebra was the highest rated mathematic skill (M = 3.89, SD = 0.33). Processing a high level of competency in trigonometry and basic computation skills were the next highest rated mathematics skills (M = 3.78, SD = 0.44; M = 3.78, SD = 0.44). Students' ability to perform graphing and competency in geometry both rated at a mean of 3.67 (SD = 0.50). Participants also indicated that students should have "an exposure to calculus" before entering into post-secondary engineering/technology program of study. When asked to define "exposure to calculus" during the study's third round, participants provided the following responses: "1) introduction to integration and differentials - when possible supported with graphic modes - visualization software - applied theory to practice; 2) knowledge of integration and differentials; 3) to take simple derivatives and integrals; 4) a very introductory understanding of concepts of coordinate vs. slope with area when looking at graphs; and 5) practice thinking about the concept of value versus rate of change."

For the science-related competencies, a student's ability to read meters, scales, and other instruments was the highest rated science skill (M = 3.89, SD = 0.33). This was followed by a student's ability to relate science to mathematical concepts (M = 3.78, SD = 0.44). Possessing a high level of skill in physics was third on the science related competency ratings (M =3.11, SD = 0.33).

Table 2 also presents the mean ratings for the competencies that did not align with engineering/technology, mathematics, or science. Eleven of these other-related competencies were rated at a mean of 3.50 or higher. The highest rated of these non-technical competencies was the students' ability to communicate effectively through writing (M = 3.89, SD = 0.33). Next on the ratings were students possessing a high level of reading comprehension, demonstration of honesty, a willingness to learn, being open minded to new ideas, problem solving skills, and the ability to follow directions (M = 3.78, SD = 0.44). A student's ability to communicate effectively through speech and their demonstration of a strong work ethic were both rated at 3.67 (SD = 0.50).

Conclusions

The results of this study clearly indicate that, in general, university-level engineering and engineering technology professors rate students' interpersonal, communication, and work ethic competencies higher than engineering/technology, mathematics, or science-related skills. Rogers (1995) noted similar results noting that, "instructors perceived the affective domain competencies as more important benefits of technology education programs that competencies in the cognitive or psychomotor domains" (p. 68). These affective domain competencies and communication skills therefore need to be a vital component of the high school pre-engineering curricula.

This study's findings support the U.S Department of Labor (1999) report *Skills and tasks for jobs: A SCANS report for America 2000.* The U.S. Department of Labor noted foundations skills like responsibility, honesty, reading, problem-solving, and writing were essential for high school students to develop. This report divided the foundation skills into three skill-sets; basic skills, thinking skills, and personal skills. Table 3 indicates which US. Department of Labor foundation skill-set is represented by each of these identified other-related competencies.

Table 3.

Other Related Competencies and their Corresponding National K-12 Standards

Competency	Standard
Students should be able to communicate effectively through writing (proper grammar)	SCANS: *Foundation Basic Skills Writing*
Students should possess a high level of reading comprehension	SCANS: *Foundation Basic Skills Reading*
Students should demonstrate honesty	SCANS: *Foundation Personal Qualities Integrity/Honesty*
Students should possess a willingness to learn	SCANS: *Foundation Thinking Skills How to Learn*
Students should be open-minded to new concepts and ideas	SCANS: *Foundation Personal Qualities Sociability*
Students should demonstrate problem solving skills	STL: *Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.* SCANS: *Foundation Thinking Skills Problem Solving*

Table 3. (continued)

Students should be able to follow directions	SCANS: *Foundation Basic Skills Listening*
Students should be able to communicate effectively through speech (public speaking)	SCANS: *Foundation Basic Skills Speaking*
Students should demonstrate a strong work ethic	SCANS: *Foundation Personal Qualities Responsibility*
Students should demonstrate effective interpersonal communication skills	SCANS: *Foundation Basic Skills Listening* SCANS: *Foundation Basic Skills Speaking*
Students should possess a high level of organizational skills	SCANS: *Foundation Personal Qualities Self Management*
Students should be able to effectively communicate technical data	SCANS: *Foundation Basic Skills Writing*
Students should possess a high level of computer literacy	STL: *Students will develop the abilities to use and maintain technological products and systems.* STL: *Students will develop an understanding of and be able to select and use information and communication technologies.*
Students should have a basic understanding of technical terminology	STL: *Students will develop an understanding of the core concepts of technology.*
Students should understand aspects of group dynamics	SCANS: *Foundation Personal Qualities Social*
Students should be able to perform basic research	SCANS: *Foundation Personal Qualities Reasoning* STL: *Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.*

Competencies related to engineering and technology, as noted in Table 4, are all addressed by the current STL (ITEA, 2000). While the mathematics-related competencies noted by this Delphi panel and displayed in Table 5 are already incorporated in the *Principles and standards for school mathematics,* (National Council of Teachers of Mathematics, 1999) except for the panel's noting of exposure to calculus. All science-related competencies shown in Table 6 are currently included by The National Committee on Science Education Standards (1999) in the *National science education standards*.

Based on the results of this Delphi study of university-level engineering and engineering technology professors, there does not appear to be a need to suggest development of K-12 engineering standards. Engineering competencies related to K-12 education are already included in current mathematics, science, and technology education K-12 standards, plus the *Skills and tasks for jobs: A SCANS report for America 2000* (U.S Department of Labor, 1999).

Table 4.

Engineering/Technology Competencies and their Corresponding National K-12 Standards

Competency	Standards
Students should be able to sketch designs	STL: *Students will develop an understanding of the attributes of design.* STL: *Students will develop an understanding of engineering design.* NMS: *Representation Standard*
Students should be able to operate fabrication equipment in a safe manner	STL: *Students will develop the abilities to use and maintain technological products and systems.*
Students should possess basic knowledge of engineering and the fields of engineering	STL: *Students will develop and understanding of the relationships among technologies and the connections between technology and other fields of study.* STL: *Students will develop an understanding of engineering design.*

Table 4. (continued)

Students should be able to apply the engineering design process	STL: *Students will develop an understanding of engineering design.*
Students should be able to design solutions to engineering problems	STL: *Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.*
Students should possess a basic knowledge of technology education	STL: *Students will develop an understanding of the characteristics and scope of technology.* STL: *Students will develop an understanding of the core concepts of technology.* STL: *Students will develop and understanding of the relationships among technologies and the connections between technology and other fields of study.*
Students should be able to disassemble an object and analyze its components	STL: *Students will develop an understanding of engineering design.* STL: *Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.*
Students should be able to perform basic 2-D mechanical drafting	STL: *Students will develop an understanding of and be able to select and uses information and communication technologies.* STL: *Students will develop the abilities to apply the design process.* NMS: *Representation Standard*
Students should be able to apply geometric constraints	STL *Students will develop: an understanding of engineering design.* NMS: *Geometry Standard*

Table 4. (continued)

Students should be able to perform deductive reasoning	STL: *Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.* NMS*: Problem Solving Standard* SCANS: *Foundation Personal Qualities Reasoning*
Students should possess basic electrical circuit theory	STL: *Students will develop the abilities to use and maintain technological products and systems.* STL: *Students will develop an understanding of and be able to select and use energy and power technologies.*

Table 5.

Mathematics Competencies and their Corresponding National K-12 Standards

Competency	Standards
Students should possess a high level of competency in algebra	NMS: *Algebra Standard*
Students should possess a high level of competency in trigonometry	NMS: *Geometry Standard*
Students should possess basic computation skills	NMS: *Number & Operations Standard* SCANS: *Foundation Basic Skills Arithmetic/Mathematics*
Students should possess a high level of competency in geometry	NMS: *Geometry Standard*
Students should have graphing skills	NMS: *Representation Standard* NSS: *Content Standard A: Science as Inquiry* SCANS: *Foundation Thinking Skills Seeing Things in the Mind's Eye*
Students should be able to perform basic statistics	NMS: *Data Analysis & Probability Standard* NSS: *Content Standard A: Science as Inquiry*
Students should have exposure to calculus	
Students should be able to perform basic Boolean mathematics	NMS: *Algebra Standard* STL: *Students will develop an understanding of and be able to select and use information and communication technologies.*

Table 6.

Science Competencies and their Corresponding National K-12 Standards

Competency	Standards
Students should be able to read meters, scales, and other instrumentation	NSS: *Content Standard A: Science as Inquiry* NMS: *Measurement Standard* STL: *Students will develop the abilities to use and maintain technological products and systems*
Students should be able to relate science to mathematical concepts.	NSS: *Content Standard A: Science as Inquiry* NMS: *Connections Standard*
Students should be able to perform the scientific method in regard to research.	NSS: *Content Standard A: Science as Inquiry*
Students should possess a high level of competency in chemistry.	NSS: *Content Standard B: Physical Science*
Students should possess a high level of competency in biology.	NSS: *Content Standard C: Life Science*
Students should possess a high level of competency in physics.	NSS: *Content Standard B: Physical Science*

Implications for Technology Education

Even though new K-12 engineering standards are not suggested by the results of this study, technology teacher educators should examine the study's findings to insure identified competencies are included in their programs or their school's mathematics, science, and language arts curricula.

Engineering-related Competencies

Since it is clear that the engineering-related competencies are imbedded components of current technology education, these skills must remain as an essential component of the program. These skills included safe operation of fabrication equipment, knowledge of electrical theory, two-dimension mechanical drafting and sketching, plus engineering problem-solving.

Mathematics-related Competencies

Skills related to algebra, trigonometry, and geometry need to be integrated into secondary education courses where applicable. Graphing, statistics, and Boolean mathematics should also be incorporated into coursework. Courses in algebra, trigonometry, and geometry should be a component of technology education courses to better aid those individuals who wish to pursue degrees in engineering/technology. This study's findings did not support the inclusion of calculus into the secondary education classroom for those students pursuing post-secondary education in engineering or engineering technology.

Science-related Competencies

Engineering/technology education programs must insure that students are versed in the use of meters, scales, and other technical instruments. This could be incorporated into existing courses such as computer-integrated manufacturing, electronics, or any science course. Biology, chemistry, and physics are indicated by this Delphi panel for inclusion into the plan of study for those students who plan to pursue careers in engineering/technology. However, little preference was noted between these three science courses.

Engineering/technology education students should be required to relate science with mathematical concepts, especially during engineering/technology problem-solving activities. Engineering design and problem-solving activities should also stress the use of the scientific method.

Other-related Competencies

As noted by the U.S. Department of Labor (1999) and Rogers (1995) affective domain personal attributes must be a key component of any engineering/technology education program. Communication skills were also noted as an essential competency for high school graduates entering engineering or engineering technology programs. Secondary programs must require in their students competency in written communications, verbal communications, reading, honesty, strong work ethics, and a willingness to learn. These attributes cannot be sectioned into a course, but must be an essential and integrated expectation from day one through graduation and beyond.

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