ITEEA *Standards for Technological Literacy* Revision Project: Background, Rationale, and Structure

Prepared by:

Jennifer Buelin
Michael K. Daugherty
Marie Hoepfl
Charlotte Holter
Todd Kelley
Thomas Loveland
Johnny Moye
Anna Sumner

June 2019

Table of Contents

Introduction ... 3
Chapter 1: Contrasting Technological, Engineering, and Scientific Literacy ... 4
Literacy, Broadly Defined ... 4
Technological Literacy ... 5
Engineering Literacy ... 7
Scientific Literacy ... 11
Toward a Broader STEM Literacy? ... 15
Chapter 2: The Rationale for Reducing the Number of Content Standards ... 19
History and Context of Standards ... 19
Problems with Early Standards ... 19
Issues in the Process of Standards Development ... 21
Conclusion ... 24
Chapter 3: Mission and Vision of the STL Revision Process ... 26
Historical Perspective ... 26
Current Status of STL ... 28
The Role of Design in the Revision of STL ... 30
The Mission of the STL Revision Project ... 33
Vision for the STL Revision Project ... 34
Structure of the Revised STL ... 34
Chapter 4: Proposed Working Title and Structure for the Revised STL ... 36
Guiding Principles for Revision of the STL ... 36
Proposed Change to the Title of the Standards ... 38
Proposed TESSE Standards ... 39
Eight Application Areas for TESSE ... 42
Summary ... 44
References ... 46
Appendix A: Engineering Content in State Standards ... 53
Appendix B: Examples of Core Standards Applied to the Eight Application Areas ... 54
Appendix C: Summary Report of Review Team Members’ Survey ... 61

Introduction

The *Standards for Technological Literacy* (STL) Revision Leadership Team worked through Spring 2019 to plan and provide direction for the STL Revision Project. This work included multiple meetings, conference presentations, and preparation of reports based on an international survey conducted in Fall 2018 and, more recently, targeted reviews of literature. This report is the result of the team's efforts to more clearly define the goals, rationale, and structure for the STL Revision process. It represents the consensus view of the eight Leadership Team members, and incorporates feedback solicited via a survey conducted in June 2019 of the 30 Review Team members. A summary of the June 2019 survey results can be found in Appendix C.

This document contains four chapters. Chapter One contrasts technological literacy, engineering literacy, and scientific literacy, and suggests how STEM literacy could be used as a unifying framework. Chapter Two reviews the literature on the history of standards and current thought on the best process for determining standards, including the importance of making standards succinct. Chapter Three revisits the discussion of how STL can/should include engineering and technology in a STEM model and presents a mission and vision statement for the revision work. Chapter Four takes into account the previous three chapters and proposes a new working title and structure for the revised standards.

This report will serve as a guide and foundation for the standards revision work to be completed at the August 2019 Standards Revision conference.

Chapter 1: Contrasting Technological, Engineering, and Scientific Literacy

The overarching questions guiding this review of literature are: What are the characteristics of technological, engineering, and scientific literacy? How are they similar, and what are the important points of contrast? In order to address these questions we first look at each "literacy" individually, then summarize our findings in an attempt to define these literacies in a way that might guide the *Standards for Technological Literacy* revision process.

Literacy, Broadly Defined

The National Academies, in their 2016 report *Science Literacy: Concepts, Contexts, and Consequences,* provided a helpful discussion of the word literacy:

> Literacy as a term and a concept has great usefulness and seemingly boundless semantic potential, such that it is used to refer to an ever-larger array of ideas, and the central concept has drifted dramatically from its original meaning. The origin is *letra*, Latin for letter, and literacy once very simply referred to the capacity to recognize letters and decode letter strings…. That circumscribed meaning has long been transcended. (National Academies of Sciences, Engineering, and Medicine [National Academies], 2016, p. 16)

The report contrasts "foundational literacies"—such things as "numeracy, textual literacy, visual literacy, and understanding of graphs and charts"—from the more focused "disciplinary literacy" that is associated with knowledge within the specific domain (p. 32). Both are useful concepts, and arguably a set of content standards for any disciplinary field must address both types of literacy.

A broad notion of literacy, particularly within a disciplinary field, must also acknowledge that what constitutes literacy is a shifting landscape, subject to change as cultural conditions change (Fourez, 1997; National Research Council, 2002; Williams, 2009). According to Zollman (2012), “there is a difference between literacy and being literate. STEM literacy should not be viewed as a content area but as a shifting, deictic means (composed of skills, abilities, factual knowledge, procedures, concepts, and metacognitive capacities) to gain further learning” (p. 12). Krupczak et al. (2016) echoed this idea when noting that both engineering and technological literacy contain elements that are permanent or time-independent as well as elements that are “constantly evolving or changing” (p. 13). The overarching message for technology and engineering education is that because technological literacy is a fluid construct, “to maintain relevance its content [must] evolve as a function of changing cultural traditions. The utility of such a literacy would depend on its ability to adapt and keep pace with constant change” (Gagel, 1997, p. 22).

Technological Literacy

Efforts to define, and arguments about the need for, technological literacy are widespread. Yet conveying the full meaning of this literacy is difficult when many people associate technology only with information technologies (Fleming, 1989; Heywood, 2017; Mitchell, 2017), or when the disciplinary fields that comprise the STEM umbrella are conflated into a single entity, as is widely done. It is nevertheless important to try to tease out the unique characteristics of the various STEM literacies before examining their points of overlap and complementarity. France (2015) referred to technology and science as “two intersecting social systems” that, although parallel, possess “particular characteristics and ways of working” that can be identified (p. 41).

The much-quoted definition of technological literacy provided in the ITEEA’s *Standards for Technological Literacy* (STL) document is: “The ability to use, manage, assess, and understand technology." A technologically literate person understands "what technology is, how it is created, and how it shapes society, and in turn is shaped by society" (ITEA/ITEEA, 2000, 2002, 2007, p. 9). The STL elaborated on the content that would underpin this "understanding" of technology by providing a detailed list of content standards. Such standards pose inherent challenges, however. First, "what … is required in order to be considered technologically literate remains difficult to articulate as there is no one universal set of requirements that satisfies technological 'literateness'" (Ingerman & Collier-Reed, 2011, p. 138). Second, as acknowledged earlier, technological content is contextual and can change along with temporal, cultural, and geographic changes. To address this potential for contextual variation, some argue for an emphasis on process and action:

> Complementary to the content of technological literacy, is the idea of the *function* [emphasis added] of technological literacy, which would appear to be less clearly articulated in the literature. We suggest that the function of technological literacy—"the mode of action by which [technological literacy] fulfills its purpose" (Simpson et al., 1989, p. 263)—is important to articulate with respect to both individuals and society. In relation to the function of technological literacy, we will focus our attention on 'the mode of action', rather than on the purpose. (Ingerman & Collier-Reed, 2011, p. 139)

Although writing in 1997, Gagel reached much the same conclusion: "Given that utility and adaptability depend heavily on what is known by the individual, the form of knowledge that appears most useful is praxiological knowledge" (p. 23). In response, Gagel laid out what he called an "identity kit" for technological literacy—"one containing those effectual elements having an inherent, unchanging, and enduring quality.... that would enable one to (a) accommodate and cope with rapid and continuous technological change, (b) generate creative and innovative solutions for technological problems, (c) act through technological knowledge both effectively and efficiently, and (d) assess technology and its involvement with the human lifeworld judiciously" (Gagel, 1997, p. 25). From this praxiological point of view, "expertise (or enhanced literacy) is developed through repeatedly acting in technology and engineering contexts, building experience in the selective application of epistemic practices" (Tang & Williams, 2018, p. 14).

The process of design has long been a hallmark of the technology education classroom (Antink-Meyer & Brown, 2019; Williams, 2009) and this process figures heavily in existing content standards in science and technology at the national level, and in science, technology, and engineering at the state level (Carr, Bennett, & Stroebel, 2012; Koehler, Faraclas, Giblin, Moss, & Kazerounian, 2013). More recently, the term "engineering design" has seen wide use (e.g., ITEA/ITEEA, 2000, 2002, 2007; NGSS Lead States, 2013). It is in the area of design activity that it becomes most difficult to differentiate technology and engineering, because both areas (rightly) claim design as a core function within the discipline. The concept of "technological multiliteracy" proposed by Williams (2009, p. 246) may be helpful here in that it acknowledges the many synergies between technological and other forms of literacy and highlights the breadth of technological literacy—including, very importantly, "an awareness or appreciation of the relationships between technology, society and the environment" (Williams, 2009, p. 246).

Engineering Literacy

More so than with any two other disciplines within the STEM umbrella, technology and engineering are often conflated (e.g., Krupczak et al., 2016) and are frequently referred to by the unified phrase "technology and engineering." Given the frequent pairing of these terms, it might seem futile to try to define engineering literacy separately from technological literacy. Asunda (2012) stated, “The idea of engineering literacy is synonymous with technological literacy, since it is difficult to differentiate between the two, though engineers may argue differently” (p. 48). Technology theorists might also find points of contention, such as with the characterization of engineering versus technological literacy shown in Table 1, which depicts technological literacy as being focused on products and objects, rather than on actions. Krupczak et al. (2016) elaborated on their comparison of the two disciplines, noting: “If engineering literacy is viewed as having a focus directed more toward understanding the process of creating or designing technological artifacts or systems, then technological literacy includes a broader view of the products or results of the engineering process as well as the relation between technology and society” (p. 12). Note that Table 3 summarizes the approaches taken across the STEM disciplines as a way of contrasting and illustrating these differences.

Table 1. *Differentiating Engineering and Technological Literacy* (Krupczak et al., 2016, p. 11)

Engineering Literacy	**Technological Literacy**
Process	Product
Verb (Actions)	Noun (Objects)
Narrow Focus	Broader Focus

Antink-Meyer and Brown (2019) wrote, “Modern engineering and technology [have] common ancestors and significantly overlap, [but] they are not identical constructs” (p. 13). These researchers went on to identify seven features that describe the nature of engineering knowledge; understandings that they claim “are foundational in the sense that they are accessible without oversimplifying engineering, as well as that they contextualize engineering in relation to society, culture, science, and technology in ways that can be taken up, elaborated on, and refined" (p. 7). According to their analysis, engineering is solution-oriented ("because it is motivated by human problems and desires" [p. 7]), contextually responsive, and empirical ("evidence-based modeling is the central means of data gathering and feedback" [p. 9]); has a personal dimension; is influenced by societal and cultural factors; and is both a social process (often involving work in teams) and interdisciplinary because of its co-dependent relationship with science and technology.

Carr et al. (2012) conducted an analysis of engineering content across all 50 U.S. states. In setting up their research methodology, they "deliberately chose definitions which encompass the broad and multi-faceted concepts" of engineering:

> *Engineering is* iterative design and the optimization of materials and technologies to meet needs as defined by criteria under given constraints. *Engineers use* systematic processes, mathematical tools and scientific knowledge to develop, model, analyze and improve solutions to problems. *Engineering design processes are* dynamic and include phases of problem definition, problem solving, testing and iteration. (Carr et al., 2012, p. 547).

These concepts mirror the three general principles for engineering education identified by the National Academy of Engineering to create a broad framework for engineering literacy: "K-12 engineering education should emphasize engineering design…[It] should incorporate important and developmentally appropriate mathematics, science, and technology knowledge and skills….[and it] should promote engineering habits of mind….[including] systems thinking, creativity, collaboration, and communication" (National Academy of Engineering [NAE], 2010, p. 45).

The extent to which engineering content and practices have been adopted by states was examined by both Carr et al. (2012) and Koehler et al. (2013). Koehler and colleagues specifically analyzed how much engineering content was written into states' science standards, whereas Carr and his team looked more broadly at all content standards. Koehler et al. found that New England, the Mid-Atlantic, and Great Lakes regions reflected the greatest amount of engineering content in their state science standards, and noted that some states "have used [the Science, Technology, and Society approach] as the bridge between the disciplines of science and technology" (Koehler et al., 2013, p. 10). Taking a broader census, Carr et al. found that 36 U.S. states had a "strong presence of engineering" in their educational standards (p. 549), with 11 states having explicit engineering standards and another six presenting engineering in the context of technological design. A full listing of the content analysis undertaken by Carr et al., which identified the "big ideas" of "doing engineering," can be found in the Appendix.

Reimers, Farmer and Klein-Gardner (2015) framed engineering literacy through its fundamental nature, subject content, and practices in three categories. The first, engineering design, is linked to innovation, creativity, critical thinking, problem solving, collaboration, solving problems within design parameters and constraints, iteration, optimization and continual improvements, acceptance of failure as part of the process, systems thinking, multiple solutions, and multiple ways of communicating results. The second category of engineering literacy is related to engineering careers. The third category is engineering and society, which describes the impact of engineering on society and of society on engineering.

The Next Generation Science Standards (NGSS Lead States, 2013) described three stages of engineering design. Students using the engineering design process would first need to define and delimit the problems being worked on. This includes understanding the criteria and constraints. Second, generating multiple potential solutions and evaluating those solutions is normal in this process. Finally, solutions need to be tested to determine the optimal solution for a final design.

Scientific Literacy

Determining what constitutes scientific literacy is a difficult task. As with other forms of literacy, there are differing thoughts and definitions. According to a 2016 National Academies report on the topic, scientific literacy can be broadly defined as having "some level of familiarity with the enterprise and practice of science" (National Academies, 2016, p. 1). A central theme of the National Academies' work on this topic is that scientific literacy should be considered a characteristic not only of individuals, but also of communities and societies (National Academies, 2017). As early as 1971, the National Science Teachers Association (NSTA) declared scientific literacy to be "the most important goal of science education" because it allows individuals to use scientific understanding and values to "make everyday decisions" (National Academies, 2019, p. 27).

The National Academies' report *Science Literacy* (2016) noted that the definition of scientific literacy has changed over the years as ideas about science have changed. The report summarized definitions of scientific (or science) literacy by identifying seven elements that were evident across the multiple definitions they examined to create "a sort of theoretical common ground…. [of what] many scholars *expect* would be useful or valuable" in relation to scientific knowledge (National Academies, 2016, p. 137). These included foundational literacies; content knowledge ("scientific terms, concepts, and facts," although "there is disagreement over the scope of knowledge required"); understanding of scientific practices (broadly speaking, "how scientists do science"); identifying and judging scientific expertise; epistemic knowledge ("an understanding of how the procedures of science support the claims made by science"); cultural understanding of science (which "acknowledged the interrelationships of science and society"); and dispositions and habits of mind (which might include "inquisitiveness, open-mindedness, a valuing of the scientific approach to inquiry, and a commitment to evidence") (pp. 32-33).

These seven elements were operationalized neatly in the following definition found in the 1996 *National Science Education Standards:*

> Scientific literacy means that a person can ask, find, or determine answers to questions derived from curiosity about everyday experiences. It means that a person has the ability to describe, explain, and predict natural phenomena. Scientific literacy entails being able to read with understanding articles about science in the popular press and to engage in social conversation about the validity of the conclusions. Scientific literacy implies that a person can identify scientific issues underlying national and local decisions and express positions that are scientifically and technologically informed. A literate citizen should be able to evaluate the quality of scientific information on the basis of its source and the methods used to generate it. Scientific literacy also implies the capacity to pose and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately. (National Academy of Sciences, 1996, p. 22)

In the current *Next Generation Science Standards* (NGSS), scientific literacy is still seen as a compelling need although the term isn't explicitly defined as in past science standards documents. The NGSS is based, in part, on the National Academy of Sciences report *A Framework for K-12 Science Education* (National Research Council, 2012). This report made a much more explicit connection between science and engineering, notably structuring the discussion about science education around three "dimensions" that are echoed in the NGSS. "Dimension 1 describes scientific and engineering practices. Dimension 2 describes crosscutting concepts…those having applicability across science disciplines. Dimension 3 describes core ideas in the science disciplines and of the relationships among science, engineering, and technology" (National Research Council, 2012, p. 29). As these dimensions suggest, at the same time that the door was opened more widely to engineering (and, to a lesser extent, to technology), an effort was made to pare down the "cornucopia of information" to a manageable set of ideas that could represent "core knowledge" (p. 31). The report stated: "An education focused on a limited set of ideas and practices in science and engineering should enable students to evaluate and select reliable sources of scientific information and allow them to continue their development well beyond their K-12 school years as science learners" (p. 31).

Although the report (pp. 50-53) went to some length to contrast the practices of scientists with those of engineers, this was only within a parallel structure that they identified as the "essential elements of the K-12 science and engineering curriculum":

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)

7. Engaging in argument from evidence

8. Obtaining, evaluating, and communicating information. (p. 49)

The disciplinary core "ideas" that form the largest share of the NGSS are largely based around the conventional sub-categories of science education encompassing the physical, life, and earth and space sciences. However, these also include elements related to the engineering design process. Similarly, the crosscutting concepts include one that focuses on the "interdependence of science, engineering, and technology" and another on the "influence of engineering, technology, and science on society and the natural world."

Table 2 summarizes some contrasting definitions of technological, scientific, and engineering literacy. In addition to examining definitions of these literacies, it is also informative to look at Kelley's (2015) model comparing scientific inquiry to engineering design (Figure 1). "Scientific inquiry includes the traditional science processes, but also refers to the combining of these processes with scientific knowledge, scientific reasoning, and critical thinking to develop scientific knowledge" (Lederman, Lederman, Antink, 2013, p. 142). The scientific inquiry wheel is a student focused process, open-ended and iterative. As students progress in their learning, the process becomes even more student driven.

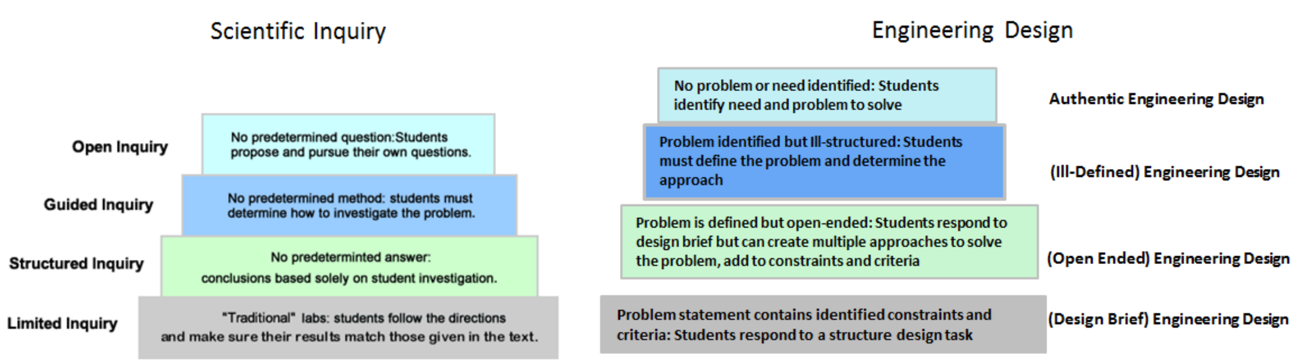

Figure 1. Comparison of scientific inquiry and engineering design (Kelley, 2015).

Table 2. *Contrasting Technological, Engineering, and Scientific Literacy* (Zollman, 2012, p. 14)

Scientific Literacy	National Science Education Standards (1996)	Knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity
	Organization for Economic Cooperation and Development (2003)	Ability to use scientific knowledge (in physics, chemistry, biological sciences, and earth/space sciences) and processes to understand, and additionally, to participate in decisions that affect science in life and health, earth and environment, and technology
Technological Literacy	National Assessment Governing Board (2010)	Capacity to use, understand, and evaluate technology, as well as to understand technological principles and strategies needed to develop solutions and achieve goals
	International Society for Technology in Education (2000)	Ability to demonstrate creativity and innovation, communicate and collaborate, conduct research and use information, think critically, solve problems, make decisions, and use technology effectively and productively
	International Technology Education Association (2007)	Ability to understand, in increasing sophistication over time, how technology is created and how it shapes society, and further, is shaped by society
Engineering Literacy	Organization for Economic Cooperation and Development (2003)	Ability to systematically and creatively apply scientific and mathematical principles to practical ends such as the design, manufacture, and operation of efficient and economical structures, machines, processes, and systems
	Accreditation Board for Engineering and Technology (2010)	Knowledge of the mathematical and natural sciences gained by study, experience, and practices that is applied to develop ways to utilize economically the materials and forces of nature for the benefit of mankind

Toward a Broader STEM Literacy?

The past 10 to 20 years have seen a marked expansion of interest in interdisciplinary STEM approaches, with the acronym STEM becoming a common part of the conversation among educators and members of the public (e.g., National Governors Association, 2007; Zollman, 2012). The ITEA (now ITEEA) expanded its name to include the word engineering in 2010. The NGSS and its precursor reports, including the AAAS *Project 2061* (American

Association for the Advancement of Science [AAAS], 2007), embraced the connections between the STEM disciplines. STEM is seen as an “interdisciplinary area of study that *bridges* the four areas of science, technology, engineering, and mathematics. STEM literacy does not simply mean achieving literacy in these four strands or silos” (National Governors Association [NGA], 2007, p. 7). Yet, because it is a relatively new term and because effective interdisciplinarity dictates working beyond and outside of these silos to include the social sciences, arts, and humanities, “STEM literacy” has still not been precisely defined (Cencelj, Abersek, Bersek, & Flogie, 2019; Zollman, 2012), and the wide-ranging definitions of STEM and its component parts “present an obstacle for the field to have meaningful conversation revolving around STEM literacy” (Tang & Williams, 2018, p. 2). Based on this review of the literature, two points seem clear, however: (1) STEM is a unitary force that must be accounted for; and (2) technology and engineering must better establish their roles in this disciplinary quartet, including better articulating the core elements of their respective disciplinary literacy.

With respect to the first point, Zollman (2012) articulated a vision for how we might think about STEM literacy that details a deictic model for STEM as a unified entity even as it suggests that the core content areas contain their own specific educational objectives:

> In education, we need to view STEM literacy as a *dynamic process*, spotlighting the three strata in the STEM literacy process: educational objectives of the content areas; cognitive, affective, and psychomotor domains from learning theory; and economic, societal, and personal needs of humanity. Such a vision allows us to evolve from focusing on *learning for STEM literacy* to using *STEM literacy for continued learning*. (Zollman, 2012, p. 18)

This dualistic vision of STEM literacy was described by Tang and Williams (2018), who wrote: "STEM literacy is more than the sum of its parts. What STEM literacy provides, that the independent disciplines do not, is also a holistic understanding of how concepts, processes and ways of thinking can be integrated and applied to the design of a solution to a real-world problem. These 'wicked' problems often require an interdisciplinary approach rather than a singular disciplinary approach" (p. 18). These authors proposed that because there are specific skills and knowledge reflective of each disciplinary area, we might better use the phrase "S.T.E.M. literacies" (p. 18) to refer to the kind of literacy we wish to emphasize. "It is reasonable that the skills introduced or learned in one discipline can be applied and reinforced (with careful pedagogical consideration) in another discipline, as well as learning these overlapping skills in an integrated STEM approach" (Tang & Williams, 2018, p. 17). The idea of "STEM literacies" was also promoted by Cencelj et al. (2019), who said, "While science, mathematical, engineering and technological literacy may well refer to competences sharing common roots and a set of common attributes, they are ultimately different kinds of literacy competences, which serve different goals, lead to different results and must therefore be developed systematically, each of them separately" (p. 133). In spite of this recognition that the STEM fields have different goals and disciplinary content, and in the face of inconsistent models for how to best integrate STEM into the K-12 school curriculum, "there is agreement that an integrated approach may provide more promising results" (Mitchell, 2017, p. 67), and "an interdisciplinary approach is clearly necessary" to achieve the kind of functional literacy needed to solve our pressing societal needs (Heywood, 2017, p. 2).

With respect to the second point, that technology and engineering need to better articulate their roles in STEM, the National Governors Association called for increased support for emerging work on the "'T' and 'E' of STEM," as a key strategy to "increase the relevancy of STEM to students' lives" (NGA, 2007, p. 19), and U.S. schools need to do more to incorporate technology and engineering in their curricula (Mitchell, 2017). Part of this emerging work on technology and engineering is consideration of content standards for these disciplinary fields, with the STL currently under revision and ongoing debate about whether standards specific to K-12 engineering education should be developed (National Academy of Engineering, 2010; Carr et al., 2012). Even in the absence of standards developed specifically for K-12 engineering education, engineering content features prominently in both the NGSS and the *Standards for Technological Literacy*, a trend that is likely to be expanded in the coming years as states modify their educational standards and through the development of the Technology and Engineering Literacy component of the National Assessment of Educational Progress (IES/NCES, 2019). As was done for the NGSS, the STL revision team will need to give careful thought to the ways that, and the extent to which, the "big ideas" of engineering are infused into the standards.

Finally, care must be taken to address the kinds of mathematical knowledge needed for students to engage in the study of technology and engineering across the PK-12 spectrum. In other words, what are the foundational understandings and practices needed for numeracy within the technology and engineering context? Furthermore, in what ways can technology and engineering provide opportunities for meaningful application of mathematical processes? The "processes and proficiencies" laid out in the Common Core *Standards for Mathematical Practice*—such as problem solving, quantitative reasoning, modeling, and so on (Common Core State Standards Initiative, 2019)—must play a role in the broader STEM literacy that is envisioned.

Chapter 2: The Rationale for Reducing the Number of Content Standards

History and Context of Standards

The National Commission on Educational Excellence in 1983 released *A Nation at Risk,* which proclaimed the United States was at an economic competitive disadvantage due to mediocrity in American schools. This report led to the standards movement starting in the late 1980s with the release of National Council of Teachers of Mathematics (NCTM) mathematics standards in 1989, *Science for All Americans* the same year from the American Association for the Advancement of Science, the federal *Goals 2000: Educate America Act,* and English content standards from the National Council of Teachers of English (NCTE) in 1996. These standards outlined what students should know and be able to do in the respective content areas. At the time, Massell (1994) stated that effective standards must be world-class, public, realistic, and valued.

According to Barton (2010), there were generally two different goals for the development of standards. The first was to establish content standards that added rigor to instruction. The second was to standardize what knowledge all students should be taught. Different organizations made choices in the development of their content-specific standards based on their goals. Some organizations, like the (then) International Technology Education Association (ITEA), focused on standards and benchmarks as “big idea” or conceptual guidelines. Other standards, such as the Next Generation Science Standards and Common Core, went further and provided performance objectives tied to benchmarks, which aided in the development of assessments.

Problems with Early Standards

Over time, researchers were able to discern problems with the development and dissemination of content standards. Barton (2010) pointed out that standards are the product of compromises among committee members that often results in their being overly broad. Massell (1994) discussed how the development and certification of content standards is a series of tradeoffs, like in any social undertaking. Top-down standards often ignore social, political and technical realities in their implementation. Some content areas, like mathematics, are less fragmented into multiple sub-areas and therefore consensus can be more easily reached. Other content areas like English, social studies, science, and technology education have many sub areas which leads to greater potential for political landmines in the form of public opposition to specific standards (Suhor, 1994; White & Rizzo, 2008). For example, some states are pushing to remove the teaching of evolution (Watts, Levit, & Hossfeld, 2016)

In order to achieve consensus, standards may be developed that use broadly-worded statements. Reeves (2000) indicated a “coverage” approach to standards is about displacing rigor with girth through quantity of topics to be covered. The resulting impact on stakeholders can be predicted accurately. “To appease the watchful eyes of vocal interest groups, publishers have traditionally watered down their materials by using vague language, avoiding controversy, and covering as many topics as possible to make sure they have broad consensus and a broad market” (Massell, 1994, p. 189). White and Rizzo (2008) stated that a coherent foundation for standards cannot be attained through consensus. Consensus building may be democratic and representative, but the standards created tend to be unfocused.

Another issue with standards development can occur when the development committee embarks on a process of representational equality whereby competing perspectives are given equal space in the curriculum. This results in the view that it is easier to layer in new benchmarks with the original rather than take the time to remove redundancies and inconsistencies to achieve uniform and consistent standards. Standards developed in this way essentially provide a layer of content for teachers and students to skim through, but not deeply engage in (Massell, 1994).

Popham (2006) reported on the impact of too many content standards at the state level that were poorly conceptualized for instruction or assessment. State curriculum specialists may include their cherished skills or knowledge despite the better judgment of the standards development committee. Wiggins (2011) warned about the danger of not providing specific selection criteria to weed out pet topics. Committees may be "merely rearranging the furniture of the traditional core content areas: they replicate the past that they feel comfortable with rather than face the future that is on its annoying but inexorable way" (Wiggins, 2011, p. 31). White and Rizzo (2008) stated that standards developers must "let go of what's familiar and comfortable and approach the work objectively" (p. 4). In an interview with Ramsey Selden from the Council of Chief State School Officers, O'Neil (1995) reported on the cumulative effect of too many standards for teachers to address in a coherent manner. Faced with standards too numerous to cover in their courses, teachers are left in a state of indecision as to what to focus on in their instruction.

Issues in the Process of Standards Development

Ujifusa (2014) reported on when states began to move away from the Common Core State Standards (CCSS) for political reasons. States were either approving standards that were Common Core but named something else or they proposed starting from scratch. McGuinn (2015) reported that opposition to the CCSS centered on concerns about federal overreach, fears of data privacy breaches, pushback on corporate school reform, anti-testing sentiments, fears of progressive educators intent on teaching multiculturalism, and worries by educators that their evaluations would be tied to national assessments of students. Thus, standards development efforts must tread a fine line between providing a well-curated set of norms for what content should be taught and being potentially over-prescriptive about what students should know and be able to do.

Standards reform is complicated and must be done in an informed way. Massell (1994) indicated that broad review and feedback from diverse points of view can lead to shared vision and support. Committees should construct support internally through a grassroots development process. A broad-based dialogue can yield goal clarity and purposes that are supported from the field. Massell asserted that leaders of standards development committees must realize that they will have to move ahead with their standards even though not everyone will approve of or support them. In the fight for supremacy of view, there is “no easy, single litmus test that will determine how much consensus is enough, or when standards meet world-class leadership criteria” (1994, p. 189).

Content standards should be sufficiently flexible and open-ended to be able to stay current with changes in the disciplinary field. One way to do this is to use broad language—the so-called big ideas—or guidelines instead of prescriptive objectives. They should have sufficient detail, however, to “effectively guide the development of other policy components such as assessment and instructional materials” (Massell, 1994, p. 192). If sufficient detail is not included standards will be operationalized by assessment developers, possibly with very different meaning than what was intended by the standards team.

White and Rizzo (2008) cautioned about potential landmines in the process of developing standards. Will there be a perception that the revised standards are more rigorous and thus potentially more burdensome to teachers? By incorporating complex, multi-faceted concepts in new standards, standards developers may make it more likely for groups to rise up in opposition to what is being proposed.

Benjamin and Schwartz (1994) reported on how fraught the development of English standards was due to the inclusion of a philosophical statement, vignettes, learning goals, and instructional tips. They suggested that in a quest to apply to all, the standards became "a tangled web of ideas, beliefs and goals" (p. 28). Marshall (2011) referred to curriculum developed in this way as "problematic and baggy" (p. 187). The process of writing standards should focus on conveying to parents what their children should know and be able to do. A solution is to make the standards more accessible, educator-friendly, and usable by including less verbiage.

Best Practices in Standards Development

Bitter and Thomas (1997) stated that standards development work should be organized to identify standards related specifically to the curriculum area and to build academic integration and connections between the curriculum areas. This may be helped by including representatives from other content organizations (e.g., National Science Teachers Association, American Society for Engineering Education, and National Council of Teachers of Mathematics).

White and Rizzo (2008) reported on efforts by the Hunt Institute to improve standards. The Institute concluded that content standards must be fewer, clearer, and at a higher level than what is typically found in state standards. They stated that earlier standards included too many topics and excessive repetition within and between grade levels. Quality standards must be viewed from the "criteria of specificity, clarity, rigor, balance of knowledge and skills, and teaching approaches" (p. 2). Standards must be grounded in evidence about essential knowledge and skills that students need in order to be prepared for college and work. Wiggins (2011) stated that standards should emphasize practical applications and focus less on factual content mastery.

One concept that has scholarly support (Popham, 2006; Reeves, 2000) is the idea that the number of standards and benchmarks should be reduced to focus on “power” (a.k.a. prioritized) standards. Reeves (2000) posed three critical questions in the development of power standards: (1) Are the standards and benchmarks enduring? (2) Are the standards applicable across a wide spectrum of other standards? (3) Are the standards required for the next level of instruction? Reeves suggested that good standards reflect brevity and balance. Massell (1994) also encouraged standards developers to focus on the idea that less is more, and to choose depth over breadth. This goal may be thwarted, though, when curriculum specialists have to decide what to eliminate. One strategy to resolve this problem is to develop detailed and precise strands of knowledge and skills tied to a common set of power standards.

Conclusion

For revision of the *Standards for Technological Literacy* the standards development work must consider (a) what the fundamental goal of the standards is; (b) how to achieve rigor as opposed to “girth” in detailing the standards; (c) what are the big ideas or power standards that will promote technological and engineering literacy; and (d) how these standards relate to, and interact with, content standards from other fields. Foster (2005) pointed out that it is “an opportunity to show children how a subject may be viewed from multiple perspectives” (p. 21).

The process of developing precise standards and benchmarks that are acceptable to all content field stakeholders will remain an unfinished dream. That doesn’t mean that as an organization the ITEEA should sit by while educators move away from using the standards. Benjamin and Schwartz (1994) stated that “reassessing one’s beliefs and values from time to time is healthy. A profession which does not enter into this exercise runs a serious risk of becoming complacent or stagnant” (p. 30). Revising the STLs is not only necessary and important, but may be liberating. In the June 2019 survey of Review Team members, 100% agreed that the current standards should be reduced. By reducing the number of standards to focus on essential content of technology and engineering, the field will ultimately be better served.

Chapter 3: Mission and Vision of the STL Revision Process

In 1995, an effort to create a rationale and structure for the study of technology was initiated to increase efforts to improve technological literacy for all Americans. Funded by the National Science Foundation (NSF) and the National Aeronautical and Space Administration (NASA) and spearheaded by the International Technology Education Association, *Technology for All Americans: A Rationale and Structure for the Study of Technology* (ITEA, 1996) was crafted and guided by the National Commission for Technology Education (NCTE). This commission was made up of 25 members from engineering, science, mathematics, humanities, education, government, professional associations, and business and industry. These individuals were called upon to describe the need for national standards for technological literacy. The NCTE brought a wealth of knowledge from extensive and diverse backgrounds that clearly shaped the resulting *Rationale and Structure* document. Additionally, over 500 individuals from inside and outside the field of technology were called upon to review, discuss, and ultimately come to consensus for this rationale document (ITEA, 1996).

Historical Perspective

To better understand the full scope of the *Standards for Technological Literacy: Content for the Study of Technology* (ITEA/ITEEA, 2000, 2002, 2007) and its development one must review the original project's history. The STL document was the first time there was a national effort to address the concept of educating all students to become technologically literate citizens. The writing process involved many views from individuals both inside and outside of technology education. As a result, the final version of *Standards for Technological Literacy* contained a holistic and comprehensive set of standards for all students from kindergarten to grade 12.

When one reviews the history of the national science standards documents created just prior to the STL, it is clear the STL document was influenced by these science standards efforts. Similar to the recent *Next Generation Science Standards* (NGSS Lead States, 2013) and the National Research Council's *A Framework for K-12 Science Education: Practices, Crosscutting Concepts and Core Ideas* (2012), the earlier science standards sought to clarify and identify the close connections and possible intersections between technology, engineering, and science. For example, *Science for All Americans* (American Association for the Advancement of Science, 1989) contained a chapter on the Nature of Technology (Chapter 3). Additionally, *The National Science Education Standards* (National Research Council, 1996) addressed the connections between the natural world (science) and the designed world (technology) within the content standards. *The National Science Education Standards* emphasized that the technology standards identified in the document were not *technology education* standards but rather standards that emphasized the capabilities of design and technology's links to fundamental understandings about the enterprise of science. Reading *The National Science Education Standards* today illustrates the influence that document had upon both *Technology for All Americans* (ITEA, 1996) and *Standards for Technological Literacy* (ITEA/ITEEA, 2000, 2002, 2007). Instead of viewing these national education standards and the processes that crafted them as isolated efforts, we must recognize that each document influenced the next sets of standards. Furthermore, the effort to revise the *Standards for Technological Literacy* must seek clarity not only for technology educators but also for science educators, engineering educators, mathematics educators, and any other discipline seeking to integrate technology within their domain.

The National Science Teachers Association published a revised position statement on the *Next Generation Science Standards* in 2016 that reflected on the current state of the NGSS in ways that are germane to the STL revision work:

> Science education traditionally has focused on large volumes of content, primarily basic facts and vocabulary, while falling short on the deeper understanding of key scientific concepts and the application of these concepts to daily life. The *NGSS* calls for refocusing K–12 science to improve college preparation, STEM career readiness, and the ability of all members of society to make informed decisions. (NSTA, 2016, para. 3)

Loewus (2016) reported the NGSS were finding greater acceptance by states than the Common Core State Standards did. This was due to a slow and steady adoption process through which states took a deliberate approach to implementation and no assessments were linked to the implementation process, so the stakes were lower for states to adopt them. Haag and Megowan (2015) reported the "current science teaching practices often emphasize the memorization of facts, yet NGSS emphasizes the primacy of the active construction by students of conceptual knowledge by 'doing science' via science and engineering practices" (p. 424).

Current Status of STL

It has been 19 years since the first version of the *Standards for Technological Literacy* was published. Although the document was slightly updated in 2002 and 2007, a full revision has not been initiated until now. Loveland (2019) reported on survey results from Fall 2018 that showed at least 14.5% of states have stopped using the STL as the basis of their curriculum frameworks. Since 2000 there have been many technological advancements as well as new initiatives to integrate technology with other subjects, the most common of which are the efforts to improve K-12 STEM education. Moreover, our world has “flattened” due to technology (Friedman, 2005) and therefore provides many new opportunities as well as challenges to educate students to become technologically literate within a global society. Never before in history have the lines between technology and other content domains become so blurred. As educators, especially those in science, mathematics, and engineering, seek to integrate these subjects with technology, confusion abounds regarding the “T” and “E” in STEM. The current *Standards for Technological Literacy* (ITEA/ITEEA, 2000, 2002, 2007), while providing a detailed set of standards for technological literacy, require revision if they are to better define the core set of standards for technology educators and to bring clarity for those outside the field who seek to address the role of the “T” and “E” in STEM (Dugger & Moye, 2018; Reed, 2018). In the internal survey of the STL Revision Review team, 92.6% agreed that the revised standards should be about technological and engineering literacy within a broader STEM framework.

Although the T & E in STEM are often treated synonymously, it is necessary to more closely define the intent of including engineering within the context of the revised STL document. One way this relationship has been expressed is as “big ‘T’ and e,’” meant to acknowledge that the STLs do not attempt to encompass the full spectrum of engineering content. We believe that technological literacy, with its emphasis on technological products, design, and technology/society interactions, affords a broader base than would a more exclusive focus on engineering and its content subfields (e.g., mechanical, civil, electrical, and so on) (Krupczak et al., 2016; Grubbs, Strimel, & Huffman, 2018). Another way this relationship has been expressed is to refer to the disciplinary study of engineering as a noun (Engineering), and the use of engineering design and application of engineering habits of mind as a verb (engineering). This latter characterization is the one we have chosen to use in this report. In this formulation, Technology provides the base for the STL while engineering (as a verb) brings in the big ideas and selected engineering practices and habits of mind that provide critical linkages within STEM and the broader educational environment. The STL Revision survey indicated that 88.9% of the reviewers support the approach of using engineering as a verb. Table 3 provides a brief summary of how these approaches might be contrasted within the context of educational standards.

The Role of Design in the Revision of STL

At the heart of the current *Standards for Technological Literacy* there exist underlying conceptual understandings of design, technological design, and engineering design. Often used indiscriminately, conceptual and operational definitions of these terms must be clarified and recognized by those making determinations regarding any potential changes to the number and breadth of the standards. The following definitions may prove beneficial in considering potential changes to the STL format.

The Accreditation Board for Engineering and Technology's (ABET) defines engineering design as:

> The process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative), in which the basic sciences, mathematics, and the engineering sciences are applied to convert resources optimally to meet these stated needs. (Accreditation Board for Engineering and Technology [ABET], 2016-17)

The NGSS description of what students' demonstration of engineering design can do is:

> Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and

> potential impacts on people and the natural environment that may limit possible solutions. *(*NGSS Lead States, 2013)

ITEEA defines technological design as “an iterative decision-making process that produces plans by which resources are converted into products or systems that meet human needs and wants” (ITEA/ITEEA, 2000, 2002, 2007, p. 237). As is evident from these three definitions, design is viewed broadly as a decision-making or “reasoning” process (NAE & NRC, 2009, p. 39) that uses knowledge and practices from across disciplinary areas. Nevertheless, some distinct differences can be detected, and should be taken into account when addressing “design” within the revised standards.

In technology and engineering education and design education as delivered in other countries, design is defined and operationalized in more broad terms than just as engineering design. These might include industrial design, graphic design, mathematical design through modeling and simulations, science and engineering science design through material design experiments and testing prototypes, communication design, design and technology capability, and computer-aided design (CAD). Williams, Cowdroy and Wallis (2012) described how design in technology education should focus on development of an innovative society through covering the spectrum of design from the arts to the sciences. The core abilities needed in students are the ability to conceptualize outcomes of multiple and complex needs and to rationally analyze these outcomes. Based on these other types of design, it might be considered limiting to only use the terms engineering design in technology and engineering education.

Table 3. *Comparisons across Content Areas*

	Engineering as a Noun	Engineering as a Verb	Technology Education	Science	Mathematics
Focus	Preparation for engineering careers	Develop engineering habits of mind; modeling practices, reverse engineering	Hands-on, design-based learning linked to relationships between technology, society, and environment	Use of scientific understanding to make everyday decisions, describe, explain, and predict natural phenomena	Combines a deep understanding of mathematics with procedural fluency and mathematical practices and processes to solve problems of today and the future
What is done in PK-6 education?	Build basic awareness about the engineering profession. Explore and become aware of how people create, use, and control technology	Learning and using an engineering design process. Use design and engineering principles to discover how the human made world works	Hands-on, design-based activities, particularly to integrate and support foundational literacies	Know how the natural and human made world interface by engaging in scientific practice	Development of numerical and geometric reasoning, understanding, and skills; problem-solving; use of multiple representations; data analysis; and measurement
What is done in secondary education?	Data-based decision-making, numeracy, engineering design	Design and making based on criteria and constraints	Design and making based on criteria and constraints	Scientific facts, lab procedures, hypothesis testing	Conceptual knowledge development; connections across mathematical concepts and in real-world applications; development and application of mathematical skills; problem-solving
Selected courses and programs	Civil, Mechanical , Chemical, Aerospace, and Electrical Engineering	Project Lead the Way (PLTW); Engineering by Design (EbD); NAE Grand Challenges	Foundations of Technology, Information & Communication Technology, Technological Design, Technology and Society	Physics, Biology, Earth Science, Chemistry, etc.	Numeracy, Algebra and Functions, Geometry, Measurement, Probability, Statistics, Pre-Calculus, Calculus, Mathematical Modeling, etc.
Design	*Engineering design is the process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative), in which the basic sciences,*	*The stages of the design process require students to draw on many different ways of learning and thinking. They exercise imagination, communication skills, artistic or creative faculties, technical*	*An iterative decision-making process that produces plans by which resources are converted into products or systems that meet human needs and wants.* (ITEEA 2000, 2002, 2007)	*Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and*	*Design thinking requires redefining and reimagining solutions to everyday problems, utilizes creative problem-solving approaches, and allows one to put themselves in the place of another (i.e., to empathize). Supports collaboration to*

	mathematics, and the engineering sciences are applied to convert resources optimally to meet these stated needs. (ABET, 2016-2017)	*knowledge, and…patience with failure… The design process might be the most valuable lesson students take away from studying engineering.* (Iversen, 2015, para. 8)		*potential impacts on people and the natural environment that may limit possible solutions.* (NGSS Lead States, 2013.)	*generate ideas, approaches, and solutions. Requires testing hypotheses. Spans both interdisciplinary and transdisciplinary lines to improve the world. Includes incorporation of both mathematical content and practices.* (Bush & Cook, 2019; Cook & Bush, 2018; Wrigley & Straker, 2017)
Necessary Foundational Literacies	Numeracy, textual literacy, data analysis, 21st Century Skills (NEA)	Numeracy, textual literacy, data analysis, 21st Century Skills	Numeracy, textual literacy, data analysis, 21st Century Skills	Numeracy, textual literacy, data analysis, 21st Century Skills	Numeracy, visualization, textual literacy, data analysis, 21st Century Skills, problem solving
Linked Standards and Assessments	*Dimensions of Engineering Literacy, Learning Progressions for P-12 Engineering Education* (AEEE)	ITEA, 2000,2002,2007 NAEP TEL 2014	ITEA, 2000,2002,2007 ITEA, AETL 2003 ISTE 2014 NAEP TEL 2014, edTPA, Praxis II 5051	NGSS, 2013 NSES, 1996 AAAS Project 2061 (1989, 2007)	CCSSM, 2010 GAISE, 2005 NAEP, 2017 NCTM (1995, 1989, 2000, 2006, 2014, 2018) TIMSS

The Mission of the STL Revision Project

The mission of the STL Revision Project is to revisit the *Standards for Technological Literacy* (ITEA/ITEEA, 2000, 2002, 2007) in order to carefully analyze and identify the core disciplinary ideas of technological and engineering literacy within a STEM framework. The standards revision team must sift out the most essential ideas, core concepts, and necessary skills and practices bounded by the subject of technology and engineering. Additionally, the revision team must clearly define grade-level achievements for technological and engineering literacy from PK- 12.

Vision for the STL Revision Project

We believe there has never been a greater opportunity to bring clarity to the study of technology and engineering and its place in the education of all students. Due to the efforts to improve STEM education on a national scale and the opportunities for local, state, and federal funding to support STEM programs, now is the time for the field of technology and engineering education to clearly, concisely, and accurately define the core standards for technological and engineering literacy. Because the scope of technology reaches far beyond science, mathematics, and engineering, there is a need to provide boundaries by defining *core* disciplinary standards. Because the current STL sought to be an all-encompassing document for technological literacy for all Americans, the breadth of the current standards might have inadvertently added confusion as educators sought to address as many of the standards as possible. With a renewed focus on core standards for the study of technology and engineering within the context of a broader STEM literacy, the revised STL will give educational policy makers, curriculum developers, teachers, and assessment teams the tools needed to refine curricula, educational policies, and assessments for technology and engineering education.

Structure of the Revised STL

The structure created by the standards revision team must be created in such a way that it mirrors similar recent standards documents from science, mathematics, and other disciplines. The final revised STL should read like a complementary document to recent documents such as the *Next Generation Science Standards* (NGSS Lead States, 2013) and *Common Core State Standards* (NGA & Council of Chief State School Officers, 2010). A revised standards document must address the needs of the current educational movements, policies, and educational research discoveries.

Taking a page from the NGSS, we must locate similar ways to identify, define, and describe the core disciplinary ideas. Similar to the NGSS Dimension 3, we should stipulate that the core disciplinary ideas for technology in the context of STEM literacy aspire to meet all of the following criteria:

- “Have broad importance across multiple [technology] or engineering disciplines or be a **key organizing concept** of a single discipline:
- Provide a **key tool** for understanding or investigating more complex ideas and solving problems;
- Relate to the **interests and life experiences of students** or be connected to societal or personal concerns that require scientific or technological knowledge;
- Be **teachable** and **learnable** over multiple grades at increasing levels of depth and sophistication.” (NGSS Lead States, 2019, para. 5)

Chapter 4: Proposed Working Title and Structure for the Revised STL

Changes for the *Standards for Technological Literacy* include reducing the standards to a total eight core standards and followed by eight core applications. Support for changes to the standards was documented in the Fall 2018 survey to ITEEA member/stakeholders and the 2019 June survey to the STL Revision Review Team. Loveland (2019) reported that classroom teachers and university professors used the first 13 original STL standards at higher levels than the Designed World standards (Table 4). In the June 2019 survey to STL reviewers, 96% of reviewers supported eliminating the Designed World standards and replacing them with descriptive application areas. A set of premises has been suggested to focus our work upon, a new title for the standards has been suggested, and some name changes for the core standards and the application areas have been suggested.

Table 4. *Use of Standards by Classroom Teachers and University Professors*

	n	STL #1-13	STL #14-20
Classroom Teachers	644 - 659	3.37 / 5	2.88 / 5
University Professors	94-97	3.86 / 5	3.16 / 5

Guiding Principles for Revision of the STL

We believe the process of revising the STL should be guided by a set of principles, assumptions, and ideas, including the following:

- Technology and engineering education requires the integration of learning and application (ITEA/ITEEA, 2000/2002/2007).
- Students develop conceptual understandings and retain that information most effectively when they have *applied* those concepts (Moye, Dugger, & Starkweather, 2016).

- Learning occurs in technology and engineering when students apply, test theories, and solve real-world problems using newly learned concepts in various formats, settings, and over periods of time (Daugherty, 2009).
- Fewer concepts applied deeply is better than more concepts applied shallowly (Wiggins, McTighe, Kiernan, Frost & ASCD, 1998).
- To *know* technology and engineering, one must *do* technology and engineering (Moye, Dugger, & Starkweather, 2016).
- Technology and engineering is an integrated field, of little consequence when unapplied or when isolated from other fields of study (mathematics, science, engineering, art, etc.) (Reed, 2017).
- There exist core ideas and practices associated with technology and engineering education that all learners require for disciplinary literacy (Dugger, 2016).
- Individuals seeking content for the “T” and the “E” in STEM often use the STL as their source (Daugherty, 2009).
- Discussions about the inclusion of each standard should be based on the responses to the following questions (1) How essential is it (conversely, how esoteric)? (2) How deeply does it allow investigation of the essential knowledge and skills we hope all students will acquire? (M. Hoepfl, personal communication, May 2019).
- The revised STL must identify the “power” or prioritized standards for technology and engineering in the STEM context.
- The completed standards should describe, in clear terms, what it means to be a technologically literate citizen (T. Kelley, personal communication, May 2019).

- The revised STL must use consistent terminology throughout so that the reader is not confused by the use of differing terms (C. Holter, personal communication, May 2019).

Proposed Change to the Title of the Standards

Technological literacy, or the ability to use, manage, assess, and understand technology, has “remained the core of technology and engineering (T & E) education courses in many countries for a number of years” (Loveland & Love, 2017, p. 14). Unfortunately, many individuals inside and outside the field have trouble defining “technological literacy” adequately and are unable to effectively measure it (Krupczak, Pearson, & Ollis, 2006). The educators who use the STL are searching for *content* for the “T” and the “E” in the STEM acronym. They want to know which technology and engineering concepts should be focused upon within their respective STEM programs. Regardless of whether that STEM program is a secondary technology and engineering education program or an elementary STEM program, teachers need to know the content expectations for what they are teaching (Daugherty, 2009). If one conducts an Internet search for STEM standards the search term *technological literacy* may not be used, and the STL often do not appear as a result. In the Fall 2018 STL Revision survey, 73% of the respondents (*n*=1,443) agreed that the word engineering should be included in the title of the new standards (Loveland, 2019). We therefore suggest that the standards be retitled to reflect both the nature of the standards that we already have and the name of the professional association (ITEEA). The following working title has been suggested: *Technology and Engineering Standards for STEM Education (TESSE)*. This working title was approved by 69% of the STL Revision Review Team members in an internal survey taken in June 2019.

Proposed TESSE Standards

Based on the preparatory work conducted to date, the Leadership Team's thinking has coalesced on reducing the overall number of standards to focus on the "power" or core standards for technology and engineering education. The original 20-standard structure has been collapsed into eight core standards, with eight associated application areas.

The STL Revision Project writing teams will be asked to apply decision filters in their discussions about the standards and benchmarks. We do note that in many cases the original standards may only see minor changes. The filters provided in Chapter 2 of this document should factor into these discussions:

- The resulting standards and benchmarks should clearly show teachers, parents, and students what students should know and be able to do.
- Standards and benchmarks should reflect specificity, clarity, rigor, balance of knowledge and skills, and a balance of teaching approaches.
- Selection of standards and benchmarks should be grounded in evidence about essential knowledge and skills that are time-independent—that is, that will endure in the face of technological, cultural, and temporal changes.
- Standards and benchmarks should provide open-ended, "big idea" guidelines, and not be written to serve as prescriptive objectives (Loveland, 2019).

1. **Nature and Characteristics of Technology and Engineering**: Changed from "The Characteristics and Scope of Technology."

    Discussion: The word "nature" seems like a better fit and it mirrors the NGSS (NGSS Lead States, 2013). In this standard, we are examining the differences and similarities between science and technology. Many universities offer courses titled *The Nature of Science*. It seems that we could and should offer courses titled *The Nature of Technology*. During revision, there should be an effort to simplify and streamline the current benchmarks, and to include PreK benchmarks.

2. **Core Concepts of Technology and Engineering**: Changed from "The Core Concepts of Technology."

   Discussion: This standard offers an introduction to fundamental concepts in technology and engineering, including design, constraints, optimization, trade-offs, and related concepts. During revision, there should be an effort to simplify and streamline the current benchmarks, and to include PreK benchmarks.

3. **Integration of Knowledge, Technologies, and Practices**: Changed from "The Relationships Among Technologies and the Connections Between Technology and Other Fields."

   Discussion: Introduces the idea of STEM education and the role that technology and engineering play in an integrated or interdisciplinary STEM framework and other disciplines. During revision, there should be an effort to simplify and streamline the current benchmarks, and to include PreK benchmarks.

4. **Impacts of Technology**: Changed from "The Cultural, Social, Economic, and Political Effects of Technology." Also incorporates current Standard 5, "The Effects of Technology on the Environment."

   Discussion: Overall, few changes are recommended but aside from this simplification in the wording of the standard. Consider integrating the NAE Grand Challenges (NAE, 2019) or other more current societal issues. During revision, there should be an effort to simplify and streamline the current benchmarks, and to include PreK benchmarks.

5. **Influence of Society on Technological Development**: Changed from “The Role of Society in the Development and Use of Technology.”

   Discussion: This would be a great place to add some content supporting the 21st Century Learning Standards (Alismail & McGuire, 2015). These standards address practices and aptitudes such as collaboration, cooperation, communication, etc. Consider integrating the NAE grand challenges or other more current cultural issues related to STEM (NAE, 2019). During revision, there should be an effort to simplify and streamline the current benchmarks, and to include PreK benchmarks.

6. **Influence of Technology on Human Progress**: Changed from “The Influence of Technology on History” to be more accurate concerning the core content of the standard.

   Discussion: During revision, there should be an effort to simplify and streamline the current benchmarks, and to include PreK benchmarks.

7. **Design and Problem Solving in Technology and Engineering**: Changed from “Engineering Design.”

   Discussion: This was addressed in the original Standard #9, #10 and #11 and now becomes Standard #7. The new standards should integrate former Standard #9 *Engineering Design*, Standard #10: *The Role of Troubleshooting, Research and Development, Invention and Innovation, and Experimentation in Problem Solving*, and Standard #11 *Apply the Design Process*. Engineering design is not the only method of problem solving. The proposed title was selected to avoid using a laundry list of design methods and problem solving methods. The revised standard should clarify the difference between how a technologist and an engineer approach problems (Land, 2012), incorporate engineering habits of mind and computational thinking in the benchmarks (Lucas & Hanson, 2016), as well as "abilities" from NGSS (NGSS Lead States, 2013).There should be an effort to simplify and streamline the current benchmarks, and to include PreK benchmarks.

8. **Applying, Maintaining, and Assessing Technological Products and Systems**: Changed from "Use and Maintain Technological Products and Systems."

   Discussion: Most of the same content as in the current STL should apply, and it is considered core knowledge. Incorporate elements from former standards #12 and #13. Add PreK benchmarks.

Eight Application Areas for TESSE

As the leaders worked over the past six months, the issue of what to do with the current "Designed World" standards (Standards 14 through 20) kept being discussed. At an early point there was consideration of keeping the 20 original standards and possibly adding three new standards. In subsequent discussions and reflecting on the literature reviewed to write Chapter 2, it became apparent that we should streamline the standards to focus on a smaller number of core standards. A potential problem could occur from abruptly dropping the Designed World standards, however. Would we be sending out a message that existing technology and engineering programs or courses might no longer be aligned with the standards? On the other hand, attempting to achieve comprehensive "coverage" could promote further expansion of courses and approaches within the already overcrowded school curriculum. The solution we propose, therefore, is to provide a discussion of eight "application areas" that illustrate how the core standards could manifest across a variety of topics, while still emphasizing the core knowledge and skills. As noted in Chapter 1, opportunities to apply and reinforce key concepts and practices in different contexts will allow for deeper STEM learning (e.g., Tang & Williams, 2018; Zollman, 2012).

To engage students in scholarship encompassing the TESSE, the standards must include opportunities for student application (Daugherty, 2009). The standards were designed to provide educators, parents, and citizens with a succinct framework of core competencies exhibited and practiced by technologists in our society (ITEA/ITEEA, 2000, 2002, 2007). To engage fully with these core competencies, learners must be provided with opportunities to practice applying these standards in authentic contexts (ITEA/ITEEA, 2000, 2002, 2007). This application should involve working in collaborative teams to solve problems (Alismail & McGuire, 2015) and implementing the common practices of technologists and engineers in some or all of the following eight application areas of technology and engineering.

To transition from the current *Designed World* standards #14-20 (ITEA/ITEEA, 2000, 2002, 2007), revision team writers are encouraged to revise the context language at the beginning of the *Designed World* section to focus on the need to apply the newly proposed eight core standards in the context of the eight identified *Applications*. After this has been completed, the authors should focus on transitioning many of the former benchmarks in the original standards #14 – 20 to develop application statements. For example, in the former STL #16, Energy and Power Technologies, a grade 6-8 benchmark reads as follows: *Energy can be used to do work, using many processes*. This benchmark should be changed to an application of one or more of the eight new standards. Suggested language is: Students will apply Standard #7, *Design and Problem Solving in Technology and Engineering*, in the application area of energy and power by working as a member of a small engineering team to design, build, and test a simple battery-powered direct-current electric motor; and then describe how energy can be applied to do the work that humans require.

The proposed eight Application Areas are listed below. Examples that illustrate each of these can be found in Appendix B.

1. Applications in Automation, Computation, Artificial Intelligence, and Robotic Technologies
2. Applications in Manufacturing Technologies
3. Applications in Transportation and Logistics Technologies
4. Applications in Energy and Power Technologies
5. Applications in Information and Communication Technologies
6. Applications in Construction of the Built Environment
7. Applications in Medical and Health-Related Technologies
8. Applications in Agriculture and Biotechnologies

Summary

The STL Revision Leadership Team has worked on this project with a focus, individual flexibility of views, and determination to complete this important task. As can be seen in this review of literature, the issues we are wrestling with are similar to those being discussed in other disciplines. Through this document we have attempted to provide and support a rationale for the changes being proposed to the STL. Based on this rationale, we have proposed a modified structure for the revised STL and now seek input on these ideas from a broader audience. We ask for your input and support to help us complete the revitalization of the standards for technology and engineering education.

For our stakeholders, particularly teachers, who want the standards to provide them with prescriptive measurable objectives to plan lessons from, it is the intent of the STL Revision leaders to encourage and support the development of a comprehensive website where teachers can post lesson plans in the application areas that address grade level standards and benchmarks. In addition, we are encouraging ITEEA to apply for additional funding to develop a new TESSE Addendum book that focusses on how the benchmarks can be applied in technology and engineering classrooms.

References

National Academy of Engineering. (2019). Engineering Habits of Mind. Retrieved from https://www.linkengineering.org/Explore/what-is-engineering/5808.aspx

Partnership for 21st Century Learning. (2019). Framework and Resources. Retrieved from http://www.battelleforkids.org/networks/p21/frameworks-resources.

Todd, R. (1991). The natures and challenges of technological literacy. In Dyrenfurth, M. and Kozak, M. (Eds.), *Technological literacy, 40th yearbook of the Council for Technology Teacher Education* (pp. 10-27). Peoria, IL: Glencoe.

Accreditation Board for Engineering and Technology (ABET). (2016-2017). *Criteria for accrediting engineering programs, 2016-2017.* Retrieved from https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2016-2017/

Alismail, H., & McGuire, P. (2015). 21st Century standards and curriculum: Current research and practice. *Journal of Education and Practice*, *6*(6), 150-155.

American Association for the Advancement of Science. (1989). *Science for all Americans*. Oxford University Press.

American Association for the Advancement of Science and National Science Teachers Association. (2007). *Atlas of science literacy: Project 2061*. Washington, DC: Author. Retrieved from http://www.project2061.org/publications/sfaa/

Antink-Meyer, A., & Brown, R. (2019). Nature of engineering knowledge: An articulation for science learners with nature of science understandings. *Science & Education* (online). https://doi.org/10.1007/s11191-019-00038-0

Asunda, P. (2012). Standards for technological literacy and STEM education delivery through career and technical education programs. *Journal of Technology Education*, *23*(2), 44-60.

Barton, P. (2010). National education standards: To be or not to be? *Educational Leadership*, *67*(7), 22–29.

Benjamin, S., & Schwartz, W. (1994). When less is more: A devil's advocate position on standards. *English Journal 94*(7).

Bitter, G., & Thomas, L. (1997). National educational technology standards: Developing new learning environments for today's classrooms. *NASSP Bulletin*, *81*(592), 52.

Bush, S. B. & Cook, K. L. (2019). *Step into STEAM: Your standards-based action plan for deepening mathematics and science learning, Grades 5-8*. Thousand Oaks, CA: Corwin & Reston, VA: NCTM.

Carr, R., Bennett, L., & Strobel, J. (2012). Engineering in the K-12 STEM standards of the 50 U.S. states: An analysis of presence and extent. *Journal of Engineering Education, 101*(3), 539-564.

Cencelj, Z., Abersek, M., Bersek, B., & Flogie, A. (2019). Role and meaning of functional science, technological and engineering literacy in problem-based learning. *Journal of Baltic Science Education, 18*(1), 132-146. https://doi.org/10.33225/jbse/19.18.132

Common Core State Standards Initiative. (2019). *Standards for mathematical practice.* Retrieved from http://www.corestandards.org/Math/Practice/.

Cook, K. L. & Bush, S. B. (2018). Design thinking in integrated STEAM learning: Surveying the landscape and exploring exemplars in elementary grades. *School Science and Mathematics,118*(3-4), 93-103. doi:10.1111/ssm.12268

Daugherty, M. (2009). The T and E in STEM education. In *The Overlooked STEM Imperatives: Technology and Engineering, International Technology Education Association* (pp. 18 - 25). Reston, VA: ITEEA.

Dugger, W. (2016). The Legacy Project. *The Technology and Engineering Teacher, 76*(2), 36-39.

Dugger, W., & Moye, J. (2018). Standards for technological literacy: Past, present, and future. *The Technology and Engineering Teacher,* 77(7), 8-12.

Fleming, R. (1989). Literacy for a technological age. *Science Education, 73*(4), 391-404.

Foster, P. (2005). Technology in the standards of other school subjects. *The Technology Teacher, 65(*3), 17-21.

Fourez, G. (1997). Scientific and technological literacy as a social practice. *Social Studies of Science, 27*, 903-936.

France, B. (2015). Technological literacy: A realisable goal or a chimera? *ACE Papers*, Issue 5: Issues in Educational Professional Development, Paper 3. Auckland, New Zealand: University of Auckland. Retrieved from https://researchspace.auckland.ac.nz/handle/2292/25056

Friedman, T, (2005). *The world is flat: A brief history of the twenty-first century*. New York: Farrar, Straus and McKinsey.

Gagel, C.W. (1997). Literacy and technology: Reflections and insights for technological literacy. *Journal of Industrial Teacher Education, 34*(3), 6-34.

Grubbs, M., Strimel, G., & Huffman, T. (2018). Engineering education: A clear content base for standards. *Technology and Engineering Teacher, 77*(7), 32-38.

Haag, S., & Megowan, C. (2015). Next Generation Science Standards: A national mixed-methods study on teacher readiness. *School Science and Mathematics, 115*(8), 416-426.

Heywood, J. (2017). Why technological literacy and for whom? In Heywood et al. (2017). *Philosophical and educational perspectives on engineering and technological literacy, IV* (pp. 2-9). Iowa State University. Retrieved from https://lib.dr.iastate.edu/ece_books/4/

Ingerman, A., & Collier-Reed, B. (2011). Technological literacy reconsidered: A model for enactment. *International Journal of Technology and Design Education, 21*, 137-148. doi: 10.1007/s10798-009-9108-6

Institute of Education Sciences/National Center for Education Statistics. (2019). *Technology and engineering literacy.* Retrieved from https://nces.ed.gov/nationsreportcard/tel/

International Society for Technology in Education. (2014). *ISTE standards*. Retrieved from https://www.iste.org/standards

International Technology Education Association. (1996). *Technology for all Americans: A rationale and structure for the study of technology*. Reston, VA: Author.

International Technology Education Association (ITEA/ITEEA). (2000, 2002, 2007). *Standards for technological literacy: Content for the study of technology*. Reston, VA: Author.

International Technology Education Association. (2003). *Advancing excellence in technological literacy: Student assessment, professional development, and program standards.* Reston, VA: Author.

Iversen, E. (2015). *K-12 learning by engineering design.* Start Engineering. Retrieved from http://start-engineering.com/start-engineering-now/2015/11/3/k-12-learning-by-engineering-design

Kelley, T. (2015). *Annual NSF Report for Science Learning Through Engineering Design*. The National Science Foundation, Unpublished.

Koehler, C., Faraclas, E., Giblin, D., Moss, D. M., & Kazerounian, K. (2013). The Nexus between science literacy & technical literacy: A state-by-state analysis of engineering content in state science standards. *Journal of STEM Education, 14*(3), 5–12.

Krupczak, J., Pearson, G., & Ollis, D. (2006, June). *Assessing technological literacy in the United States.* Paper presented at 2006 Annual Conference & Exposition, Chicago, Illinois. Retrieved from https://peer.asee.org/396

Krupczak, J., Blake, J., Disney, K.A., Hilgarth, C., Libros, R., Mina, M., & Walk, S. (2016). Defining engineering and technological literacy. In Blake et al. *Philosophical and educational perspectives on engineering and technological literacy, III* (pp. 8-14). Iowa State University. Retrieved from https://lib.dr.iastate.edu/ece_books/3/

Land, R. (2012). Engineering technologists are engineers. *Journal of Engineering Technology*. *1*(5), 32-39.

Lederman, N., Lederman, J., & Antink, A., 2013). Nature of science and scientific inquiry as contexts for the learning of science and achievement of scientific literacy. *International Journal of Education in Mathematics, Science and Technology*, *1*(3), 138–147.

Loewus, L. (February 23, 2016). *Eight things to know about the next generation science standards* [Education Week blog post]. Retrieved from http://blogs.edweek.org/edweek/curriculum/2016/02/next_generation_science_standards_8_things_to_know.html

Loveland, T. (2019). Standards for technological literacy revision survey: Preliminary results. *Technology and Engineering Teacher (electronic version), 78*(8).

Loveland, T., & Love, T. (2017). Technological literacy: The proper focus to educate all students. *The Technology and Engineering Teacher*, *76*(4), 13-17.

Lucas, B. & Hanson, J. (2016). Thinking like an engineer: Using engineering habits of mind and signature pedagogies to redesign engineering education. *International Journal of Engineering Pedagogy*, *6*(2), 4-14.

Marshall, B. (2011). English in the national curriculum: A simple redraft or a major rewrite? *The Curriculum Journal, 22*(2), 187-199.

Massel, D. (1994). Three challenges for national content standards. *Education & Urban Society*, *26*(2), 185.

McGuinn, P. (2015). Complicated politics to the core. *Phi Delta Kappan*, *97*(1), 14–19.

Mitchell, T. (2017). Examining the relationship between technology & engineering instruction and technology & engineering literacy in K-8 education (Doctoral dissertation, Duquesne University). Retrieved from https://dsc.duq.edu/etd/179

Moye, J., Dugger, W., & Starkweather, K. (2016). Learning by doing study: Third-year results. *The Technology and Engineering Teacher, 76*(1), 18-25.

National Academy of Engineering [NAE]. (2010). *Standards for K-12 engineering education?* Washington, DC: The National Academies Press.

National Academy of Engineering. (2019). *NAE grand challenges for engineering.* Retrieved from http://www.engineeringchallenges.org/

National Academy of Engineering and National Research Council. (2002). *Engineering in K-12 education: Understanding the status and improving the prospects.* Washington, DC: The National Academies Press.

National Academy of Engineering and National Research Council. (2009). *Technically speaking: Why all Americans need to know about technology.* Washington, DC: The National Academies Press.

National Academy of Sciences. (1996). *National science education standards.* Washington, DC: The National Academies Press.

National Academies of Sciences, Engineering, and Medicine. (2016). *Science literacy: Concepts, contexts, and consequences.* Washington, DC: The National Academies Press. doi:10.17226/23595

National Academies of Sciences, Engineering, and Medicine. (2017). *Communicating science effectively: A research agenda*. Washington, DC: The National Academies Press. doi: 10.17226/23674

National Academies of Sciences, Engineering, and Medicine. (2019). *Science and engineering for grades 6-12: Investigation and design at the center*. Washington, DC: The National Academies Press. doi: https://doi.org/10.17226/25216.

National Center for Education Statistics. (2014). *National assessment of educational progress: Technology and engineering literacy (NAEP-TEL)*. Washington, DC: U.S. Department of Education.

National Education Association. (2019). *An educator's guide to the "four Cs": Preparing 21st century students for a global society.* Retrieved from http://www.nea.org/tools/52217.htm

National Governors Association. (2007). *Innovation America: Building a science, technology, engineering, and math agenda.* Washington, DC: Author.

National Governors Association Center for Best Practices and Council of Chief State School Officers. (2010). *Common core state standards*. Washington D.C.: Authors.

National Research Council. (1996). *National science education standards*. Washington, DC: The National Academies Press. https://doi.org/10.17226/4962

National Research Council. (2002). *Investigating the influence of standards: A framework for research in mathematics, science, and technology education*. Washington, DC: National Academies Press.

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas.* Washington, DC: The National Academies Press.

National Science Teacher Association (2016). NSTA position statement: The next generation science standards. Retrieved from https://www.nsta.org/about/positions/ngss.aspx

NGSS Lead States. (2013). *Next generation science standards: For states, by states.*

Washington, DC: The National Academies Press. Retrieved from https://www.nextgenscience.org/

NGSS Lead States. (2019). *Three dimensional learning.* Retrieved from https://www.nextgenscience.org/three-dimensions

O'Neil, J. (1995). On using the standards: A conversation with Ramsay Selden. *Educational Leadership*, *52*(6), 12.

Popham, W. (2006). Content standards: The unindicted co-conspirator. *Educational Leadership*, *64*(1), 87–88.

Reed P. (2017) Technology Education Standards in the United States: History and Rationale. In: M. de Vries (Ed.) *Handbook of Technology Education*. Springer International Handbooks of Education.

Reed, P. (2018). Reflections on STEM, standards, and disciplinary focus. *The Technology and Engineering Teacher,* 77(7), 16-20.

Reeves, D. (2000). Standards are not enough: Essential transformations for school success. *NASSP Bulletin*, *84*(620), 5.

Reimers, J., Farmer, C., & Klein-Gardner, S. (2015). An introduction to the standards for preparation and professional development for teachers of engineering. *Journal of Pre-College Engineering Education Research*, *5*(1), 40-60.

Suhor, C. (1994). National standards in English: What are they? Where does NCTE stand? *English Journal*, *83*(7), 25.

Tang, K., & Williams, P. (2018, in press). STEM literacy or literacies? Examining the empirical basis of these constructs. *Review of Education*. Retrieved from https://onlinelibrary.wiley.com/doi/10.1002/rev3.3162

Ujifusa, A. (2014). As states drop common core, replacement hurdles loom. *Education Week*, *33*(36), 27.

Watts, E., Levit, G., & Hossfeld, U. (2016). Science standards: The foundation of evolution education in the United States. *Perspectives in Science*, *10*, 59–65.

White, A., & Rizzo, J. (2008). World-class standards: Setting the new cornerstone for American education. *James B. Hunt Jr. Institute for Educational Leadership and Policy*, *2*, 1-8.

Wiggins, G. (2011). A diploma worth having. *Educational Leadership*, *68*(6), 28–33.

Wiggins, G., McTighe, J., Kiernan, L., Frost, F., & Association for Supervision and Curriculum Development. (1998). *Understanding by design*. Alexandria, VA: Association for Supervision and Curriculum Development.

Williams, P. (2009). Technological literacy: a multiliteracies approach for democracy. *International Journal of Technology and Design Education, 19*, 237-254. doi: 10.1007/s10798-007-9046-0.

Williams, A., Cowdroy, R., & Wallis, L. (2012). 5. Design. In J. Williams (Ed.), *International technology education series: Technology education for teachers* (pp. 93–114). Rotterdam, The Netherlands: Sense Publishers.

Wrigley, C. & Straker, K. (2017). Design thinking pedagogy: The educational design ladder. *Innovations in Education and Teaching International*, *54*(4), 374-385

Zollman, A. (2012). Learning for STEM literacy: STEM literacy for learning first. *School Science and Mathematics*, *112*(1), 12-19.

Appendix A: Engineering Content in State Standards

In Carr, Bennett, and Stroebel's *Analysis of Engineering Content in State Standards* (2012) the authors conducted a cross-state standards analysis to discover "what big ideas about engineering are currently being taught in K–12 education." They undertook a broad content analysis and based on this compiled a list that they said provides "inclusive consensus on the 'big ideas,' or what 'doing engineering' consists of":

- Identifying criteria, constraints, and problems
- Evaluating, redesigning and modifying products and models
- Evaluating effectiveness of solutions
- Devising a product or process to solve a problem
- Describing the reasoning of designs and solutions
- Making models, prototypes, and sketches
- Designing products and systems
- Selecting appropriate materials, best solutions, or effective approaches
- Explaining the solution and design factors
- Developing plans, layouts, designs, solutions, and processes
- Creating solutions, prototypes, and graphics
- Communicating the problem, design, or solution
- Proposing solutions and designs
- Defining problems
- Brainstorming solutions, designs, design questions, and plans
- Constructing designs, prototypes, and models
- Applying criteria, constraints, and mathematical models
- Improving solutions or models
- Producing flow charts, system plans, solution designs, blue prints, and production procedures

(Carr et al., 2012, p. 556)

Appendix B: Examples of Core Standards Applied to the Eight Application Areas

#1 Applications in Automation, Computation, Artificial Intelligence, and Robotic Technologies

- Include: Data and information, abstraction, creativity, algorithms, programming, Internet, and global impacts, engineering mathematics, engineering science.
- Develop narrative and applications that support teaching the eight TESSE standards in the context of automation, computation and robotic technologies.
- The applications should illustrate how the eight TESSE standards could be applied in the context of automation, computation and robotic technologies.
- Develop applications for each grade level band—including PreK applications. For example, how can Standard #1 "The Characteristics and Nature of Technology", be applied to teach Science versus Technology to grades PreK-2? How can Standard #8 "Using, Maintaining, and Assessing Technological Products and Systems", be applied to teach robotics to grade 3-5 students? How can Standard #5 "Influence of Society on Technological Development" be applied to teach automation to grade 6-8 students?

#2 Applications in Manufacturing Technologies

- Develop narrative and applications that support teaching the eight TESSE standards in the context of manufacturing technologies.
- Remove (or reconfigure) the benchmarks and replace with grade-level applications—applications of the eight TESSE standards in the context of manufacturing technologies.
- The applications should illustrate how the eight TESSE standards could be applied in the context of manufacturing technologies.
- Develop applications for each grade level band—including PreK applications. For example, how can Standard #7 "Design and Problem Solving in Technology and Engineering" be applied to teach about developing products to be sold to grades PreK-2? How can Standard #7 "Design and Problem Solving in Technology and Engineering", be applied to teach grade 3-5 students about the role of interchangeable parts in manufacturing? How can Standard #5, "Influence of Society on Technological Development", be applied to teach grade 6-8 students about the relationship between the population growth of cities and the rise of the Industrial Revolution?

#3 Applications in Transportation and Logistics Technologies: Expanded to include a field corollary to transportation

- Develop narrative and applications that support teaching the eight TESSE standards in the context of transportation and logistics technologies.

- Remove (or reconfigure) the benchmarks and replace with grade-level applications—applications of the eight TESSE standards in the context of transportation and logistics technologies.
- The applications should illustrate how the eight TESSE standards could be applied in the context of transportation and logistics technologies.
- Develop applications for each grade level band—including PreK applications. For example, how can Standard #2 “Core Concepts of Technology and Engineering” be applied to teach about forms of transportation to grades PreK-2? How can Standard #7 “Design and Problem Solving in Technology and Engineering”, be applied to teach intermodal transportation systems design to grade 3-5 students? How can Standard #5, “Influence of Society on Technological Development”, be applied to teach grade 6-8 students about the impact of the interstate highway system in the United States?

#4 Applications in Energy and Power Technologies

- Develop narrative and applications that support teaching the eight TESSE standards in the context of energy and power technologies.
- Remove (or reconfigure) the benchmarks and replace with grade-level applications—applications of the eight TESSE standards in the context of energy and power technologies.
- The applications should illustrate how the eight TESSE standards could be applied in the context of energy and power technologies.

- Develop applications for each grade level band—including PreK applications. For example, how can Standard #7 "Design and Problem Solving in Technology and Engineering", be applied to teach about how to design solar cooking devices to grades PreK-2? How can Standard #7 "Design and Problem Solving in Technology and Engineering", be applied to teach simple electrical circuitry to grade 3-5 students? How can Standard #5, "Influence of Society on Technological Development", be applied to teach grade 6-8 students about renewable energy?

#5 Applications in Information and Communication Technologies

- Develop narrative and applications that support teaching the eight TESSE standards in the context of information and communication technologies.
- Remove (or reconfigure) the benchmarks and replace with grade-level applications—applications of the eight TESSE standards in the context of information and communication technologies.
- The applications should illustrate how the eight TESSE standards could be applied in the context of information and communication technologies.
- Develop applications for each grade level band—including PreK applications. For example, how can Standard #7 "Design and Problem Solving in Technology and Engineering", be applied to teach about how to design protective hearing devices to grades PreK-2? How can Standard #7 "Design and Problem Solving in Technology and Engineering", be applied to teach basic CAD to grade 3-5 students? How can Standard #5, "Influence of Society on Technological Development", be applied to teach grade 6-8 students about photo editing?

#6 Applications in Construction of the Built Environment

- Develop narrative and applications that support teaching the eight TESSE standards in the context of the built environment.
- Remove (or reconfigure) the benchmarks and replace with grade-level applications—applications of the eight TESSE standards in the context of the built environment.
- The applications should illustrate how the eight TESSE standards could be applied in the context of the built environment.
- Develop applications for each grade-level band—including PreK applications. For example, how can Standard #7 “Design and Problem Solving in Technology and Engineering”,” be applied to teach about best materials to use when building houses in grades PreK-2? How can Standard #7 “Design and Problem Solving in Technology and Engineering”, be applied to teach grade 3-5 students basic stick-framing techniques used in single family home construction? How can Standard #5, “Influence of Society on Technological Development”, be applied to teach grade 6-8 students about the relationship between urban sprawl, single-family home construction and the rise of the middle class in the United States?

#7 Applications in Medical and Health Related Technologies:

- Develop narrative and applications that support teaching the eight TESSE standards in the context of medical and health-related technologies.

- Remove (or reconfigure) the benchmarks and replace with grade-level applications—applications of the eight TESSE standards in the context of medical and health related technologies.
- The applications should illustrate how the eight TESSE standards could be applied in the context of medical and health-related technologies.
- Develop applications for each grade level band—including PreK applications. For example, how can Standard #2 “Core Concepts of Technology and Engineering Design” be applied to teach about how everyday products we use keep us healthier to grades PreK-2? How can Standard #7 “Design and Problem Solving in Technology and Engineering”, be applied to teach medical devices to grade 3-5 students? How can Standard #5, “Influence of Society on Technological Development”, be applied to teach grade 6-8 students about medical vaccinations and the development of medicines?

#8 Applications in Agriculture and Biotechnologies

- Develop narrative and applications that support teaching the eight TESSE standards in the context of agriculture and related biotechnologies.
- Remove (or reconfigure) the benchmarks and replace with grade-level applications—applications of the eight TESSE standards in the context of agriculture and related biotechnologies.
- The applications should illustrate how the eight TESSE standards could be applied in the context of agriculture and related biotechnologies.

- Develop applications for each grade level band—including PreK applications. For example, how can Standard #2 “Core Concepts of Technology and Engineering Design” be applied to teach about how tools can be used in growing and providing food to grades PreK-2? How can Standard #7 “Design and Problem Solving in Technology and Engineering”, be applied to teach agricultural mechanization to grade 3-5 students? How can Standard #5, “Influence of Society on Technological Development”, be applied to teach grade 6-8 students about the organic food industry?

Appendix C: Summary Report of Review Team Members' Survey
June 2019

In June 2019, members of the Standards Revision Project Review Team were sent a copy of the *ITEEA Standards for Technological Literacy Project: Background, Rationale, and Structure* report, along with a link to an online survey to gather their input. The goal was three-fold: (1) to provide background information supporting the need for the Standards revision; (2) to affirm the underlying mission, vision, and philosophy of the revision project; and (3) to get input on the proposed structure of the revised standards. Twenty-seven of 30 Review Team members responded to the survey, for a 90% response rate. Key findings from the survey are reported here.

Philosophy and Rationale

Regarding the focus of the revised Standards, 93% of respondents indicated that the revised Standards should address technological and engineering literacy within a broader STEM framework (Figure 1). Although respondents acknowledged that STEM literacy is "important and more reflective of our current landscape" and that "technological and engineering literacy are intertwined," questions were raised about two key aspects of this approach. First was a fundamental concern about the role of technology and technological literacy within this broader STEM arena. A number of respondents noted the rich history of Technology as a discipline, and one that has a far more robust set of knowledge and abilities than is sometimes reflected in the literature (e.g., technology simply viewed as "products" or "objects"). Second was the limiting nature of STEM, which on its face doesn't account for the role of history, language, philosophy, culture, and the arts in technological development. To address the first concern, a greater emphasis on Technology as the core discipline in the Standards was suggested. To address the second concern, one respondent suggested focusing on the dimensions of technology outlined in *Technically Speaking* (National Academy of Engineering/National Research Council, 2002)—knowledge, capabilities, and critical thinking/decision making—which would signal an open door to a broader interdisciplinarity.

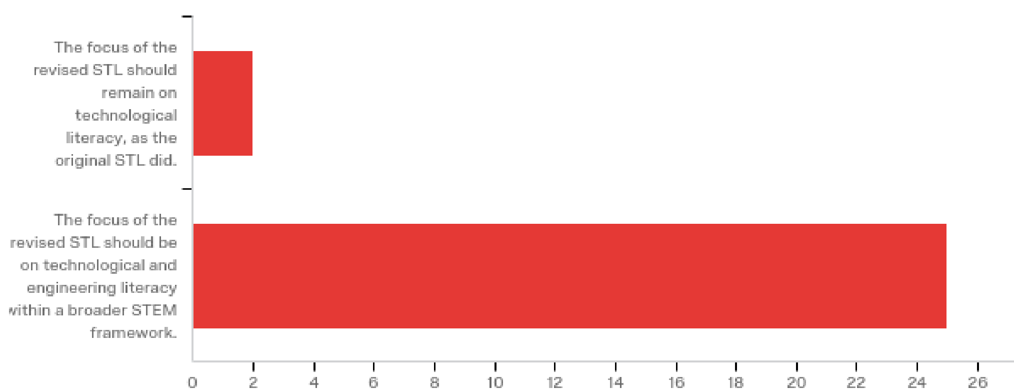

Figure 1. Preferred focus of the revised Standards among Review Team members (*n* = 27).

The writers of the original *Background and Rationale* report spent a good deal of time discussing how the marriage of technology and engineering in the revised Standards should best be handled. The team settled on a rationale in which engineering would be approached as a "verb;" that is, with an emphasis on engineering design and on engineering habits of minds as approaches used in development of technology, rather than a more explicit focus on the formal subfields of engineering (mechanical, civil, electrical, and so on). Respondents were asked whether they supported this approach; their responses are shown in Figure 2.

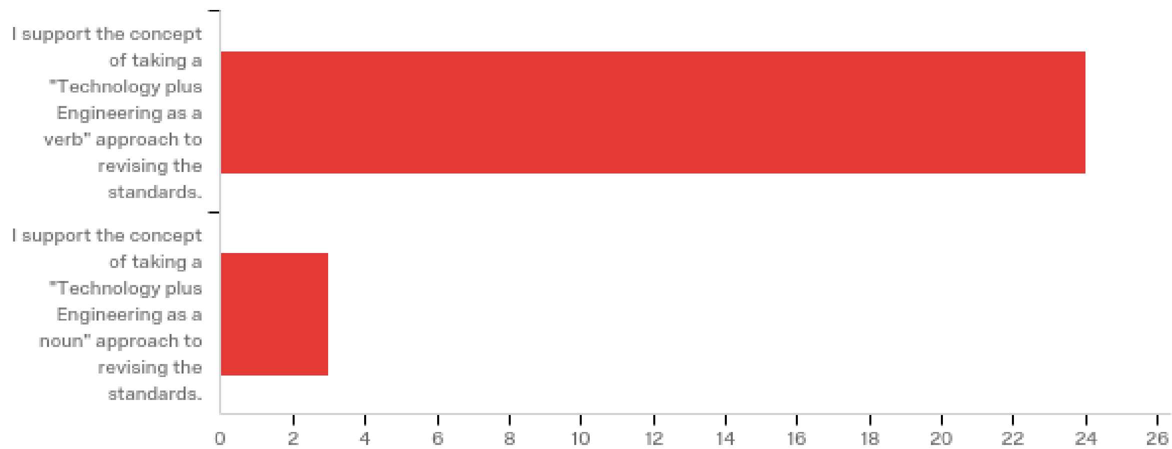

Figure 2. Support for an "engineering as a verb" approach to including engineering in the Standards (*n* = 27).

All but one respondent expressed that they either strongly support (74%) or somewhat support (22%) the mission and vision statement as presented in the *Background and Rationale* report. However, respondents raised questions about how deeply the other subject areas within the core STEM disciplines should be addressed in the revised Standards, and in particular the extent to which engineering and "engineering design" should be featured.

A set of "guiding principles" for the revision of the Standards was provided in Chapter Four of the *Background and Rationale* report. This set of 13 statements was intended to provide direction to members of the Standards revision team. Among survey respondents, 70% indicated strong support for the guiding principles and 30% said they somewhat support these principles (Figure 3).

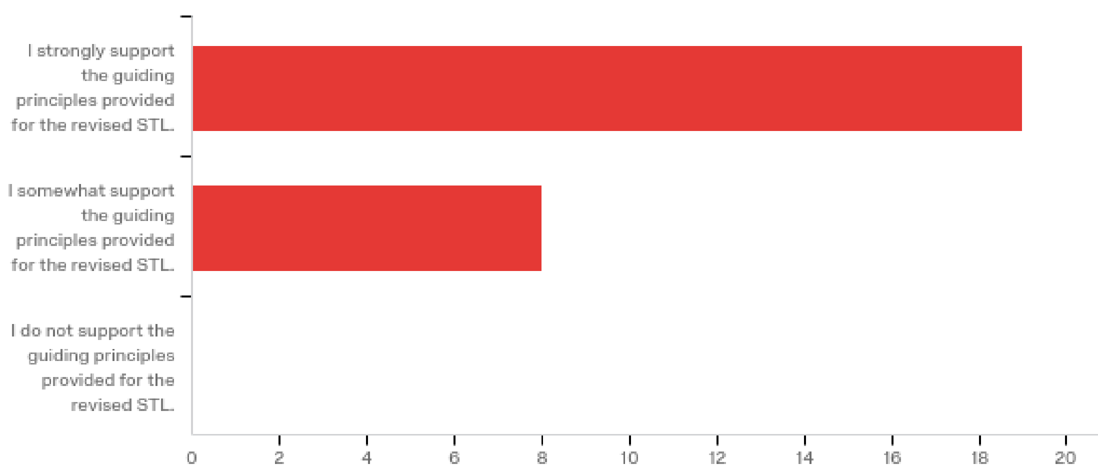

Figure 3. Level of agreement with the guiding principles for the Standards revision project (*n* = 27).

Title and Structure of the Revised Standards

Feedback on the proposed working title of the revised Standards was mixed, with 18 of 26 (69%) supporting the title "Technology and Engineering Standards for STEM Education," and 8 of 26 (31%) opposing it. Suggestions for alternative titles included:

- Standards for the Study of Technology
- Standards for Technology, Engineering, and Design
- Framework for Technology and Engineering Literacy
- Standards for Technological and Engineering Literacy
- Standards for Technological and Engineering Mastery

These findings mirror those from the 2018 survey of ITEEA members and partners, which found that 73% respondents favor inclusion of the word "engineering" in the title of the revised Standards.

With respect to the structure of the Standards, 100% of respondents to the June survey indicated their support for reducing the number of standards, and 96% supported replacing the former Designed World standards (14-20) with "Application Areas." On this latter point, however, responses were evenly split between those who strongly supported the proposed application areas (48%) and those who supported with changes in their structure and wording (48%). Respondents had a number of suggestions for ways that both the standards and the application areas could be combined and/or reworded. The leadership team incorporated a number of these suggestions in the revised *Background and Rationale* report, and stressed that the labels are "working titles" that will be refined as part of the writing process at the Standards revision conference in August 2019. Table 1 summarizes the level of support expressed for the 11 proposed standards.

Table 1. *Review Team Support for Proposed Wording of Draft Revised Standards, June 2019*

Proposed Revised Standard	**Support as Worded**	***n***	**Support with Modifications**	***n***	**Do Not Support**	***n***	**Total**
1. Characteristics and Nature of Technology	70.37%	19	29.63%	8	0.00%	0	27
2. Core Concepts of Technology and Engineering Design	77.78%	21	22.22%	6	0.00%	0	27
3. Integration of Knowledge, Technologies, and Practices	66.67%	18	33.33%	9	0.00%	0	27
4. Cultural, Social, Economic, and Political Effects of Technology	62.96%	17	37.04%	10	0.00%	0	27
5. Environmental Effects of Technology	55.56%	15	44.44%	12	0.00%	0	27
6. Influence of Society on Development	33.33%	9	66.67%	18	0.00%	0	27
7. Influence of Technology on History and Development	38.46%	10	61.54%	16	0.00%	0	26
8. Engineering Design and Other Methods of Solving Problems in Technology and Engineering	37.04%	10	51.85%	14	11.11%	3	27
9. Elements of Engineering Design	70.37%	19	25.93%	7	3.70%	1	27
10. Using Technology and Engineering Design	55.56%	15	44.44%	12	0.00%	0	27
11. Technology and Engineering Tools and Techniques	61.54%	16	38.46%	10	0.00%	0	26

References

National Academy of Engineering/National Research Council. (2002). *Technical speaking: Why all Americans need to know more about technology.* Washington, DC: National Academies P