

Analysis of Engineering Content within Technology Education Programs

Technology Education's Inclusion of Engineering

In the mid-1980s, technology education began to evolve from industrial arts curriculum (Lewis, 2004). Several developments in the field helped promote the technology education curriculum movement, including the Jackson's Mill Curriculum Theory Project (Snyder & Hales, 1981), the Standards for Technology Education Project (Dugger, 1985), and the development of a Conceptual Framework for Technology Education (Savage & Sterry, 1990). Since this evolution, technology educators have struggled to promote a human productive practice as a legitimate school subject, with the intent of producing technologically literate students (Lewis, 2005). The change of name and content to technology education was just another in a series since the inception of the practice. Previous industrial arts and technology education curriculum and content framing efforts in the United States include the Industrial Arts Curriculum Project, Maryland Plan, Jackson's Mill, and Technology for All Americans Project (Hill, 2006). The current movement involves incorporating engineering design as a focal point for technology education. Some technology education leaders believe that the incorporation of engineering in technology education will lead to greater technological literacy and promote engineering as a career choice (Lewis, 2005).

It is important to recognize the differences between technology and engineering. Technology can be defined as any modification of the natural world done to fulfill human needs or desires (Garmire & Pearson, 2006). Technology education, therefore, can be seen as the study of the history of technology, positive attributes and consequences of technology, and the development of the ability to use, manage, evaluate, and understand technology. Broadly stated, this is the definition of technological literacy. Engineers, on the other hand, are the people responsible for designing the technologies that modify the world. Engineering is a systematic and often iterative approach to designing objects, processes, and systems to meet human needs and wants (National Research Council, 2011).

The motivation for adding engineering content into the existing K-12 educational system is strong and continues to gain momentum (Katehi, Pearson, & Feder, 2009). There are many reasons for increased interest in K-12 engineering. Starting with the most general, the 21st century world is an environment designed for human comfort. Buildings, clothes, cars, clean water,

Todd D. Fantz (tfantz@odu.edu) is an Assistant Professor and Technology Education Program Director and Petros J. Katsioloudis (pkatsiol@odu.edu) is an Assistant Professor and Industrial Technology Program Director in the Department of STEM Education and Professional Studies at Old Dominion University.

indoor climate control, personal technologies, and nearly everything else people encounter in daily life are designed by the engineering community, which focuses on meeting the needs of society. Citizens need to be literate in technology and familiar with the engineering behind these technologies in order to make informed and responsible decisions. Adding engineering to the K-12 educational system will help create a technologically literate society (Pinelli & Haynie, 2010).

Similar to products or goods, engineering affects the economic health of the country. It is a national resource needed to be competitive with other countries in an increasingly technologically competitive atmosphere (Augustine, 2005). Technological innovations are a direct result of the work done by engineers. Engineers translate their understanding of fundamental science and mathematics into usable objects and applications that improve our lives, create new jobs and industries, and extend the frontiers of human possibility. The addition of engineering in secondary curriculum will help feed the engineering pipeline by exposing students to engineering content during their middle school and high school years (Pinelli & Haynie, 2010).

From a pedagogical perspective, engineering is the link that ties together mathematics and science (Katehi, et al., 2009). By providing context to the content, engineering and the engineering design process can bring to life sometimes abstract, difficult topics. Research shows that the integrative, applied nature of engineering can enhance student learning, boost test scores, and help schools meet standards-driven education requirements (Baker, 2005; Silk, Schunn, & Strand Cary, 2009). The use of engineering design provides practical classroom benefits for both educators and students. The collaborative, socially beneficial aspects of engineering have also been shown to appeal to students whom the field has traditionally failed to engage, including females and underrepresented minorities (Geddis, Onslow, Beynon, & Oesch, 1993; Wiest, 2004).

The purposeful move to include engineering was evidenced in 2009 by the International Technology Educators Association (ITEA) changing its name to the International Technology and Engineering Educators Association (ITEEA) (NRC, 2009). Following suit, the flagship technology education practitioner's journal, *The Technology Teacher*, also changed its name to *The Technology and Engineering Teacher*. Researchers are also very interested in methods and the effects of including engineering in the curriculum. After examining published research in prominent engineering journals and conferences, Williams (2011) found that the topics "design" and "curriculum" (including engineering in the curriculum) were the first and second most researched topics (Williams, 2011). Technology teachers in the field have also embraced the idea of including engineering into technology curriculum. This is demonstrated by the development of several technology education courses that promote pre-engineering, such as Project ProBase's Principles of Engineering and Project

Lead the Way's Principles of Technology, Engineering Technology, and Introduction to Engineering (Dearing & Daugherty, 2004).

Teacher Preparation

In order to effectively teach engineering, technology teachers need to be taught engineering content, concepts, and related pedagogy (Dearing & Daugherty, 2004; Fantz, De Miranda, & Siller, 2011). Some researchers posit that technology education programs may not have enough content to prepare technology teachers to teach engineering design (McAlister, 2005). Certain technology teacher education programs have responded by changing the programs' name to include engineering. However, a change of name does not necessarily indicate a change of content or pedagogy offered by the institutions. Therefore, this study is aimed at examining the differences between technology education programs that have adopted engineering into their name and those that have not. These technology education programs should not be confused with programs aimed specifically at studying methods of engineering education, such as Purdue University's and Virginia Tech's engineering education programs.

Research Questions

To determine the differences between traditional technology education programs and newer programs that have engineering embedded within their title, the authors developed two research questions.

1. Is there a different amount of engineering content between technology programs with the term "engineering" in their program title and technology programs without it?
2. Is there a different amount of engineering content between technology programs housed in engineering colleges and technology programs housed in colleges other than engineering?

Methodology

The data for this investigation is made up of undergraduate licensing technology education programs in US colleges and universities. The search for programs began with the list of 49 International Technology and Engineering Educators Association (ITEEA) institutional members (ITEEA, 2010). The website for each institution was visited and searched for a description of the technology education program. It should be noted that the websites were visited in the fall of 2010. This study is a snapshot in time of these technology education programs and may include some programs that were in the process of transitioning toward the inclusion of engineering, but had not yet changed titles, course names, or content. Due to the nature of the study and access restrictions, the data collection was limited to online catalogs and program descriptions. Eight technology education programs with engineering anywhere in the title were identified and included in the study. To gain more insight into the types of

courses for each program, online college and university catalogs describing the graduation requirements for a bachelor's degree in technology education and associated course titles were searched and downloaded into a database. For comparison, eleven technology education programs housed in various colleges that did not have engineering in their title were selected at random. See Table 1 (continued onto next page) for the list of all institutions investigated in this preliminary study. Institutions 1-8 have technology education licensing programs with engineering in the program title. Institutions 8-19 have technology education programs without engineering in the title.

Table 1
Technology Education Programs Included in the Preliminary Study

	College/University	Title of Program	Housed In
1	Central Connecticut University	Technology & Engineering Education	School of Engineering
2	Colorado State University	Engineering Education	College of Engineering
3	Eastern Kentucky University	Engineering/Technology Education	College of Business
4	Indiana State University	Technology and Engineering Education	College of Technology
5	North Carolina State University	Technology, Engineering & Design Education	College of Education
6	Purdue University	Engineering/Technology Teacher Education	College of Technology
7	The College of New Jersey	K-12 Pre-Engineering Education	School of Engineering
8	Utah State University	Engineering and Technology Education	College of Engineering
9	Appalachian State University	Technology Education	College of Fine and Applied Arts
10	Ball State University	Technology Teacher Education	College of Applied Sciences and Technology
11	Bowling Green State University	Technology Education Program	College of Technology

12	Buffalo State College	Technology Education	Technology Department
13	California University of Pennsylvania	Technology Education	Applied Engineering and Technology Department
14	Pittsburg State University	Technology Education	College of Technology
15	Rhode Island College	Technology Education	Department of Education
16	St. Cloud State University	Technology Education	College of Science & Engineering
17	State University of New York (Oswego)	Technology Education All Grades	School of Education
18	University of Arkansas	Technology Education	College of Education
19	University of Central Missouri	Technology Education	College of Education

A database was created to categorize where the technology education program is housed and the number of credit hours of engineering coursework. A course was considered to have engineering content if the word “engineering” was present in the course title or catalog description of the course. Other courses that are typically found in Accreditation Board for Engineering and Technology (ABET) accredited engineering programs, such as statics, dynamics, and mechanics of materials, were also defined as engineering coursework. Other foundational courses such as physics, chemistry, and mathematics were not counted as having engineering content. While not all-inclusive, Table 2 shows the most common course titles in the programs included in this study and how they were categorized. The number of credits for engineering related coursework and the number of credits for technology related coursework were entered into a spreadsheet, as shown in Table 3. The program was identified as being housed in a college of engineering if the term engineering was used anywhere in the college’s title. The categorization of where the programs are housed is also shown in Table 3.

Table 2
Engineering vs. Non-Engineering Course Titles

Engineering Course Titles	Non-Engineering Course Titles
Civil Engineering and Architecture	Automated Systems
Dynamics (Engineering Mechanics II)	CAD
Electrical Engineering	Communications
Engineering Design	Construction
Engineering Math	Electricity/Electronics
Mechanics and Strengths of Materials	Energy and Power
Mechatronics	Graphics
Orientation to Engineering	Manufacturing
Statics (Engineering Mechanics I)	Production
Thermodynamics and Fluid Systems	Publishing
	Transportation

Table 3
Number of Technology and Engineering Course Credits

	College/University	Technology Credits	Engineering Credits	Housed In
1	Central Connecticut University	24	9	Engineering
2	Colorado State University	0	42	Engineering
3	Eastern Kentucky University	30	3	Non-Engineering
4	Indiana State University	27	0	Non-Engineering
5	North Carolina State University	31	0	Non-Engineering
6	Purdue University	27	3	Non-Engineering
7	The College of New Jersey	9	27	Engineering
8	Utah State University	9	20	Engineering
9	Appalachian State University	19	0	Non-Engineering
10	Ball State University	21	3	Non-Engineering
11	Bowling Green State University	12	12	Engineering
12	Buffalo State College	27	0	Engineering
13	California University of Pennsylvania	27	12	Engineering
14	Pittsburg State University	29	0	Non-Engineering
15	Rhode Island College	27	0	Non-Engineering
16	St. Cloud State University	24	3	Engineering
17	State University of New York (Oswego)	39	0	Non-Engineering
18	University of Arkansas	24	5	Non-Engineering
19	University of Central Missouri	16	6	Non-Engineering

The data were entered into a statistical software package, SPSS 17, and coded to reflect where the program is housed and the use of engineering in the title. The data were evaluated for normality of distribution and determined to be in violation. Therefore, non-parametric statistics were used in analyzing the data. A Mann-Whitney test was performed to find differences in engineering content between the groups of programs with engineering in the title and those without engineering in the title. A Mann-Whitney test was also done to find differences in engineering content based on whether the program was housed in a college of engineering versus a college of education. In addition, effect sizes were calculated using Cohen's r (Cohen, 1988). Effect sizes provide a standardized method for comparing results to determine the strength of relationship between variables (Field, 2005). An effect size of 0 means there was no effect from the engineering exposure, and an effect size of 0.8 corresponds to a large effect from the exposure (Morgan, Leach, Gloeckner, & Barrett, 2007). Cohen's r was calculated by dividing the z -score by the square-root of the sample size, N (Field, 2005). A two-way or factorial ANOVA was also done to explore interactions between the two independent variables, engineering in the title and where the program is housed.

Findings

To compare technology education programs that have adopted the term engineering into their title with those that have not, a Mann-Whitney test comparing the engineering content was executed. As shown in Table 4, programs not having engineering in the title ($Mdn = 3.0$) did not statistically differ from programs with engineering in the title ($Mdn = 6.0$), $U = 29.0$, ns. The effect size, using Cohen's r , is approximately -0.29, which is a medium effect (Cohen, 1988).

Table 4

Mann-Whitney Test for Engineering Content Based on Program Title Containing Engineering

Group	Median	SD	Mean Rank	U	p	r
Engineering Not in Title	3.00	4.63	8.64	29.0	0.20	-0.29
Engineering in Title	6.00	15.30	11.88			

A similar analysis was done to determine any statistically significant differences between technology education programs housed in colleges of engineering and technology education programs housed in other colleges, regardless of the program title. As shown in Table 5, there was a statistically significant difference between the two groups, $U = 11.5$, $p = 0.006$. The effect size, r , also increased from the previous grouping to -0.63 . This is considered to be a large effect (Cohen, 1988).

Table 5

Mann-Whitney Test for Engineering Content Based on Where Programs are Housed

Group	Median	SD	Mean Rank	U	p	r
Housed in Engineering	12.0	13.72	14.06	11.50	0.006	-0.63
Housed Elsewhere	0.00	2.27	7.05			

To gain a better understanding of how the two independent variables (engineering in the title and where the program is housed) react with each other, a two-way or factorial ANOVA was used. Table 6 (next page) shows the means and standard deviations for engineering content separately for the engineering in the title groups and where the program is housed groups. Note that due to the small sample size of the preliminary study, the segregated group of programs with engineering in the title that also resides in a college of education only has one program. As statistical significance and power are directly related to sample size, these preliminary results should be looked at cautiously and used to guide or inform a more in depth study and not to draw conclusions.

As shown in Table 7, there was not a significant interaction between engineering in the program title and where the program is housed ($p = 0.44$). There was also not a statistically significant effect of engineering in the title on engineering content, $F(1, 14) = 0.08$, $p = 0.78$, or where the program is housed and engineering content, $F(1, 14) = 2.11$, $p = 0.17$. However, this result could be attributed to the small sample sizes of the segregated groups.

Table 6*Means and Standard Deviations Segregated by Title and Where Housed*

Housed	Engineering Not in Title			Engineering in the Title			Total	
	n	M	SD	n	M	SD	M	SD
Education	6	2.33	2.73	1	0	-----	2.00	2.65
Engineering	5	5.40	6.15	6	10.33	10.84	8.09	8.97
Total	11	3.73	4.63	7	8.86	10.64	5.72	7.69

Table 7*Results of the Two-Way ANOVA*

Variable and Source	df	MS	F	p
Eng. in Title	1	4.41	0.08	0.78
Housed	1	117.10	2.11	0.17
Eng. in Title*Housed	1	34.44	0.62	0.44
Error	14	55.42		

Conclusions and Discussion

This study was done to determine the differences in engineering content offered by technology education licensing programs. In particular, the study compared programs that acknowledged engineering content in their program by adding the term *engineering* to the program's title to programs that did not. In addition, this study looked at the differences between technology education programs housed in colleges of engineering versus programs housed in colleges of education, technology, business, fine arts, etc. It was found that programs with engineering in the title did not significantly differ in their engineering content from programs without a change in name. This could indicate that some programs have adopted the term engineering into their title without increasing the engineering content of their program. If this is the case, a technology teacher graduating from a program with engineering in the title would not be any more prepared to teach engineering content than graduates from a traditional technology education program. An alternative, and more positive, view is that technology programs are increasing engineering content without changing their name. It should be noted that the average number of engineering content credits of all the programs is only 7.63 (more than two courses). Regardless of the name or location, this amount of engineering content seems low compared to requirements to teach in other content areas.

When the groups were segregated based on where they were located within the university or college, regardless of the name, significant differences in engineering content were found. Technology education programs in colleges outside of engineering had a mean of 2.0 engineering content credits (less than

one course), while technology education programs in colleges of engineering had a mean of 8.1 engineering content credits (more than two courses). This result suggests technology education programs housed in engineering colleges are more likely to incorporate engineering into their curriculum regardless of program name. This could be a factor of shared courses between engineering and technology programs or a more positive view of engineering by the technology faculty and administration. It can be assumed that technology educators graduating from technology education programs located within colleges of engineering are better prepared to teach engineering concepts than educators graduating from programs located in colleges located outside of engineering. This is independent of the name of the technology education program.

As a final analysis, this preliminary study examined the interaction of both the title of the program and where it is housed by segregating the programs with engineering in their title and those without by where they are housed. While differences in the means were large and noteworthy, statistical significance was not achieved. For example, programs with engineering in their title that were housed in colleges of engineering had a mean of 10.3 credits of engineering content (more than three courses), while programs with engineering in their title that were housed in colleges other than engineering had a mean of 0.0. Further research with a larger sample size is needed to explore the interactions between both of the independent variables identified.

The current subject matter knowledge requirements based on the Elementary and Secondary Education Act, formally known as the No Child Left Behind Act, for a Highly Qualified Teacher include either an academic major in the field that the teacher will be teaching, a graduate degree in the field, or coursework equivalent to a major (30 semester credit hours) (Dorn, 2011). Science teachers generally either have a science degree or enough credits to warrant a minor in science (15 semester credit hours). The same is true with history, English, mathematics, and other licensing subjects. Therefore, it is logical to conclude that students should have expert content knowledge of engineering concepts before teaching engineering. However, this study showed an overall average of 7.63 credits, 22.37 credits less than the 30 credit hours required by the Elementary and Secondary Education Act for teaching in other disciplines. While technology education programs have taken strides to identify with engineering through name, the required content appears to be lagging behind.

Further Research

The next step for this research study is to find more programs to add to the study and gain greater knowledge about the content covered in the programs within this study. The NCATE website lists accredited programs in each of the 50 United States. Every program needs to be evaluated and added to the model,

based on whether or not the title contains the term engineering and where the program is housed. Additionally, other curriculum characteristics are going to be added to the analysis. These include course syllabi and additional course descriptions, the highest mathematics course required, number and type of science courses such as physics and chemistry, and the nature of the laboratory courses. The extent of engineering content within the technology programs can then be evaluated by comparing the programs to ABET accredited engineering programs.

The researchers acknowledge that some engineering content may be conveyed within courses that do not have engineering in the title. As there is little research on the amount of engineering content within technology programs, this study should be used as a starting point instead of a conclusive document. Further research may include an in depth analysis of program content through artifact collection, instructor interviews, or other means to obtain an accurate description of content deemed to be engineering related.

References

- Augustine, N. (2005). *Rising above the gathering storm : energizing and employing America for a brighter economic future*. Washington, D.C.: National Academies Press.
- Baker, D. (2005). *An intervention on tinkering and technical self-confidence, and the understandings of social relevance of science and technology*. Paper presented at the 2004 National Association of Research in Science Teaching Annual Conference, Vancouver, Canada.
- Cohen, J. (1988). *Statistical Power and Analysis for the Behavioral Sciences* (2nd ed. ed.). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Dearing, B.M., & Daugherty, M.K. (2004). Delivering engineering content in technology education. *The Technology Teacher*, 64(3), 8-11.
- Dorn, R. (2011). *Highly Qualified Teacher Resource Manual* (Vol. 2011): US Dept. of Education.
- Dugger, W. (1985). *Standards for Technology Education Project*. Blacksburg, Va: Polytechnic Institute and State University.
- Fantz, T., De Miranda, M., & Siller, T. (2011). Knowing what engineering and technology teachers need to know: an analysis of pre-service teachers engineering design problems. *International Journal of Technology and Design Education*, 21(3), 307-320. doi: 10.1007/s10798-010-9121-9
- Field, A. (2005). *Discovering Statistics Using SPSS: Second Edition*. Thousand Oaks, CA: SAGE Publications.
- Garmire, E., & Pearson, G. (2006). *Tech Tally: Approaches to assessing technological literacy*. Washington DC: National Academies Press.
- Geddis, A.N., Onslow, B., Beynon, C., & Oesch, J. (1993). Transforming Content Knowledge: Learning to teach about isotopes. *Science Education*, 77(6), 575-591.

- Hill, R. (2006). New perspectives: Technology teacher education and engineering design. *Journal of Industrial Teacher Education*, 64(5), 23-26.
- ITEEA. (2010). ITEEA Institutional Members Offering Technology Education Degree Programs Retrieved December 2, 2010, from <http://www.iteea.org/Resources/institutionalmembers.htm>
- Katehi, L., Pearson, G., & Feder, M. (Eds.). (2009). *Engineering in K-12 Education*. Washington DC: The National Academies Press.
- Lewis, Theodore. (2004). A turn to engineering: The continuing struggle of technology education for legitimization as a school subject. *Journal of Technology Education*, 16(1), 21-39.
- Lewis, Theodore. (2005). Coming to Terms with Engineering Design as Content. *Journal of Technology Education*, 16(2).
- McAlister, B. (2005). *Are Technology Education Teachers Prepared to Teach Engineering Design and Analytical Methods?* Paper presented at the International Technology Education Association Conference, Session IV: Technology Education and Engineering, Kansas City, MO.
- Morgan, G.A., Leach, N.L., Gloeckner, G.W., & Barrett, K.C. (2007). *SPSS for Introductory Statistics: Use and Interpretation Third Edition*. Mahwah, NJ: Lawrence Erlbaum Associates.
- National Research Council. (2011). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Washington DC: The National Academies Press.
- Pinelli, T., & Haynie, W.J. (2010). A case for the nationwide inclusion of engineering in the K-12 curriculum via technology education. *Journal of Technology Education*, 21(2), 52-68.
- Savage, E., & Sterry, L. (1990). A Conceptual framework for technology education. *The Technology Teacher*, 50(1), 6-11.
- Silk, Eli, Schunn, Christian, & Strand Cary, Mari. (2009). The Impact of an Engineering Design Curriculum on Science Reasoning in an Urban Setting. *Journal of Science Education and Technology*, 18(3), 209-223. doi: 10.1007/s10956-009-9144-8
- Snyder, J., & Hales, J. (1981). *Jackson's Mill Industrial Arts Curriculum Theory*. Charleston, WV: West Virginia Department of Education.
- Wiest, L.R. (2004). Impact of a Summer Mathematics and Technology Program for Middle School. *Journal of Women and Minorities in Science and Engineering*, 10(4), 317-339.
- Williams, P. (2011). Research in technology education: looking back to move forward. *International Journal of Technology and Design Education*, 1-9. doi: 10.1007/s10798-011-9170-8