Positioning Technology and Engineering Education as a Key Force in STEM Education

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Abstract

As the presence of engineering content and practices increases in science education, the distinction between the two fields of science and technology education becomes even more vague than previously theorized. Furthermore, the addition of engineering to the title of the profession raises the question of the true aim of technology education. As a result, the technology and engineering education community must effectively communicate its role in an evolving STEM education landscape. During this time of change, it is important that we understand how the technology education profession has transitioned in the past while we figure out how to balance traditions and contemporary needs. The authors present three pathways that appear most salient in moving forward: (1) adhering to the fundamental goals of technology education, (2) collaborating with science education to potentially become a core discipline, or (3) revitalizing the field through a shift to engineering education. A final recommendation is made to energize the field by centering on becoming a true provider of K–12 engineering education.

Keywords: technology and engineering education; science education; STEM; engineering.

The philosopher Eric Hoffer (1973) once reflected that "In a time of drastic change it is the learners who inherit the future. The learned usually find themselves equipped to live in a world that no longer exists" (p. 22). As Hoffer generalizes consequences of responding to mass movements of change, he illustrates the shortcomings of remaining stagnant and committed to previously held views. The efficacy of his quote for the field of technology and engineering education is the parallel it draws with STEM educational reform and responses to the *Next Generation Science Standards* (NGSS). Specifically, the infusion of engineering content and practices into science education further weakens the already vague distinction between the fields of science and technology and engineering education.

Although the International Technology Educators Association explicitly included engineering and design in the *Standards for Technological Literacy* 15 years ago, it is now the NGSS that is recognized and critiqued by organizations such as the American Society for Engineering Education (ASEE). Concerns have largely been directed towards science educators' ability to appropriately and effectively incorporate engineering content into science education (Buchanan, 2013; Hosni, 2013). However, the engineering communities have expressed support and recommendations for science educators' use of engineering at the K–12 level. In turn, as the ASEE has acknowledged the rise of K–12 engineering education standards, they have endorsed approaches for adequately preparing and supporting "the educators who will teach engineering in K-12 classrooms, many of whom have no experience in engineering" (Engineering4Kids, 2015, para. 1). This has resulted in the creation of resources to assist K–12 teachers who wish to teach engineering. Although such documents are aimed at all teachers, it is the NGSS that is frequently cited, the ITEEA community or the *Standards for Technological Literacy* are only referenced minimally. Perhaps this displays the engineering communities' confidence in technology and engineering educators' ability to deliver engineering content, or rather, there exists little recognition of the technology school subject as a viable pathway for engineering.

There is no doubt that the architects of technology and engineering education are confronted with a daunting task of adequately preparing for an evolving landscape. The authors of this paper recognize the urgency of this challenge. Therefore the intent of this article is to promote discussion at a time when technology and engineering education is presented with multiple avenues in response to the adoption of engineering into science education. Although this article includes commentary on past responses of technology and engineering education to change, we hope that this article will evoke discussion that will lead to the selection of viable pathways for the future.

Change and Evolution

Similar to the evolution and progress of technology over the past 100 years, change has been synonymous with the field of technology and engineering education (Hill, 2006; Lewis, 2004, 2005; Sanders, 2001). Over time, changes in technology and engineering education, often related to the dominant industries of the time (Grubbs, 2014), affected the aim, objectives, curricula, and instructional practices of the school subject. Presently in the United States, educational initiatives in STEM, focus on transdisciplinary teaching and learning, the *Next Generation Science Standards*, the ASEE Standards for Preparation and Professional Development for Teachers of Engineering, and the National Assessment of Education Progress Technology and Engineering Literacy Assessment are but a few examples promoting a shift towards engineering (Strimel, 2014b). Much like the industrial arts profession shifted to instruction on how technology affects people and the world in which we live, the technology and engineering education subject is situated within an opportunistic context for truly implementing engineering in the K–12 school setting.

Transitioning to Technology Education

A review of the transition to technology education reveals that individuals took multiple approaches when moving forward. For example, Foster (1994) reflected on three perspectives originally identified by Pullias (1989) that individuals could have taken when implementing technology education. The first view was a revolutionary position focused on discarding the old and beginning fresh (Pullias, 1989). In retrospect, this would have been removing industrial arts completely and focusing on technology education. Secondly, the evolutionary position was when an individual preferred to keep a portion of the old, while implementing components of the new, and *easing* into full enactment (Pullias, 1989). This might have been comparable to still teaching industrial processes while including open-ended problem solving and better aligning with the general education disciplines. The third position was merely masking what has been done previously with a new façade or veneer (Pullias, 1989). Although all three views examined a previous initiative of transitioning to technology education, the present focus on engineering, both within science and technology education, implies comparable routes during implementation.

Similar to Pullias' (1989) observations, the authors of this article recognize multiple implementation opportunities for engineering and identify three pathways that have seemed to present themselves. First, technology and engineering education can stay the course, continuing what has been done in the past and focusing on general technological literacy. This is similar to Pullias's first perspective. Second, considering the close relationship from implementing engineering design, the technology and engineering education profession can further collaborate with science education, finding distinctions that clarify the differences between both fields. The last, and perhaps the most viable, option is to work with the engineering and engineering education community to establish engineering education as the primary pathway for engineering content and practices.

The purpose of this article is to bring forth promising ideas with the intent to start and continue the conversation for the future of technology and engineering education. Although the authors believe that these are not the only options that exist, they do agree that in times of change it is important to determine what is essential because "what was essential before may not be crucial now or in the future. All that we can predict is that change will happen" (Starkweather, 2005, p. 1).

Balancing Traditions and Contemporary Needs

One challenge the field of technology and engineering education faces is maintaining the balance of traditions and contemporary needs. As K–12 engineering in the United States gains increased attention during STEM educational reform, addressing the traditions and contemporary needs becomes a challenge. Nearly 20 years ago, Martin (1996) commented on the challenges faced by one industrial teacher education organization as technology education further entered the K–12 arena:

> Because people create change, they must accept that there can be no perfect or permanent solutions. Similarly, finding a balance between the great traditions of the Mississippi Valley Industrial Teacher Education Conference (MVITEC) and the contemporary need of its members has no perfect or permanent solutions. In fact, finding an appropriate balance is like shooting a moving target. The balance will change hourly, daily, monthly, and yearly, and members of MVITEC must be prepared to adapt constantly. Their willingness to adapt and the methods they choose will clearly determine the very future of MVITEC. (p. 39)

A key point drawn from Martin (1996) is that there may not exist one identifiable path to meet all of the underpinnings of early industrial arts and technology education beliefs while engineering education gains significance. Rather, finding a balance between traditions of the past and contemporary needs of educators, teacher education programs, and students can provide a solid foundation for the field of technology and engineering education.

Technology Education: Staying the Course

The most convenient path, the path of least resistance, is staying the course of technology education. In this context, technology education, rather than technology and engineering education, is used to allude to the issue at hand of merely adding the term engineering. This would call for little modification to the standards, curricula, and philosophical orientation of technology and engineering education. For example, early publications such as *A Conceptual Framework for Technology Education* (Savage & Sterry, 1990) have presented a sample philosophy of technology education as providing

> Students of all grades, abilities and backgrounds with technological knowledge, skills, and attitudes necessary to become competent, contributing, and productive members of society. Through experiences in a "hands-on" cooperative environment using a systematic, problem-solving approach, students should exhibit understanding of all domains relating to technology. (p. 27)

Yet, since the addition of engineering to the title of technology and engineering education, current definitions, such as the following definition, are synonymous to early conceptualizations of the role of the discipline.

> Technology and engineering education is committed to preparing students for employment and/or continuing education opportunities by teaching them to understand, design, produce, use, and manage the human-made world in order to contribute and function in a technological society. (Utah State Office of Education, 2010, para. 1).

Consequently, the current path of technology and engineering education might be one of tradition that cannot meet recent criticism of this path that emphasizes the need to truly teach engineering rather than only adjust slightly to bumps or changes in the road. For example, staying the course does not account for the ongoing discussion of ambiguity and confusion around the term technology education. Dugger and Naik (2001) discuss the common misperception that technology education is simply computers, electronics, or educational technology. Although the mission, vision, instructional approaches, and learning outcomes of technology and engineering education are understandable to most practitioners, it is doubtful that the general populace has the same understanding of this school subject as they have regarding other core educational disciplines. Therefore, the question raised is whether theoretical understanding is more important to practitioners or if practical, immediate understanding of the overall population is a more important outcome.

Another issue the technology and engineering education profession is currently facing is the declining numbers within the discipline. Specifically, the number of "technology & engineering teacher preparation programs at colleges and universities in the United States have been in a state of decline since the 1970's" (Litowitz, 2014, p. 73). Likewise, between 2002 and 2012, studies reported that the total number of programs nationwide preparing technology teachers has dropped from 40 to 24 programs (Bell, 2002; Litowitz, 2013; Rogers, 2012). In 2013, Strimel surveyed teachers who attended training to teach the International Technology and Engineering Educators Association's Engineering byDesign™ curriculum and reported that nearly 70% of these teachers did not hold a degree in technology education. Furthermore, Strimel reports that over 20% of the teachers preparing to teach the Engineering byDesign™ curricula were not certified in teaching technology education. Anecdotally, one author of this article reports on the status of a metropolitan Atlanta school district containing only a small fraction of teachers who were traditionally certified in technology education, a large subset of whom were alternatively certified with little overall understanding of the scope of the technology and engineering education profession, and others who held certification in engineering with little educational experience. As a result, there are a limited number of individuals in the profession who fully understand technology and engineering education and who are able to promote its practices to progress the profession forward. Although recent initiatives to develop or sustain existing technology education programs have been conceptualized, such as Savanah State University, minimal approaches to sustain technology teacher education programs have arisen. However, viable options in relation to engineering education and possible partnerships will be discussed later in this article.

Science Education: Playing Nice in the Sandbox

Although the similarity between science and technology has long been discussed in educational literature (Gardner, 1994; Lewis, 2006), the recent release of the NGSS has further overlapped both disciplines. Specifically, the NGSS promotes the raising of engineering design to the same level of importance as scientific inquiry in science education frameworks (NGSS Lead States, 2013). As a result, science education and technology and engineering education now share a signature component. Moreover, as science education increasingly implements resources that were once exclusive to technology and engineering education, such as robotics, and recommends moving away from cheap, resourceful activities such as egg drops (Milano, 2013), technology and engineering education might proceed in collaboration with science education or otherwise potentially lose its own identity as a school subject.

As engineering design is implemented in science education, the opportunity arises for technology and engineering education to partner with science education for truly transdisciplinary approaches to Integrative STEM Education. Rather than being used only as a tool to teach science and assist in students working through scientific inquiry, technology and engineering educators can build ongoing collaborations that promote integration at the natural intersection of each discipline. For example, finding domains that require scientific inquiry and engineering design, such as biotechnology, provides opportunities for each discipline to contribute equally. For instance, existing biotechnology units such as the construction of a Microbial Fuel Cell (Wells, 2013) requires students to work through scientific inquiry to discover new scientific knowledge of ideal settings for bacteria to grow; those contributions would contribute to the engineering design process. Without knowledge of both disciplines, teachers might inadvertently situate students in a context that does not intentionally teach concepts from both disciplines.

Technology and engineering education has a great deal to offer the science education field as it moves towards more authentic educational approaches. Existing programs can work to support the teaching of science concepts and practices by providing a laboratory setting for the designing and making of new products and processes necessary to carry out realistic scientific investigations. Technology and engineering teachers are often more equipped and well trained for the acts of designing and making. These acts can be thought of as the kernel of technology and engineering education and can be considered what the profession does best. Therefore, technology and engineering programs are more often than not equipped with industry quality tools, materials, and equipment that can be used in conjunction with science education to advance student learning. The physical acts of designing and making while using current industry quality resources, can provide students with the experiences necessary for working in STEM-related careers. Additionally, the resources and abilities that technology and engineering instructors have, including lab safety, knowledge of material processing, and correct tool use, can aid in the scientific examination of problems facing the world. In turn, these scientific investigations can then enable students to develop authentic solutions to these real-life issues using the process of engineering design.

As engineering increasingly enters the instructional practices of science educators, this path of cooperation with science educators appears as a viable option in moving forward technology and engineering education. Moreover, the technology and engineering education profession should collaborate with science education because it is a much larger profession that could assume responsibility for teaching engineering, leaving technology education without a place in a student's general education. Science education is not only recognized and understood as a core educational subject, but it also provides a context for technology and engineering education students to apply knowledge and skills previously learned. Working closely with science education may provide a solid place for technology and engineering education in local school systems. This place can be where students actually utilize industry quality technologies to "make" solutions to engineering design problems, replacing less authentic classroom activities requiring only the use of unrealistic materials, such as Popsicle sticks, cardboard, duct tape, and hot glue.

A challenge for technology and engineering education in most states is the determination of where it fits within a student's education. Since its historical beginning, the purpose of technology and engineering education was to provide all students the knowledge, skills, and abilities to function in a technological world. However, many states have organized technology and engineering education under the umbrella of career and technical education. As a result, technological and engineering literacy has been missing from many students general education, and many technology and engineering programs lack the necessary enrollment from all student populations to sustain the subject. Now that the NGSS includes engineering and technology as one of the core disciplines for science, the technology and engineering profession can use this to solidify its spot in the Unites States education system by leveraging the support of the much larger science education profession. This being said, some questions for the technology and engineering education profession to ponder are: (a) What if technology and engineering education becomes a core discipline of the science education profession? (b) Can technology and engineering education utilize science as a means to bring technological and engineering literacy to all students? (c) What if teacher preparation programs enable science teachers to specialize in engineering or technology much like one can specialize in chemistry or physical science? These are questions that may help guide future directions for technology and engineering education. Keep in mind, that a lack of collaboration as a profession may lead to science taking the responsibility of teaching engineering, leaving technology education with little content and practices for a student's general education.

Routes for collaboration with science education already exist, including collocated professional organization meetings between science and technology. Yet, in moving forward, technology and engineering education might consider the implications of so closely aligning with science education and the effect that it might have on implementing similar instructional approaches.

E-nough is Enough: A Final Call for Engineering

The emphasis on engineering at the K–12 level has been increasing since the turn of the century (Kelley, 2008; National Research Council [NRC], 2009). This expanded interest can be attributed to the idea that engineering education can assist in creating a better educated populace and develop a workforce ready to meet the needs of high-demand careers of the 21st century, thus providing students with the skills necessary for economic success (NRC, 2009). Today there is broad agreement among educational stakeholders that the teaching of STEM subjects in K–12 U.S. schools must be improved to prepare students with the skills necessary for success in this century (National Academy of Engineering [NAE] & National Research Council [NRC], 2014). Due to its natural ability to tie mathematics and science together through solving authentic problems, the inclusion of engineering into K–12 education is now seen as an approach to addressing concerns with the U.S. educational system (NAE & NRC, 2014; NRC, 2009). As a result, the NGSS has interwoven engineering practices within its frameworks, and the National Assessment of Educational Progress is now administering a technology and engineering literacy assessment. More recently, K–12 engineering education initiatives, such as the Chevron-funded development of an engineering education community of practice website under a 3-year project called Guiding the Implementation of K–12 Engineering Education, have been surfacing throughout the nation. As a result, engineering education programs such as Engineering is Elementary have seen increased use. However, inconsistencies exist between engineering programs as to what engineering education consists of at the K–12 level, who teaches these engineering programs, how are teachers prepared to teach engineering, how engineering is taught at the K–12 level, and where it is situated within a student's general education.

The increased emphasis on K–12 engineering and the uncertainty of how it should be taught provide an opportunity for the technology and engineering education profession. The technology and engineering education profession can stake the claim for teaching engineering at the K–12 level, align with the engineering profession, and reform its instructional practices to reaffirm its place in the U.S. educational system. The term *engineering* is something that is recognized by the general population. Although it may not be fully understood by the broad populace, it is a term and a profession that is generally respected. Adding engineering to technology education brought a refreshing new view on the profession. However, the ambiguity and confusion around the term *technology* continues to hinder the general understanding of the school subject. It can be easy to understand what an engineer is; it is more difficult to explain what a technologist does. Failure to align technology and engineering education with the engineering profession has caused technology and engineering education to continue to lose a foothold within local education systems. Therefore, one possibility for the profession could be a greater emphasis on engineering education and a surrender of the "T," technology, to the educational technology that the majority of people believe that it is. As a result, the technology and engineering profession would become the provider of K–12 engineering education for all students. However, dropping the "T" will not do anything to revitalize and sustain technology and engineering education on its own. There will need to be significant work as a profession to develop a consistent and comprehensive engineering course sequence, modify preservice teacher programs, create an engineering teaching licensure, and establish clear postsecondary engineering connections and articulation pathways.

The authors of this article believe that a change to engineering education will require the development of a consistent and coherent course sequence. A major concern with technology education has always been the inconsistency of what courses students take and the content and skills that they learn from school to school. These inconsistencies can limit the ability to work as a profession to enhance technology and engineering education. However, with engineering as a focus, a core set of disciplines can be created. Much like science education has courses in physics, biology, chemistry, and earth or space science, engineering education can have coursework in the disciplines of mechanical, electrical, chemical, structural, and biological or medical engineering. These courses can be taken by all students to help better understand the designed world and do not have to focus on preparing students specifically for engineering careers. Just as students in biology class do not have to become a biologist, students in a mechanical engineering course do not have to become a mechanical engineer. However, these courses can provide all students with beneficial knowledge and skills as well as introduce them to engineering careers.

The Project Lead the Way pre-engineering program can be used as an example. The program provides core courses for introducing engineering entitled Introduction to Engineering Design and Principles of Engineering and specialization courses, such as Civil Engineering & Architecture, Biomedical Engineering, and Aerospace Engineering. However, it is still difficult to determine how this fits into a school district and whether it should be a part of student's general education. Additionally, it can be unclear as to what types of teachers are best prepared to teach these courses.

To be able to teach engineering content, teachers need to be properly prepared. The technology and engineering education profession is sometimes criticized in regards to its ability to teach engineering at the K–12 level and rightfully so. A study conducted by Strimel (2013) showed that over 62% of the teachers preparing to teach the Engineering byDesign[tm] curriculum had never completed a college-level course in trigonometry, and over 64% had never completed a college level course in calculus. Furthermore, the study reported that almost 54% of these teachers never completed a college course in physics, and almost 36% never completed a college course in chemistry and biology. The concepts in these mathematics and science courses are the foundation of theoretical engineering and are necessary for understanding the true concepts and practices of engineering professions. Many technology teacher preparation programs do not require multiple courses in mathematics and science, which is something that must be modified to produce teachers with the knowledge and skills to properly teach engineering. A study conducted by Litowitz (2014) reported there was a wide range of mathematics requirements for technology teacher education programs. The data indicated that approximately 30% of the technology teacher education programs did not require a mathematics course beyond statistics and showed that college algebra was the most frequent mathematics course required for preservice technology teachers. Additionally, his study reported that many institutions allowed technology education majors to choose any natural science course to fulfill their degree requirements.

These minimal degree requirements combined with the wide diversity of technology and engineering teacher education core curricula continues to compromise technology and engineering education. As reported by Litowitz (2014), some programs follow a traditional technology education approach that focuses on materials processing, whereas others have evolved into a more engineering design focused approach. Moreover, a study of high school students pertaining to engineering design cognition conducted by Strimel (2014a) indicated potential disconnects between technology and engineering curricula and the engineering profession. The study's findings suggested these disconnects may have resulted in students acting and thinking in a way that does not match the engineering practices. The data indicated that students were heavily focused on the act of making a solution based on an initial idea rather than thoughtfully forecasting their designs. The study also portrayed that the majority of the students studied employed a more traditional non-engineering, trial-and-error approach to solving an engineering design problem. These students were observed dedicating little time to analytical designing, modeling, experimenting with the proper materials, and utilizing testing results to optimize their designs. This study may indicate the engineering habits of mind, which involve design, analysis, modeling, and optimization, are not emphasized or correctly practiced throughout technology and engineering curriculum and instruction. Thus, it should be essential that technology and engineering education programs clarify their purpose and, if their purpose is engineering, to enhance their standards, curriculum, and instruction to include the proper engineering practices and content.

Some teacher preparation programs have modified the curriculum to address these concerns. Some programs now require preservice technology and engineering teachers to complete coursework similar to an engineering major with some additional coursework to earn a teaching license. Some notable examples are The College of New Jersey, Ohio Northern University, and University of Maryland Baltimore County (UMBC). The College of New Jersey suggests a more rigorous sequence of mathematics and science courses for the technology/pre-engineering preservice teachers through the college's school of engineering. The suggested course sequence provided on their website recommends students complete calculus, engineering mathematics, and general physics within their first year while progressing toward courses in structures, mechanics, analog and digital circuits, and mechanical system design (The College of New Jersey, 2016). Ohio Northern University offers an engineering education program that "directly addresses the need to develop a new generation of high school students who can contribute to solving our nation's challenges through engineering and innovation" (Ohio Northern University, 2014, para. 2). The program combines a general engineering degree with the required education and mathematics courses to earn a teaching certification. The 4-year engineering education degree prepares graduates to become licensed secondary mathematics teachers but with a more specialized perspective on engineering-design-based learning than teachers who have a traditional education diploma.

UMBC has developed a pre-service teacher program to prepare individuals to deliver pre-engineering curriculum in middle and high schools (University of Maryland Baltimore County, 2016). Their program ties the mechanical engineering program in with Project Lead the Way training to progress towards earning a technology education certification. Lastly, according to Reed and Cantu (2016), Old Dominion University is the first institution to utilize the UTeach program to certify more technology and engineering teachers. They describe the UTeach program as an initiative that seeks to train science, mathematics, computer science, and engineering majors to become a certified teachers while earning their undergraduate degree in their content areas. Therefore, these students may obtain the content knowledge along with the pedagogical knowledge to be effective teachers of engineering and technology.

However, preceding attention to engineering teaching programs, advocacy needs to be addressed at the state level, updating current licensure agreements. Yet, this should be done carefully as to not create two parallel teacher certifications in engineering and technology. Doing so could provide the opportunity for the engineering profession to assume complete control over K–12 engineering education, eliminating the need for any former technology and engineering programs and professionals that provide expertise in authentic pedagogical practices and the use of tools and machines to make products.

Lastly, a change to engineering education requires a clear collaboration and articulation with 4-year engineering programs and 2-year engineering technology programs. A K-12 engineering program should expose students to these career pathways and prepare them for a successful transition to postsecondary education. K–12 engineering education programs should collaborate with both engineering and engineering technology programs to ensure that the proper engineering fundamentals are taught throughout the various levels of education. Additionally, a connection between secondary and postsecondary engineering education can enable highly motivated high school students to obtain early college opportunities so they progress through their higher education studies faster and in a more affordable manner.

Erekson and Custer (2008)

> As we enter the 21st century it is clear that engineering education and technology education have the potential for a symbiotic alliance that will benefit both technology and engineering educators. Engineering educators have become very interested in strengthening the pathways to engineering by linking with K-12 education. At the same time, technology educators have developed national standards for K-12 education that include engineering content. Frankly, it is time to heighten and expand the discussion between the two technology and engineering educations. Collaboration between engineering educators and technology educators is an idea that needs to be further developed and put into practice. (p. 1)

Recommendations for Clarity

In consideration of the three previously discussed pathways, it is vital for the technology and engineering education profession to ruminate on what the purpose and fundamental expectations are for students. Specifically, if the field focuses on engineering education, it is essential that leaders fully consider the impact such a decision will make and that it leads to improvement in student learning. Thus, stakeholders might begin with why this change is most appropriate and what it will mean for teacher preparation, assessment, instructional approaches, and professional development. At the higher education level, additional research needs to be conducted to provide empirical evidence that engineering does indeed result in changes in students' higher order thinking skills and increases knowledge in other domains. Such research can benefit from partnering with engineering education to ensure proper alignment with the standards of their profession. This partnership can also help enable engineering majors to become interested in teaching K–12 engineering, thus helping fill the shortage of technology and engineering educators. Teacher preparation will also need to be examined to ensure that course work for preservice teachers is consistent and comprehensive across institutions. Teaching engineering content and the engineering design process would benefit if taught through programs supported and approved by engineering education. It is also recommended that preservice engineering teachers be required to complete similar coursework as a typical engineering major in addition to coursework in pedagogy necessary for a teaching license. Lastly, structuring pathways between K–12 schools and engineering programs would remove some of the ambiguity currently associated with technology education.

Conclusion

In conclusion, the technology and engineering education profession has multiple paths for moving forward. What appears most viable and sustainable to the authors of this article is to focus truly on engineering as a core disciplinary subject, which may help remove the long-standing confusion with technology. This shift will require increased rigor in mathematics and science applications, predictive analysis, analytical modeling and design, and executive functioning, such as decision-making, task initiation, organization, planning and prioritizing, and flexible thinking. However, the focus should ensure student opportunity for "making" or producing quality outputs that the profession may have shifted away from. Although in theory engineering has been added to the field and in practice is instilled in technology education classrooms across the country, it remains a façade or buzzword for many and has not been intentionally introduced, nor aligned to the engineering community. Most teachers are not professionally certified to teach engineering and have received little professional development to prepare them to do so. Subsequently, the thoughts and actions of technology and engineering students may not coincide with the practices of the engineering profession (Strimel, 2014a). Yet, in light of declining technology education programs and challenges for engineering education to retain students, an opportunity exists for moving forward.

As Foster (1994) suggested, when transitioning to technology education,

> The challenge in interpreting past practice is not to criticize it in an attempt to inflate the value of that perceived as new. It is to learn from it in an attempt to recognize the value in that established as eminent." (p. 27).

For the technology and engineering education profession, it can't do it all; even in ideal aspects for what technology education does, it can't be the best at everything. Engineering is recognized not only as a career that students can identify with but also provides the core outcomes for technology education, including problem-solving; hands-on, minds-on, creation of a product; and authentic, meaningful learning opportunities. A decision as large as changing the nature of a discipline is not one that should be made lightly. Rather, input from stakeholders, discussion on viable solutions, and consideration of the effect of such a change should all be considered.

Lastly, as Martin (2005) reflected on the origin of technology education he suggested some "individuals who provided the initial major impetus for technology education worked in isolation from their colleagues, while others worked in tandem" (para. 1). Although present opportunities of working with multiple STEM disciplines exist, it might be too early to determine if a similar situation will arise as technology and engineering education moves forward. Yet, in any direction, collaboration is vital to the success of the technology and engineering education profession and should be considered.

References

Bell, T. P. (Ed.). (2002). *Industrial teacher education directory* (41st ed.). Millersville, PA: Millersville University of Pennsylvania, Department of Industry and Technology, CTTE and NAITTE.

Dugger, W. E., Jr., & Naik, N. (2001). Clarifying misconceptions between technology education and educational technology. *Technology Teacher, 61*(1), 31–35.

Engineering4Kids. (2015). Teaching K-12 engineering. Retrieved from https://engineering4kids.wikispaces.com/Teaching+K-12+engineering

Erekson, T. L., & Custer, R. L. (2008). Conceptual foundations: Engineering and technology education. In R. L. Custer, & T. L. Erekson (Eds.), *Engineering and technology education* (pp. 1–12). 57th Yearbook of the Council on Technology Teacher Education. Woodland Hills, CA: Glencoe.

Foster, P. N. (1994). Technology education: AKA industrial arts. *Journal of Technology Education, 5*(2), 15–30. Retrieved from http://scholar.lib.vt.edu/ejournals/JTE/v5n2/pdf/

Gardner, P. L. (1994). The relationship between technology and science: Some historical and philosophical reflections. Part I. *International Journal of Technology and Design Education, 4*(2), 123–153. doi:10.1007/BF01204544

Grubbs, M. E. (2014). Genetically modified organisms: A design based biotechnology approach. *Technology and Engineering Teacher, 73*(7), 24–29.

Hill, R. B. (2006). New perspectives: Technology teacher education and engineering design. *Journal of Industrial Teacher Education*, *43*(3), 45–63. Retrieved from http://scholar.lib.vt.edu/ejournals/JITE/v43n3/pdf/hill.pdf

Hoffer, E. (1973). *Reflections on the human condition.* New York, NY: Harper & Row.

Kelley, T. R. (2008). Cognitive processes of students participating in engineering-focused design instruction. *Journal of Technology Education, 19*(2), 50–64. Retrieved from http://scholar.lib.vt.edu/ejournals/JTE/v19n2/pdf/kelley.pdf

Lewis, T. (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. Retrieved from http://scholar.lib.vt.edu/ejournals/JTE/v16n1/pdf/lewis.pdf

Lewis, T. (2005). Coming to terms with engineering design as content. *Journal of Technology Education, 16*(2), 37–54. Retrieved from http://scholar.lib.vt.edu/ejournals/JTE/v16n2/pdf/lewis.pdf

Lewis, T. (2006). Design and inquiry: Bases for an accommodation between science and technology education in the curriculum? *Journal of Research in Science Teaching, 43*(3), 255–281. doi:10.1002/tea.20111

Litowitz, L. S. (2013, December). *An analysis of undergraduate technology & engineering teacher preparation programs in the United States*. Paper presented at the Pupils Attitudes Towards Technology Conference, Christ Church, New Zealand.

Litowitz, L. S. (2014). A curricular analysis of undergraduate technology & engineering teacher preparation programs in the United States. *Journal of Technology Education, 25*(2), 73–84. Retrieved from https://scholar.lib.vt.edu/ejournals/JTE/v25n2/pdf/litowitz.pdf

Martin, G. (2005, April). *From ideas to fruition—External funding and its impact on technology education*. Paper presented at the meeting of the Pupils Attitudes Towards Technology conference, Haarlem, the Netherlands. Retrieved from http://iteea.org/Activities/1307/PATTConferences/52403/52448.aspx

Martin, G. E. (1996). Balancing traditions and contemporary needs. *Journal of Technology Studies, 22*(2), 39–42. Retrieved from http://scholar.lib.vt.edu/ejournals/JOTS/Summer-Fall-1996/PDF/7-special-section.pdf

National Academy of Engineering & National Research Council. (2014). *STEM integration in K–12 education: Status, prospects, and an agenda for research.* Washington, DC: National Academies Press. doi:10.17226/18612

NGSS Lead States. (2013). *Next generation science standards: For states, by states.* Washington, DC: National Academies Press. doi:10.17226/18290

National Research Council. (2009). *Engineering in K–12 education: Understanding the status and improving the prospects*. Washington, DC: National Academies Press. doi:10.17226/12635

Ohio Northern University. (2011, March 8). *Ohio Northern University meets critical need in engineering teacher prep: University unveils plans to launch one of nation's first undergraduate degrees in engineering education* [Press release]. Retrieved from http://www.onu.edu/page/33420

Pullias, D. (1989). Where do we go from here? *ATTE Journal, Winter*, 3–4.

Reed, P. A., & Cantu, D. V. (2016, March). *MonarchTeach.* PowerPoint presentation at the International Technology and Engineering Educators Association 2016 conference, National Harbor, MD.

Rogers, G. E. (Ed.) (2012). *Engineering & technology teacher education directory* (51st ed.). West Lafayette, IN: Purdue University, College of Technology, CTTE and NAITTE.

Savage, E., & Sterry, L. (Eds.). (1990). *A Conceptual framework for technology education*. Reston, VA: International Technology Education Association.

Starkweather, K. N. (April, 2005). *PATT 15: A retrospective look at what was essential during the past 20 years*. Paper presented at the meeting of the Pupils Attitudes Towards Technology conference, Haarlem, the Netherlands. Retrieved from http://iteea.org/Activities/1307/PATTConferences/52403/52430.aspx

Strimel, G. (2013). Engineering by Design^{TM}: Preparing STEM teachers for the 21st century. In P. J. Williams & D. Gedera (Eds.), *Technology education for the future: A play on sustainability* (pp. 447–456). Christchurch, New Zealand: Technology Environmental Science and Mathematics Education Research Centre, University of Waikato.

Strimel, G. J. (2014a). *Engineering design: A cognitive process approach* (Doctoral dissertation). ProQuest Dissertations and Theses database. (UMI No. 3662376)

Strimel, G. (2014b). Shale gas extraction: Drilling into current issues and making STEM connections. *Technology and Engineering Teacher, 73*(5), 16–24.

The College of New Jersey. (2016). *Bachelor of Science (BS) in technology/pre-engineering education*. Retrieved from http://technologicalstudies.tcnj.edu/curriculum/bachelor-of-science-bs-in-technology-pre-engineering-education/

University of Maryland Baltimore County. (2016). *Project lead the way hosted by University of Maryland, Baltimore County*. Retrieved from http://pltw.umbc.edu/

Utah State Office of Education. (2010). Technology & engineering education: Hands-on, minds-on education. Retrieved from http://schools.utah.gov/cte/tech/

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