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# Overview of Standards for Technological and Engineering Literacy (Other)

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# Overview of Standards for Technological and Engineering Literacy (Other)


## Philip Reed

Philip A. Reed, PhD, DTE, is a Professor in the Darden College of Education and Professional Studies at Old Dominion University in Norfolk, Virginia. Dr. Reed was the 2020-2021 President of the International Technology and Engineering Educators Association (ITEEA). Dr. Reed was the ITEEA Region One Director from 2015-2017 where he helped establish the ITEEA China International Center and assisted with the implementation of the Engineering by Design (EbD) curriculum in Kuwait. In November 2019 he represented ITEEA at the Asia STEM Summit in Cebu, Philippines. He has also served as secretary and vice president of the Council on Technology and Engineering Teacher Education (CTETE), an affiliate council of ITEEA.

## Kelly Dooley (Executive Director/CEO)

Kelly Dooley joined ITEEA as Executive Director/CEO in August 2021, bringing over 8 years of association management experience, including a proven track record of working collaboratively with volunteer Boards and Committees, implementing professional development programs, and supporting the development of industry standards. To complement everything she has learned on-the-job, in 2020, Kelly completed her master's degree in management, specializing in nonprofits and associations, from University of Maryland, further equipping her with knowledge of organizational theory and behavior, strategic planning and implementation, and process and outcome evaluation. Her creative problem-solving approach to association challenges, strong leadership and communication skills, and commitment to constant growth and improvement will be an asset to ITEEA. Prior to joining the association world, Kelly completed her bachelor's degree in architectural engineering and practiced as a structural engineer for 5 years. Kelly is licensed as a Professional Engineer (P.E.) and actively pursues professional development opportunities through organizations such as the American Society of Association Executives (ASAE) and Toastmasters International. Kelly is truly passionate about STEM education and attributes much of her career success to the foundation built through her own STEM journey and a hands-on, systems-thinking approach to learning and development. She is excited to serve the ITEEA community of educators and advance technological and engineering capabilities for all.

## Tyler Love

Tyler S. Love, Ph.D. is an Assistant Professor of elementary/middle grades STEM education and the Director of the Capital Area Institute for Mathematics and Science (CAIMS) at The Pennsylvania State University's Capital Campus. He was previously an Associate Professor and Coordinator of Technology and Engineering Education at the University of Maryland Eastern Shore. His research interests include safety and liability in STEM education labs and makerspaces, teacher preparation in STEM, and physical computing. He co-authored the free electronic book co-published in May 2022 by ITEEA, ASEE, and NSELA titled "Safer Engineering and CTE Instruction: A National STEM Education Imperative. What the Data Tells Us".

## Scott Bartholomew

Scott R. Bartholomew is an assistant professor of Technology & Engineering studies at Brigham Young University. He is a Fulbright Scholar (Philippines) and a former middle-school teacher. His research interests revolve around adaptive comparative judgment, STEM professional development, and design education. He and his wife Julie are the parents of five children and they love living in the mountains of Utah.

# Overview of Standards for Technological and Engineering Literacy (Other)

In 2020, the International Technology and Engineering Educators Association (ITEEA) published *Standards for Technological and Engineering Literacy: The Role of Technology and Engineering in STEM Education* (*STEL*) [1]. These standards open with a clear rationale why all Pk-12 students should study technology and engineering:

> Technology and engineering are pervasive in all aspects of our lives. Every human activity is dependent upon the products, systems, and processes created to help grow food, provide shelter, communicate, work, and recreate. As the world grows more complex, it is increasingly important for everyone to understand more about technology and engineering [1, p. 1].

The goal of *STEL* is not to turn Pk-12 students into technologists or engineers—although many students may end up pursuing these career paths—rather *STEL* was created to broaden all student's technological and engineering literacy so they can make informed decisions about the technologies they encounter in the world around them, and better contribute to their design, development, and use. This paper will provide a brief history of Pk-12 technology and engineering standards in the United States, an overview of *STEL* [1], and recommendations for *STEL* implementation.

## A brief history of Pk-12 technology and engineering standards in the United States

Technology and engineering education standards in the United States began with the 1929 publication *Improving Instruction in Industrial Arts: Bulletin on Standards of Attainment in Industrial Arts Teaching* [2]. These early standards were highly prescriptive and organized around three constructs that continue to shape the field: knowing, doing, and being (i.e., worthy attitudes and habits) [3]. These standards, published by the American Vocational Association (AVA) [2], were widely distributed in the 1930's and 1940's. For many decades, these standards were the only option for teacher utilization (e.g., there was a 40+ year gap in standards development until a research group affiliated with the American Industrial Arts Association (AIAA, now ITEEA) released *Standards for Industrial Arts Programs* [4] in 1981). During the 1980s and corresponding with the release of *Standards for Industrial Arts Programs*, the technology and engineering education profession was transitioning from a content grounded in industrial practices of the day to a content base that more broadly reflected technological products, systems, and processes. This paradigm shift brought about a name change and cursory update of the AIAA standards in 1985 to *Standards for Technology Education Programs* [5].

ITEEA's *Standards for Technological Literacy: Content for the Study of Technology* (STL) [6] was developed throughout the 1990's, published in 2000, and last updated in 2007. The development of *STL* was part of the *Technology for All Americans* (TfAA) project, funded by the National Science Foundation (NSF) and National Aeronautics and Space Administration (NASA),which resulted in the publication of several other significant documents beyond *STL*, including *A Rationale and Structure for the Study of Technology* (1996) and *Advancing Excellence in Technological Literacy: Student Assessment, Professional Development, and Program Standards* (2003) [3].

Disciplines outside of technology and engineering (e.g., social studies, mathematics, science, and instructional technology) often include technology and engineering ideas, concepts, and practices in their standards, albeit to differing degrees [7], [8]. Of the disciplines outside of technology and engineering, the *Next Generation Science Standards (NGSS)* [9] have the strongest connections to, and the most crossover with, technology and engineering education [10]. Science, technology, society, and the environment connections are woven throughout the natural sciences disciplines in *NGSS* and, most notable among these connections is that engineering design has been raised to the same level as scientific inquiry in *NGSS* with science and engineering practices woven throughout. These developments in *NGSS* are a significant milestone towards infusing technology and engineering into a core Pk-12 discipline. Beyond the additional content and pedagogical knowledge required of science educators to teach engineering content and practices [11], concerns have been raised about science educators' preparation to safely teach engineering concepts which can involve equipment, materials, and/or processes requiring unique training and expertise [10], [12], [13]. It is important to note, however, that the stated goal of *NGSS*'s inclusion of technology and engineering practices is to perpetuate the study of science and *NGSS* is explicit that the included engineering content may not be deep enough for dedicated technology and engineering 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 [9, p. 107].

In 2009, the National Academy of Engineering and the National Research Council published *Engineering in K-12 Education: Understanding the Status and Improving the Prospects* [14]. The committee recommended against the creation of separate engineering standards, partly because they would largely duplicate ITEEA's *STL* [6]. By 2016, however, research indicated that *STL* required updating, so ITEEA sought funding and began the revision process [15].

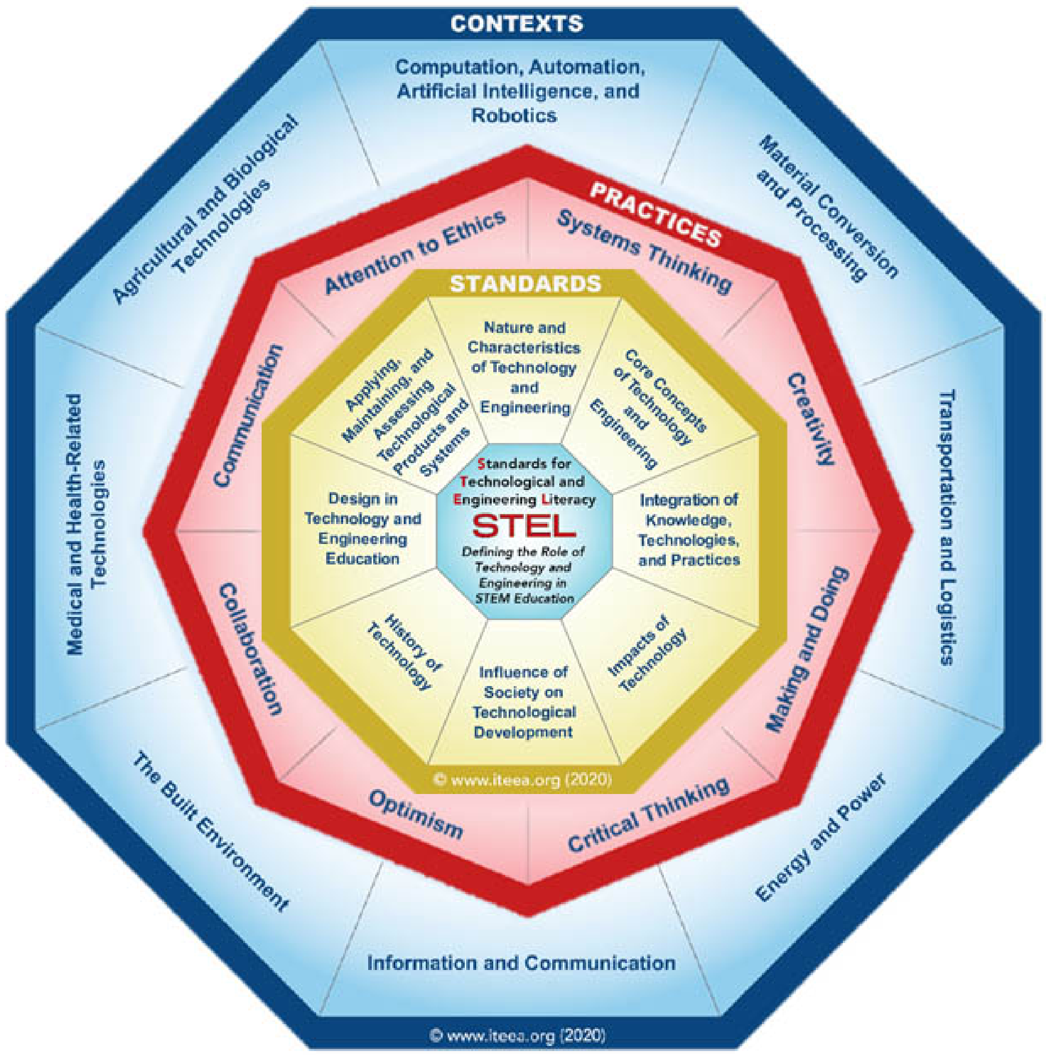
**Standards for Technological and Engineering Literacy (STEL)**

A challenge in communicating a clear picture of technological and engineering literacy is that it encompasses a broad area of human activity, one that is constantly evolving. Additionally, core subjects such as mathematics and science have long histories and clearly articulated content at the Pk-12 level while technology and engineering are not as well understood at this level and have a stronger history at the tertiary level of education [16]. The recently released *STEL* [1] take into account the dynamic nature of the discipline as well as contemporary research in the development of academic standards. The development of *STEL* was supported by the National Science Foundation (NSF) and the Technical Foundation of America and is a significant update on ITEEA's *STL* [6].

*STEL* defines the field of Pk-12 technology and engineering education as a set of eight core disciplinary standards and eight practices that are widely applied across a range of eight technology and engineering contexts (Figure 1). Students should study all eight standards and apply all eight practices in a variety of contexts. Figure 1 should be thought of as a set of three spinning octagons where standards, practices, and contexts can be rotated and aligned to develop a particular unit or lesson.

**Figure 1**

Organization of *Standards for Technological and Engineering Literacy* [1, p. 11]




Each of the eight *STEL* standards, shown in the innermost octagon (gold), are explained with a brief narrative containing several key ideas that provide detail, or broad understandings, of the standard. Within each standard, there are benchmarks provided by grade band (Pk-2, 3-5, 6-8, and 9-12) that detail what students should know and be able to do within the specified context. Benchmarks are written with active, measurable verbs to facilitate unit and lesson planning as well as assessments. Additionally, each of the 142 benchmarks align with one or more of the domains of learning – cognitive, psychomotor, and/or affective – and ITEEA offers an online resource to aid curriculum developers and classroom teachers in making these connections. Each of these three domains are also correlated to the technology and engineering dimensions of knowing, thinking, and/or doing and the student outcomes of knowledge, skills, or dispositions (Table 1). For example, a benchmark in the P-2 grade band that is purely knowledge-based, such as "Explain ways that technology helps with everyday tasks," aligns with the cognitive domain of learning only and can therefore be achieved through knowing and thinking.

**Table 1**
Alignment of the domains of learning, technology and engineering dimensions, and student outcomes [1, p.121].

| Domains of Learning | | Technology & Engineering Dimensions | | Student Outcomes (as defined by Benchmark verbs) |
|---|---|---|---|---|
| Cognitive | → | Knowing & Thinking | → | Knowledge |
| Psychomotor | → | Doing | → | Skills |
| Affective | → | Knowing, Thinking, & Doing | → | Dispositions |

*STEL* is designed for all students to apply the eight technology and engineering practices, reflected in the middle (red) of the octogon. These practices were derived from current research (e.g., NGSS science and engineering practices, 21st century skills, and engineering habits of mind). Table 2 illustrates the eight technology and engineering practices across the grade bands, and it is important to note the increasing complexity of the verbs (i.e., practices) as students progress through grade bands.

The outermost (blue) octagon in the *STEL* graphic organizer (Figure 1) represents the eight major contexts in which we study technology and engineering. These have been expanded from the Designed World section of *STL* [6] and offer curriculum developers and teachers more flexibility in how they are addressed. The *STEL* authors designed the contexts to be broadly applicable to state/province or local school system models of instruction. Some curriculum developers and/or teachers may have classes that focus on one context (e.g., a "Transportation and Logistics" class) while others may implement the contexts as units or individual lessons. Unlike the eight standards and eight practices, students need not master all eight contexts. Regardless of how the contexts are used, curriculum developers and teachers should always start with the standards and contexts as the foundations for teaching and learning.

**Table 2**
Technology and engineering practice expectations by grade band [1, p.72].

| Grade Bands | TEP-1: Systems Thinking | TEP-2: Creativity | TEP-3: Making and Doing | TEP-4: Critical Thinking | TEP-5: Optimism | TEP-6: Collaboration | TEP-7: Communication | TEP-8: Attention to Ethics |
|---|---|---|---|---|---|---|---|---|
| PreK-2 | Learns that human-designed things are connected | Learns that humans create products and ways of doing things | Learns to use tools and materials to accomplish a task | Engages in listening, questioning, and discussing | Sees opportunities for making technologies better | Learns to share technological products and ideas | Learns that humans have many ways to communicate | Learns that use of technology affects humans and the environment |
| 3-5 | Provides examples of how human-designed products are connected | Tries new technologies and generates strategies for improving existing ideas | Safely uses grade-appropriate tools, materials, and processes to build projects | Knows how to find answers to technological questions | Engages in "tinkering" to improve a design | Works in small groups to complete design-based projects | Develops written and oral communication skills | Explains ethical dilemmas involving technology, such as trade-offs |
| 6-8 | Uses the systems model to show how parts of technological systems work together | Exhibits innovative and original ideas in the context of design-based activities | Exhibits safe, effective ways of producing technological products, systems, and processes | Defends technological decisions based on evidence | Critiques technological products and systems to identify areas of improvement | Demonstrates productive teamwork in design-based projects | Exhibits effective technical writing, graphic, and oral communication abilities | Shows an understanding of ways to regulate technologies and the reasons for doing so |
| 9-12 | Designs and troubleshoots technological systems in ways that consider the multiple components of the system | Elaborates and articulates novel ideas and aesthetics | Demonstrates the ability to regulate and improve making and doing skills | Uses evidence to better understand and solve problems in technology and engineering, including applying computational thinking | Shows persistence in addressing technological problems and finding solutions to those problems | Considers and accommodates teammate skills and abilities when working to achieve design and problem-solving goals | Conveys ideas clearly in constructive, insightful ways, including through written and oral communication and via mathematical and physical models | Assesses technological products, systems, and processes through critical analysis of their impacts and outcomes |

## Implementing STEL

*STEL* [1] is available at https://www.iteea.org/STEL.aspx. Several studies have analyzed *STEL* and demonstrated how it can be used to guide the development of integrated STEM teaching and learning experiences in Pk-12. Han *et al.* [17] described how *STEL* promotes interdisciplinary connections between STEM subjects while upholding technology and engineering as a disciplinary integrator. Moreover, they found the emphasis on engineering design throughout *STEL* helps educators incorporate societal concerns, teach disciplinary knowledge and skills from various content areas, and increase students' problem-solving abilities [17]. Another analysis found a greater emphasis on safety concepts (encompassing design considerations, testing, and construction of design solutions) embedded throughout the *STEL* document in comparison to other STEM-related standards documents and frameworks [18].

*STEL* has also been considered helpful in guiding technology and engineering teaching and learning internationally. Choon-Sig [19] noted that the decrease from 20 standards and 279 benchmarks in *STL* [6] to eight standards and 142 benchmarks in *STEL* [1] would be beneficial for lessening the learning burden placed on Korean students. They concluded that the focus on Pk-12 would increase the influence of *STEL*, and the structure (core disciplinary standards, practices, and technology and engineering contexts) could help enhance the technological and engineering literacy of students in Korea [19].

Researchers and educators have shared numerous examples demonstrating how *STEL* can be used in a practical way to guide purposeful integrated STEM teaching and learning experiences. Bartholomew *et al.* [20] showed how a *STEL* aligned lesson about automated structures could be developed using Danielson's *Framework for Teaching* [21], Wiggins and McTighe's *Understanding by Design* [22], and the *6E Learning byDesign* model [23]. Other examples have demonstrated how lessons within the contexts of biomimicry [17], reading/literacy and computational thinking [24], and artificial intelligence [25] centered around engineering design can integrate content and practices from *STEL*, *NGSS*, and the *Common Core State Standards (CCSS)* to provide rigorous integrated STEM learning experiences.

To help teachers and curriculum developers implement *STEL* there have been a number of presentations, videos, crosswalks to other standards, lesson plans, an app, and other user-friendly resources developed. The crosswalks can help teachers align their lessons to the *CCSS* in language arts and mathematics, *NGSS*, Project Lead the Way (PLTW), and the National Assessment of Educational Progress Technology and Engineering Literacy (NAEP TEL) framework. The *STEL* eTool offers a robust search function that aids with lesson development and allows educators to easily share their lesson plans. Lastly, the ITEEA STEM Center for Teaching and Learning (STEM CTL™) provides overviews of *STEL* as well as professional development to help schools develop and implement *STEL* aligned instruction.

There remain challenges for the implementation of STEL despite the emerging resources, translations, and research. For example, the field should look at the implementation of other standards when it comes to equity and access [26]. Additionally, there were still debates during the development of STEL that need to be rectified by the field:

> Despite this common goal, there were still concerns about the structure and content of the standards in relation to past standards documents. This resulted in a thought-provoking debate during one of the whole-group meetings in Chinsegut. These concerns were well summarized by one participant, 'Educators will benefit from these revised standards because they do a better job of clarifying what we value in T&E education. However, if we fail to take ownership of the 'context areas' by not raising them to the level of standards and benchmarks, I think we are doing a huge disservice to our teachers and teacher educators, especially at the secondary level' [26, p. 12].

Codifying a discipline in Pk-12 education through standards is a complex task that will never have complete consensus. The development of STEL, however, was inclusive, rigorous, and well-grounded upon the epistemological foundations of technology and engineering education. Now it is time for research and practice to shape the implementation of STEL and the field overall.

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