2018

Reflections on STEM, Standards, and Disciplinary Focus

Philip A. Reed
Old Dominion University

Original Publication Citation
Reed, P. A. (2018). Reflections on STEM, standards, and disciplinary focus. *Technology and Engineering Teacher, 71*(7), 16-20.

Figure 3: The National Academies and National Assessment Governing Board consistently reference the importance of *Standards for Technological Literacy* in a variety of contexts.

reflections on STEM, standards, and disciplinary focus

A revision of STL *must transcend the current K-12 focus and include PreK, informal and extracurricular technology education, adult learning, and other settings and populations to truly reflect technological literacy for all.*

Technology Education as a discipline is at a historical point of two extremes. On one hand it is clear that what we do in technology education is highly valued; after all, imitation is said to be the sincerest form of flattery. The proliferation of "Makermania," technical competitions, engineering design in *Next Generation Science Standards* (NGSS Lead States, 2013), and other initiatives is clear affirmation that the broader educational community feels that all students need more exposure to technology. Upon closer inspection, however, it is apparent that most of these activities are a mile wide and an inch deep: Great for public relations but with very little to offer students in the way of a deep, sustained study of technology. For example, participation in a robotics competition can provide students with a good introduction to mechatronics but likely does not cover as much content as a quarterly, semester, or year-long technology education course. Additionally, students attending a school maker space or conducting an engineering

by
Philip A. Reed, DTE

NOTE: The author has consciously selected the disciplinary title Technology Education solely because of the widespread acceptance of this title. Globally, Technology Education is also known as Design and Technology, Technological Studies, Technology and Engineering Education, among other titles.

design project in science class likely do not receive the depth of iterative design or the sociocultural aspects they would encounter in a quarterly, semester, or year-long technology education course.

The second extreme is the shrinking Technology Education discipline. We continue to see a decline of teachers, courses, and teacher education programs in the United States (Volk, 1997; Sanders, 2001; Moye, 2009; Moye, Jones, & Dugger, 2015). How do these two extremes coexist? Perhaps it is due to the focus on standardized testing, shrinking school funding, or maybe because there have been few substantial reforms to the core school curriculum in the United States since it was established in 1893 (Reed, 2007). Is the current climate of tinkering with technology education content through maker spaces in libraries, engineering design in science classes, and extracurricular activities merely because it is the best way to fit this valued subject matter into the crowded, complex, and seemingly unchangeable education system of the United States?

The current climate of infusing technology activities throughout the broader school curriculum and cocurricular activities fits Petrina's (2007) explanation of "technoenthusiasm." Additionally, many current educational practitioners fit within Petrina's (2007) definition of technonaïvete, since they feel the study of technology is "covered" under the technoenthusiast mindset. This line of thinking undermines the study of technology as a subject in its own right. It is wrong for the technology education profession to sell out and blindly get on the technoenthsiasm bandwagon without advocating for dedicated technology education programs and courses. However, our field should openly support the technoenthusiasts from the standpoint that their activities serve as entrée into our deeper technology education programs and courses (Figure 1).

Figure 1: Cocurricular and extracurricular activities should be used to support technology education programs and courses, not in lieu of technology education programs and courses.

As a discipline, we need to stay focused despite the seemingly unchangeable U.S. education system and widespread technonaïvete. A loss of disciplinary focus at this point could perpetuate the demise of the Technology Education discipline. The noted business researcher Jim Collins has found that enduring, great organizations confront facts, avoid distractions, and maintain a laser-like focus on their mission (Collins, 2001). Some of these business concepts clearly apply to the Technology Education discipline. The brutal fact facing technology education at this point in history is that we must not overstep our role in STEM education. Overstepping dilutes our focus and is a distraction from our mission. Our mission must continue to be built on the pillars that define our discipline: content, an epistemological basis, and our history of practice, inclusive of curriculum, teaching, and research. We must stay the course by clarifying our role in STEM education and revising *Standards for Technological Literacy* (ITEA/ITEEA, 2000/2002/2007).

Defining STEM

There is no question that the focus on science, technology, engineering, and mathematics (STEM) education has proliferated in the last two decades (Sanders, 2009). If technology education is to maintain a relevant identity as a STEM discipline, then we must avoid vague terms (Jones, Bunting, and Vries, 2013). Currently, the T in STEM is extremely nebulous. A closer look at each STEM discipline can help define technology (T) and add clarity to the role of technology education.

Science is well-defined in PK-12 education. Historians point to the National Education Association's (NEA) Committee of Ten in 1893 as the launching point for science in the core curriculum (DeBoer, 1991). Most states have similar secondary science programs that include courses in Earth science, biology, chemistry, and physics. Is there room to subsume technology education in science? Several factors indicate the answer is no. *Next Generation Science Standards* (NGSS Lead States, 2013) is explicit that engineering, technology, and applications of science are included in *NGSS* to further the study of science. So, even though engineering design has been raised to the same level as scientific inquiry, the goal is to perpetuate science. Additionally, *NGSS* declares that the engineering content may not be deep enough for dedicated courses:

> The decision to integrate engineering design into the science disciplines is not intended either to encourage or discourage development of engineering courses…
> …The engineering design standards included in the *NGSS* could certainly be a component of such courses but most likely do not represent the full scope of such courses or an engineering pathway. Rather, the purpose of the *NGSS* is to emphasize the key knowledge and skills that all students need in order to engage fully as workers, consumers, and citizens in 21st century society (NGSS Lead States, 2013, p. 107).

Given the *NGSS* view of engineering design and engineering courses, as well as the role of standardized testing in the common science areas listed above, it seems science is focused on its mission. *NGSS* has deeper interdisciplinary connections than *National Science Education Standards* (National Research Council, 1996) and *Benchmarks for Science Literacy* (American Association for the Advancement of Science, 1993), but still focuses on the study of the natural environment.

Mathematics is similar to science in that it has a long history in PK-12 education. Historians attribute the inclusion of mathematics as a core subject to a bill introduced by Thomas Jefferson in 1778 to help students "manage their affairs" (Urban and Wagoner, 1996, p. 72). Many states have similar secondary mathematics programs that include courses in pre-algebra, algebra I & II, geometry, trigonometry, precalculus, and calculus. The role of standardized testing in these common areas arguably anchors mathematics as the most entrenched STEM discipline. Additionally, the importance of mathematics in STEM education is widely validated through the interdisciplinary connections in documents such as *NGSS* and *STL*.

The T in STEM is perhaps the least understood STEM area because, if we are confronting the facts, there are at least four major areas defining technology in STEM (Table 1: The four Ts of STEM Education). First, there is the discipline of technology education (T1) with a focus on the study of the humam-designed world and the goal of technological literacy for all. The content and theoretical basis for technology education has developed over time (Warner, 1947; Olson, 1963; DeVore, 1964; Savage & Sterry, 1990) and most recently has been articulated in *Standards for Technological Literacy* (*STL*; ITEEA, 2007). *STL* was funded by the National Science Foundation (NSF) and National Aeronautics and Space Administration (NASA), endorsed by the National Academy of Engineering, has been translated into multiple languages, and is widely recognized by the National Academies (National Research Council, 2002, 2006; National Academy of Engineering, 2010), the National Assessment Governing Board

Table 1: The four Ts of STEM education.

	Technology Education (T1)	Technical Education (T2)	Information Technology (T3)	Instructional Technology (T4)
Focus:	Study of the human designed world.	Preparation for a specific occupation.	Information and communication industries.	The use of technology to facilitate teaching and learning.
Attributes:	• Based on *Standards for Technological Literacy* (ITEA/ITEEA, 2000/2007). • Secondary programs vary by state but most have a dual purpose of focusing on technological literacy for all *and* providing a foundation for technical education. • Referred to as Design and Technology in countries using the British education model.	• Based on specific industry standards (i.e., National Institute for Automotive Service Excellence (ASE). • Secondary programs are typically organized under Trade and Industry (T & I), a specialty area of Career and Technical Education (CTE). • Commonly associated with community colleges, trade schools, and apprenticeship programs.	• Based on specific industry standards (i.e., CompTIA A+ Certification). • Secondary programs fall under several Career and Technical Education (CTE) specialty areas, primarily Business, Trade and Industry (T & I), and Technology Education. • Also referred to as Computer and Information Technology (U.S. DOL, 2017) or the Information Sector (U.S. Census Bureau, 2017).	• Based on International Society for Technology in Education Standards (ISTE, 2017). • Content neutral. All disciplines utilize technology to enhance the teaching and learning process. • Also referred to as Educational Technology.

(2014), and other organizations. The support and recognition technology education has received since the release of *STL* (ITEA/ITEEA, 2000/2002/2007) is strong validation of the discipline and its contributions to the overall educational enterprise.

The second T in STEM is technical education (T2). Although closely related to technology education, technical education is multidisciplinary and focuses on training people to have deep knowledge and skills in one or more career areas. In secondary education these programs and courses are under the career and technical education (CTE) area known as trade and industry (T&I). Technology education (T1) is often mistaken for T&I due to the similarity in content and because many states fund and organize both T&I and technology education under CTE. Technical education (T2) is clearly a part of STEM because it adds significantly to the STEM workforce and economy (Rothwell, 2013), but it is often overlooked in light of the other STEM disciplines (Symonds, Schwartz, and Ferguson, 2011).

The third T in STEM, like T2, is a broad employment area: information technology (T3). Information technology involves careers and organizations involved in developing and maintaining hardware, software, and services in virtually every facet of information and communications technologies. Information technology is clearly a part of technology education (T1) and technical education (T2) but has become a pervasive employment area with vague boundaries. After all, how often do we hear phrases such as high tech, tech stocks, or the tech sector in conversations about IT? Nevertheless, there is strong support for this notion, as IT is one of the sixteen Career Clusters (NASDCTEC, 2015), returns 780 career codes when searched in the Department of Labor O*NET database (www.onetonline.org/), and has been incorporated into the National Assessment of Educational Progress Technology and Engineering Literacy (NAEP TEL) assessment (National Assessment Governing Board, 2014). Even though IT is comprised of multiple disciplines, it is coalesced as one area of study with broad labor implications. Technology education, as well as any other discipline, is not in a position to claim IT outright or refute its position in STEM education.

The fourth T in STEM, instructional technology (T4; also known as educational technology), is distinguished from T1 in *STL* (ITEA/ITEEA, 2000/2002/2007) as a tool that enhances the teaching and learning process. Such hair-splitting definitions are necessary for academic, economic, and other reasons, but there are compelling arguments that the masses see T1, T3, and T4 as one and the same (Petrina, 2003). But what about T2? There is an undeniable relationship between T1 and T2 that in many ways blurs distinction (Williams, 2015). So, if T1 transcends T2, T3, and T4, then isn't it the T in STEM? Absolutely not. None of these four areas can claim to be the T in STEM. Flowers (2010) provides a compelling argument that T1 has a definite article problem by overusing "the," and this implication must not be overlooked by

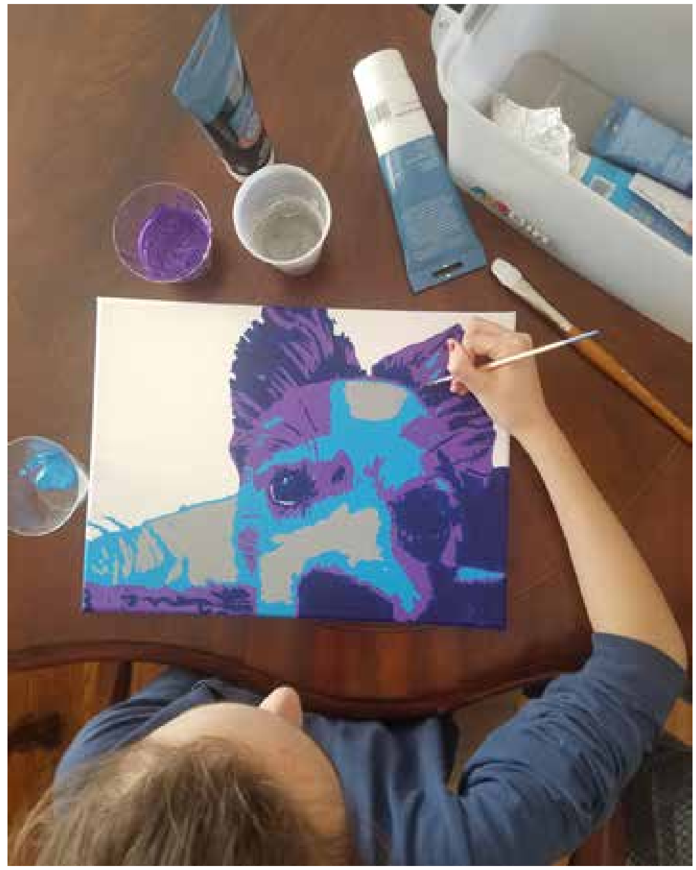


Figure 2: Every Career Pathway requires some degree of technological literacy. Even an artist needs to understand where his/her materials come from and how the materials can be refined and manipulated.

any T area. Technology education (T1), technical education (T2), information technology (T3), and instructional technology (T4) are all unique, symbiotic, and necessary.

Engineering is well defined at the postsecondary level but still evolving in PreK-12 education. There are many historical engineering areas at the postsecondary level such as mechanical, civil, and electrical engineering, as well as newer areas such as bioengineering. Some secondary programs take a "technological literacy for all" approach (i.e., Engineering by Design™, EbD™) by recognizing engineering as a verb and focusing on the engineering design process. Other programs use the proper noun approach and are more focused on getting students to pursue a career in Engineering (i.e., Project Lead the Way, PLTW). Both the verb and noun approaches to PreK-12 engineering education are valid and needed. However, technology education has historically taken the verb approach, and the field must be honest as to whether we can or should attempt both approaches. Even the National Academy of Engineering realizes the synergetic relationship between technology education and engineering education:

> The committee believes that the value of K-12 engineering curricula and of professional development for teachers of K-12 engineering would be increased by stronger connec-

tions to technological literacy, as described in such documents as *Standards for Technological Literacy: Content for the Study of Technology* (Katehi, Pearson, and Feder, 2009, pp. 158-159).

The discussion surrounding the nature of engineering and technology education may be the most critical debate in the profession today. Scholars have long noted the need for consensus with regard to direction in T1 (Buffer, 1999), and others have claimed we cannot be everything to everyone (Scott, 1999). Can technology education legitimately be a discipline that focuses on both technological literacy and engineering?

Conclusion and Recommendations

The preceding section intended to demonstrate how science, mathematics, and engineering have longer histories as academic areas and clearer disciplinary structures than the multifaceted STEM area of technology. In many ways, T1 is like mathematics and science in that each discipline focuses on understanding and organizing nature for human gain. We often distinguish the natural world and designed world, but in many ways they cannot and should not be separated (Olson, 2013). Engineering, in many regards, is like T2 and T3 in that they are more focused on employment. Clearly T1 has an employment function as well. For example, if you look at the 16 Career Clusters and 79 Pathways (NASDCTEC, 2015), all require some level of technological literacy (Figure 2). So where does this leave T1 as a discipline?

There is no shortage of publications that focus on future directions for technology education. Several published volumes have extensive perceptions from leaders on issues related to the future of technology education (Karnes, 1999; Martin, 2000; Williams, Jones, and Bunting, 2015). Futuring is vital to keep a profession moving forward, but T1 must be cautious that an individual's (or group of individuals') vision or research agenda adds to, but does not dominate, the mission of the discipline. For example, technology education can and should contribute to pre-engineering education just as it can and should be pre-vocational for other areas (i.e., T2). Information and communication technologies provide a second example. Technology education has taken an approach that includes T3 and T4, but T1 has not narrowed to one aspect of information and communications technology (i.e., programming). Technology education should continue this broad, liberal approach if it is to remain a field focused on technological literacy for all. The profession should take proactive steps to keep moving forward and focused on its mission.

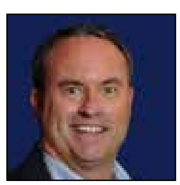
Foremost, T1 needs to clarify its position in STEM with laser-like focus. Many organizations are aiding this effort. The NAEP TEL Framework (National Assessment Governing Board, 2014) provides an introduction and rationale that parallels *STL*. The National Academies have published reports focused on technological literacy (NRC, 2002, 2006), standards (Weiss, Knapp, Hollweg, & Burrill, 2002), K-12 engineering (Katehi, Pearson, & Feder, 2009; NAE, 2010), and STEM (Honey, Pearson, & Schweingruber, 2014) that reference *STL*, help solidify T1's role in STEM, and clarify T1's position in the broader educational environment (Figure 3, page 16). The profession should continue to work with, but not rely on, outside entities to clarify its mission. For example, it should continue to develop documents such as *The Overlooked STEM Imperatives* (ITEA, 2009). Perhaps ITEEA, like many professional associations, should consider reorganizing to include special interest groups (SIGs) and divisions that would help clarify its role with regard to T2, T3, T4, the history and philosophy of technology, engineering, leadership, teacher education, elementary, and other areas. Williams (2015) highlights the broader view of T1 in many countries around the world, so such a reorganization may aid professional focus beyond the U.S.

There is no question *Standards for Technological Literacy* (ITEA/ITEEA, 2000/2002/2007) must be revised and continue to reflect technological literacy for all. Note that the previous sentence did not say technological literacy for all students. A revision of *STL* must transcend the current K-12 focus and include PreK, informal and extracurricular technology education, adult learning, and other settings and populations to truly reflect technological literacy for all. Scholars also believe the language in *STL* should be updated to reflect wider ranges of cognition (Tom Shown, personal communication, October 6, 2017).

STL codifies the content and theoretical basis of T1. An expeditious revision process must be undertaken, regardless of funding. ITEEA should outline a plan that leverages existing partnerships, new partnerships, Councils (SIGs, Divisions), its membership, and other stakeholders to revise *STL*. For example, ITEEA's Council on Technology and Engineering Teacher Education (CTETE) is comprised of university faculty from around the world with experience conducting research as well as developing standards, curriculum, and other instructional materials. The CTETE membership is well-positioned to lead a revision of *STL*. This revision process addresses the crossroads discussed in this article because it forces T1 to confront the facts, avoid distractions, and maintain a laser-like focus.

References

References are included in the online article at www.iteea.org/TETApr18Reed.aspx.



Philip A. Reed, PhD, DTE, *is a Professor in the Department of STEM Education and Professional Studies at Old Dominion University in Norfolk, Virginia. He can be reached at preed@odu.edu.*

This is a refereed article.