standards for technological and engineering literacy and STEM education

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STEL provides STEM educators with not only a comprehensive guide for delivering big ideas and core disciplinary content, but also identifies contexts within which these big ideas might be applied, suggests disciplinary alignment and integration strategies, provides a crosswalk matrix that helps align lessons to other sets of standards from complementary disciplines, and makes suggestions for connecting standards, engineering practices, and core content to the 21st Century Learning Skills.

Introduction

Both those inside and outside of the education community are becoming increasingly familiar with the STEM acronym and the extensive efforts underway nationally to develop integrated PK-12 STEM programs that promote critical thinking, problem solving, 21st Century skill development and authentic learning experiences (Ingram, 2019). However, for those teachers on the front lines, the standards used to guide the curriculum and learning experiences in these new STEM programs have not been nearly as obvious. Some STEM educators utilize *Next Generation Science Standards* (*NGSS*), emphasizing science and engineering in practice, with a focus on the core disciplines and their intersections. An equally large group of educators have based curriculum and instruction in STEM on *Standards for Technological Literacy* (*STL*), which has emphasized the relationship between technology (broadly defined) and engineering design and problem solving. Other educators use the *ISTE Standards* developed by the International Society for Technology in Education (ISTE) that accentuate the constantly evolving educational technology landscape. Still other educators utilize state and local standards that sometimes include variations of *NGSS*, *STL*, and *ISTE* standards. The purpose of this manuscript is to reveal the newly revised *Standards for Technological and Engineering Literacy* (2020) and discuss the powerful role it will play in PK-12 STEM education curriculum.

The standards within *Standards for Technological and Engineering Literacy* (2020) were adapted from *Standards for Technological Literacy* (2000), with new emphasis on engineering practices and connections to *NGSS* and Common Core State Standards for Mathematics. The *STEL* standards articulate the role that technology and engineering play within STEM as well as the interdisciplinary connections between technology and engineering and other subjects that do not stop with science and mathematics (ITEEA, 2020). The standards outline the relationship between technology, engineering, mathematics, and science as well as English language arts, social studies, and the arts—highlighting the interdisciplinary nature of STEM. Essentially, the new standards provide a contemporary vision of what students should know and be able to do in order to be technologically and engineering literate. While not claiming to be the all-inclusive set of STEM standards, the standards do include the tagline: *The Role of Technology and Engineering in STEM Education*, implying that they provide a vision of what students need to know and be able to do with regard to the "T" and the "E" in STEM education at various grade-level bands. "Too often, however, what passes for 'STEM education' involves an unbalanced focus on science and mathematics, with marginal attention to technology and engineering" (ITEEA, p. 5). These standards were developed in an attempt to overcome this instructional and curricular shortcoming.

In application, *Standards for Technological and Engineering Literacy* (2020) provides teachers with an extensive list of broad conceptual understandings and abilities related to technology and engineering. This knowledge and these skills encompass necessary content needed to adequately prepare students of all ages for active participation in a technological world. But, perhaps more importantly, the *STEL* Standards assist the teacher in forming the interdisciplinary connections between technology, engineering, mathematics, science, and a host of other disciplines like social studies, language arts, and the arts (ITEEA, 2020). Through the implementation of the tools provided in these Standards, teachers may be better able to offer students opportunities to apply content knowledge, skills and dispositions that cut across multiple discipline areas and lines of inquiry.

The "T" and the "E" in STEM

A common mistake in STEM curriculum development and instructional design/delivery is the tendency to treat the "T" and the "E" in STEM synonymously, as if the central two letters of the acronym were interchangeable (ITEEA, 2020). Subsequently, *STEL* provides guidance on the respective roles of both technological literacy and engineering literacy in the education of students within a STEM program or class. Technology is defined as "the processes undertaken to modify the natural environment through human-designed products, systems, and processes to satisfy human needs and wants." Meanwhile, engineering is described as "the scientific principles and mathematical reasoning humans use to develop and optimize human needs and wants" (ITEEA, 2020). It should be noted that the term "engineering" is treated as a verb in *STEL* and not a noun. In other words, *STEL* refers to the act of engineering rather than the career of engineering.

STEL was created with the following basic features:

- It offers a common set of expectations for what students in technology and engineering or STEM laboratory-classrooms should learn through the dimensions of knowing, thinking, and doing.
- It is developmentally appropriate for students.
- It provides a basis for the creation of meaningful, relevant, and articulated curricula at the national, state/provincial, and local levels.
- It promotes interdisciplinary connections with other school subjects in Grades PreK-12 (p. 9).

Subsequently, *STEL* is not a curriculum, but it does provide curricular and content guidance to educators. *STEL* can serve as a guide for developing appropriate curricular approaches for a given educational setting. Similarly, *STEL* does not prescribe a given assessment tool for determining whether students have achieved technological or engineering literacy but does provide the criteria and outcomes that should be used to develop formative and summative assessments (ITEEA, 2020).

The Structure of *STEL*

STEL utilizes three organizers that work together as a framework for teaching technology and engineering within a STEM program or class. These include the core disciplinary standards, technology and engineering practices, and technology and engineering contexts (ITEEA, 2020). The core disciplinary standards represent the information, ideas, and processes all students should know and be able to do regardless of eventual academic pursuit or career destination.

The eight *STEL* core disciplinary standards guide students to the big ideas and central understandings of the fields of technology and engineering and the "T" and the "E" in STEM education. The core standards also identify the relationships between technology, engineering, and other fields of study as well as technology and engineering in broader contexts (e.g., technological effects on human society and the built and natural environments, impacts, design and problem solving, societal factors, and the history of technology and engineering) (p. 12). The eight core disciplinary standards and their associated grade-level benchmarks encompass three types: what students should know and understand about technology and engineering, what they should be able to do, and their attitudes towards technology and engineering (ITEEA, 2020). The eight core disciplinary standards include:

1. Nature and Characteristics of Technology and Engineering
2. Core Concepts of Technology and Engineering
3. Integration of Knowledge, Technologies, and Practices
4. Impacts of Technology
5. Influence of Society on Technological Development
6. History of Technology
7. Design in Technology and Engineering Education
8. Applying, Maintaining, and Assessing Technological Products and Systems (p, 12).

The second organizer within the *STEL* standards are technology and engineering practices. These practices were adapted from the 21st Century Skills (Partnership for 21st Century Learning, 2019) and from research on engineering habits of mind (e.g., National Academy of Engineering, 2019b). The resulting practices are a student-centered set of practices that reflect the knowledge, skills, and dispositions students need in order to successfully apply the previously mentioned eight core disciplinary standards in the different context areas. The eight practices include:

1. Systems Thinking
2. Creativity
3. Making and Doing
4. Critical Thinking
5. Optimism
6. Collaboration
7. Communication
8. Attention to Ethics (p. 14)

Although not content standards, these technology and engineering practices provide educators with opportunities to incorporate authentic and real-world expectations into lessons, activities, and other learning experiences to mimic work and civic life outside the classroom. For example, students working in teams assigned to complete a design activity based on one of the eight core standards might be expected to illustrate their ability to be creative, or their ability to work effectively in a collaborative team, or to communicate the results of their efforts and defend their work. The eight technology and engineering practices provide the teacher with ample opportunities to complete formative assessments of student growth with respect to the knowledge, skills, and dispositions needed beyond the classroom environment.

The final organizer within *STEL* are technology and engineering contexts. These contexts might also be thought of as content areas or, simply stated, settings where the core disciplinary standards and practices might be applied. The eight core standards and eight practices could be applied in any, or all, of the context areas outlined below. It should be noted that the core disciplinary standards and practices could also be applied in other contexts, but the following eight context areas are predominant in the fields of technology and engineering. The eight *STEL* contexts are:

Table 1. Sample from *Table A.2 Three Example Matches Between* STEL *and* NGSS*, CCSS Math, and CCSS ELA (p. 120).*

Grade Band	*STEL*	NGSS	CCSS Math	CCSS ELA
9-12	*Standard 7 – Design in Technology and Engineering Education* **STEL-7Y.** Optimize a design by addressing desired qualities within criteria and constraints.	**HS-ETS1-3.** Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.	**S-IC.2.** Decide if a specified model is consistent with results from a given data generating process, e.g., using simulation.	**ELA-Literacy. RST.9-10.3.** Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.

Table 2. Sample from *Table A.4* STEL *Benchmark Verb Alignment to Domain and Knowledge Dimensions (p. 122).*

STEL and Benchmark	Cognitive Domain	Affective Domain	Psychomotor Domain	Knowledge Dimension
Standard 7 – Design in Technology and Engineering Education **STEL-7Y.** Optimize a design by addressing desired qualities within criteria and constraints.	Analyze	-	Adapting	Procedural

1. Computation, Automation, Artificial Intelligence, and Robotics
2. Material Conversion and Processing
3. Transportation and Logistics
4. Energy and Power
5. Information and Communication
6. The Built Environment
7. Medical and Health-Related Technologies
8. Agricultural and Biological Technologies (p. 16)

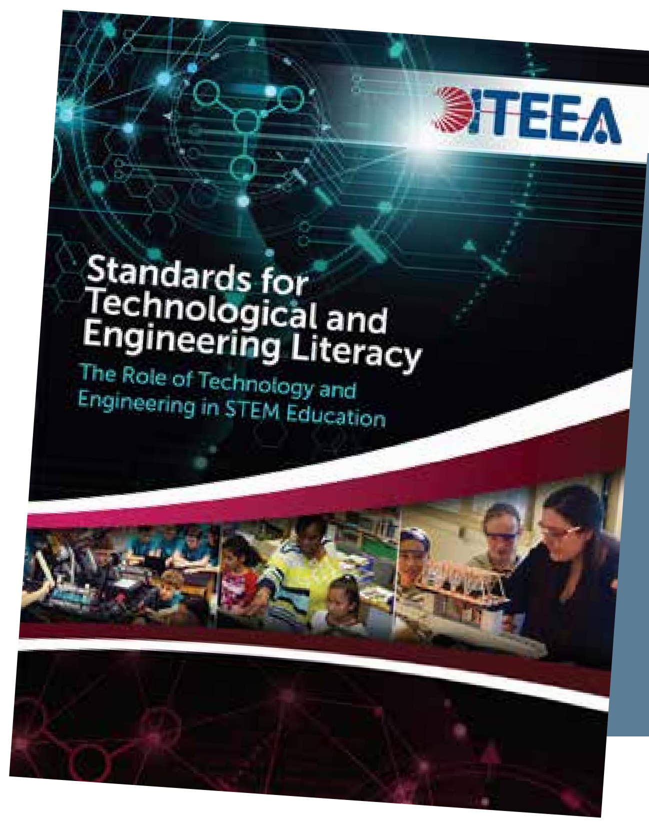
Using the *STEL* Standards in STEM Programs, Courses, or Classes

For many teachers outside of the technology and engineering education profession, *NGSS* and the inclusion of engineering practices provided the first glimpse of the possibility of bringing engineering design into the classroom (Capobianco, 2016). Additionally, reports such as STEM Integration in K-12 Education: Status, Prospectus and Agenda for Research (NAE & NRC, 2014) have driven the importance of connecting STEM learning in schools. However, since the inception of integrated STEM programs, courses, and classes, educators have struggled to clearly articulate the standards upon which their curriculum rested. *STEL* provides a clear instructional foundation for content and practices related to technology, engineering, critical thinking, problems solving, design, and so many related conceptual fields. *STEL* provides a comprehensive representation of the essential knowledge, skills, and practices of technology, engineering, and related or integrated fields or concepts. *STEL* provides grade-level benchmarks that assist the educator in gauging student knowledge acquisition and skill development as they transition through courses and programs. Most importantly, the *STEL* standards are designed to complement standards from adjoining or integrated fields of study (i.e., science, mathematics, English language arts, social studies, etc.). This is particularly useful for educators attempting to integrate additional levels of integrated STEM content into elementary, middle school, or high school lessons or courses.

A unique tool provided in the new standards and highlighted in Appendix A of *STEL* is on ITEEA's interactive *STEL* website (www.iteea.org/STEL/stel_resources.aspx), which provides resources and examples to assist educators in the development of integrated STEM curriculum and lessons. These resources include:

1. A compendium of benchmarks at the grade-band level.
2. A crosswalk matrix that links *STEL* standards and benchmarks to *Next Generation Science Standards* (*NGSS*), Common Core Mathematics (CCSS-Math) benchmarks, and Common Core English Language Arts (CCSS-ELA) benchmarks.
3. A verb matrix that aligns benchmarks to the cognitive, affective, and psychomotor domains (p. 118).

This unique tool (see Table 1) provides the teacher with samples that illustrate the methods by which a *STEL* standard and benchmark can be integrated with and supported by standards in *NGSS*, *CCSS* Math, and *CCSS* ELA. With this information, teachers can easily craft integrated lessons and curricula that cut across big ideas, core concepts, and important standards from five different fields of study—technology, engineering, science, mathematics, and English language arts.



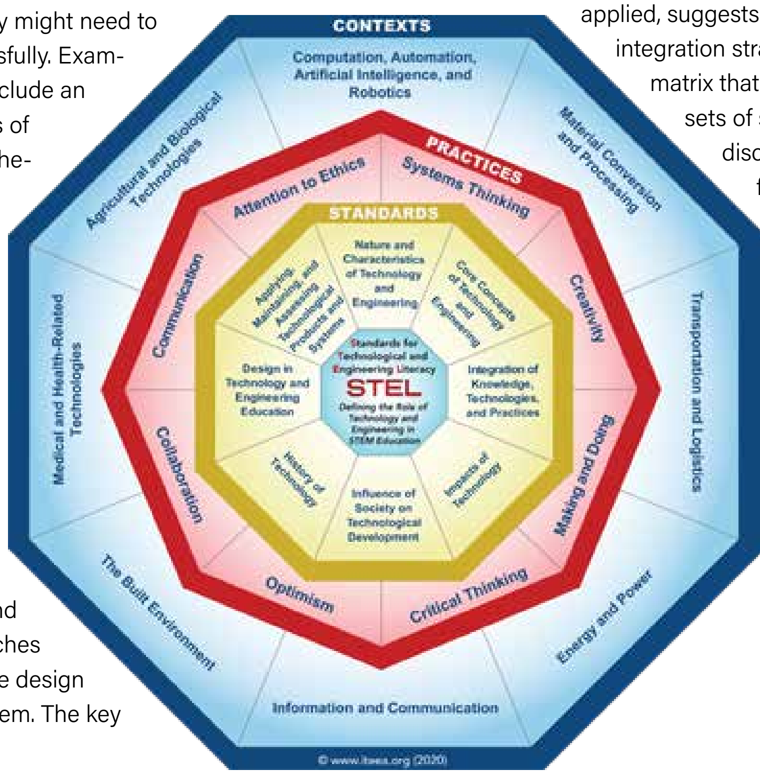
In addition to resources for aligning lessons to science, mathematics, and English language arts standards, the interactive *STEL* website provides educators with *STEL* benchmark verb alignment to domain and knowledge dimensions. This information will assist the teacher in developing appropriate cognitive, affective, psychomotor and knowledge dimension lessons and activities (see Table 2 below). Additionally, the verb alignment provides an invaluable tool for helping teachers define appropriate assessment strategies.

STEL provides a clear instructional foundation for course or lesson content, practices, and context as well as tools that assist the teacher in developing truly integrated lessons that provide a real-world flavor and 21st Century learning practices. The standards also provide curriculum developers and teachers with guidelines for content and practices related to technology, engineering, critical thinking, problem solving, design, and many related conceptual fields. *STEL* provides a comprehensive representation of the essential knowledge, skills, and practices of technology, engineering, and related or integrated fields and concepts.

STEL Benchmarks and the Interaction of Science, Math, and English Language Arts

Beyond the resources found within *STEL*, including just a glimpse of the possibilities of content alignment, the new standards provide a pathway for educators to highlight the interaction and integration of science, mathematics, and English language arts in the classroom. For example, Standard 7: Design in Technology and Engineering Education, and the benchmarks for each grade level provide students with opportunities to implement their scientific knowledge and mathematical problem-solving abilities to create solutions to design challenges. It is important that the teacher serves as a hands-on facilitator of this knowledge and directs students to those skills that they might need to complete the challenge successfully. Examples of this knowledge might include an understanding of the properties of materials available and the mathematical modeling skills needed to develop the solution.

The inclusion of collaborative design and design assessment, evaluation, and presentation can be the catalyst for the inclusion of English language arts. The use of an engineering design journal may provide opportunities for students to display written work, create empathy for the end user of a product, prepare sketches and drawings, and reflect on the design process used to solve the problem. The key is the intentional planning of these interactions and the depth of the *STEL* benchmarks in making this challenge easier for teachers to promote the importance of integrated learning in all classrooms.



Conclusions

Adapted from *Standards for Technological Literacy* (2000), *STEL* is an inclusive document that guides developers and teachers to provide students with a balanced STEM education. It defines the role of the T and E in STEM by using three distinct organizers: the core disciplinary standards, technology and engineering practices, and technology and engineering contexts. These organizers become the foundation for developing and delivering integrated *STEL* lessons.

STEL is adaptable. It establishes a guide for engineering practices in STEM content learning at all grade levels. With technological and engineering literacy at its core, the organizers establish a path for programs to articulate curriculum in schools, districts, states, or countries.

A useful interactive website that complements standards from adjoining or integrated fields of study is provided in the *STEL* Appendix A. The resource lists grade-level benchmarks, has a verb matrix aligning benchmarks to domain/knowledge domains, and provides a crosswalk matrix linking the *STEL* standards and benchmarks to *Next Generation Science Standards* (*NGSS*), Common Core Mathematics (CCSS-Math) benchmarks, and Common Core English Language Arts (CCSS-ELA) benchmarks.

STEL provides STEM educators with not only a comprehensive guide for delivering big ideas and core disciplinary content, but also identifies contexts within which these big ideas might be applied, suggests disciplinary alignment and integration strategies, provides a crosswalk matrix that helps align lessons to other sets of standards from complementary disciplines, and makes suggestions for connecting standards, engineering practices, and core content to the 21st Century Learning Skills. Currently, ITEEA is developing a *STEL* standards alignment to ISTE and NAEP-TEL as well as enhanced connections for *NGSS* and Common Core Mathematics and ELA standards. This information is expected to be published during the Summer of 2021.

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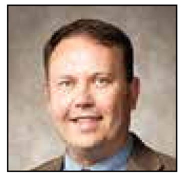

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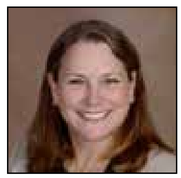

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