An Overview of State Developed P-12 Standards for Technological and Engineering Literacy (Other)

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Abstract

In recent years, many states in the United States (U.S.) have made efforts to include engineering content and practices within their P-12 technology education and/or science academic standards. However, the depth and breadth of engineering concepts added in state standards has been questioned. The release of the *Standards for Technological and Engineering Literacy: The Role of Technology and Engineering in STEM Education* (*STEL*) [1] in 2020 provided a clear rationale for the importance of high-quality technology and engineering (T&E) learning opportunities for all P-12 students. These standards and accompanying curricular and instructional resources provided guidance for states to examine how engineering content and practices are being taught in their P-12 school systems. Numerous states have opted to adopt the STEL as published; however, some states used the STEL as the foundation for developing standards that fit the localized needs of their students and teachers. This paper will examine the process that the Commonwealth of Pennsylvania engaged in to develop academic standards that will guide T&E curricular and instructional efforts for 500 K-12 school districts.

From 2020-2022, the Pennsylvania Department of Education (PDE) led a rigorous T&E education standards development process. National and state level standards and frameworks from P-12 T&E and science education were reviewed to aid in the conceptualization of the standards for Pennsylvania. Through multiple rounds of reviews, input from various stakeholders across Pennsylvania informed the development of standards that will serve the diverse needs of approximately 1.7 million K-12 students. This process was a collaborative effort among T&E, science, and environmental literacy and sustainability educators. This paper will describe the valuable conversations that occurred among the committees as they contemplated the focus and direction of T&E education in Pennsylvania as well as the structure and content of the standards. Modifications made to the STEL in developing standards for T&E education in Pennsylvania included condensing some of the standards, aligning with the Pennsylvania Career Readiness standards, providing connections to content and practices from other standards (e.g., PA Core Standards: Reading and Writing in Science and Technical Areas, PA Core Standards and Practices: Math), providing clarification statements for each standard similar to the format used in the *Next Generation Science Standards* [2], and providing exemplars of Pennsylvania specific contexts in which the standards could be applied. This paper will provide an overview of the approved T&E standards that school districts in Pennsylvania must align instruction with by the 2025-2026 academic year. These standards have resulted in T&E questions being added to the fifth and eighth-grade state assessments which will also be discussed in this paper. Additionally, examples of supplemental resources created to assist educators and school districts in aligning with these standards will be presented. This paper may assist other states with updating or developing P-12 T&E education standards.

Background

Technology and engineering (T&E) education has historically been rooted in hands-on, minds-on learning. Over more than 100 years the field has evolved from manual arts, to industrial arts, to industrial technology education, to technology education, to T&E education, and more recently focused on the integrative aspect of the T&E within STEM education contexts [3]. These continual changes make T&E education unique from many content areas in that it is rapidly evolving to provide students with the latest design thinking skills, technical skills, and many other competencies. The name changes reflect a shift in the focus of the field to keep up with emerging societal needs and educational initiatives. While early manual arts and industrial arts programs primarily focused on developing technical skills in students (predominantly males), the field shifted toward a focus on the application of skills related to various technologies and implementing design-based thinking to help all students become more technologically and engineering literate citizens and consumers. These name changes reflect the continually adapting nature of the field to provide relevant and authentic learning experiences that better prepare the next generation of innovators and problem solvers.

As the standards-based education movement gained momentum in the United States (U.S.), T&E educators, researchers, and teacher educators (technology education at the time) realized that T&E education would need to develop their own set of standards if they wanted to establish the field as a distinct content area among other disciplines like science education, mathematics education, and other content areas that already had well-established standards and frameworks [3]. Hence, in 2000 the *Standards for Technological Literacy* (STL) [4] were published. These standards helped to guide many states in establishing T&E as an important content area within their school curriculum. They provided the foundation to help many states develop their own state-specific standards, they informed assessment items, and they informed the development of later released teacher preparation and professional development (PD) standards [5]. However, as T&E fields evolved, so did the teaching of T&E concepts. While this standards document saw minor updates in 2002 and 2007 to reflect the field's focus on engineering concepts, it was in need of some major revisions to reflect the current initiatives of T&E fields. That resulted in some substantial changes to the focus of the T&E standards which were published in the *Standards for Technological and Engineering Literacy* in 2020 [1].

A brief history of K-12 T&E education standards in Pennsylvania

Specifically within Pennsylvania, the *Academic Standards for Science and Technology Education* were developed and published in 2002. This document presented the standards according to grade bands specific to elementary, middle, and high school grades. These standards focused on unifying themes of science and technology education (systems, models, etc.), inquiry and design, and science/technology human endeavors. The standards also featured content explicitly addressing concepts within biological sciences, physical sciences, earth sciences, and technology education. While these standards aligned with the core concepts and technological literacy focus of the STL, the Pennsylvania standards did not adopt the format or exact wording of the STL standards. Pennsylvania's *Academic Standards for Science and Technology Education* featured a more integrated approach among science and technology education. While the STLs advocated for integrative teaching of technology within other content areas [4, p. 6-9], they focused primarily on the core areas of technology education (e.g., nature of technology, technology and society, design), including the designed world areas (manufacturing technologies, transportation technologies, etc.). In 2010 Pennsylvania made updates to their standards to include engineering concepts that reflected modifications also made to the STL and the evolving focus of the field from technology education to T&E education. These standards were offered as a voluntary resource for Pennsylvania's schools and guided T&E curriculum, instruction, assessment, and teacher preparation until the adoption of the *Science, Technology & Engineering, Environmental Literacy and Sustainability* (STEELS) standards in July of 2022. Like the previous Pennsylvania standards, the STEELS feature an integrative science and T&E perspective [6]. The T&E standards within the STEELS were developed on the following foundational beliefs:

- Every student is capable of technological and engineering literacy.
- Technology and engineering can be explored through an integrated and active learning process.
- Iteration and reflection are a critical component of the learning process.
- Success depends upon the partnerships between educators, students, families, postsecondary providers and institutions, legislators, businesses, and industries.
- Science, technology, engineering, and mathematics (STEM) fields are for all students and should be committed to equity and inclusivity.

Goals of this paper

For the purpose of this paper we will focus exclusively on the T&E standards within the STEELS [6]. In the following sections we will provide a brief overview of the process that the Commonwealth of Pennsylvania engaged in to develop these standards, examples of resources that were developed or are in development to support school districts and educators in implementing these standards, and recommendations for the development of state P-12 T&E standards based on insight gained from this process in Pennsylvania.

Pennsylvania's 2022 Science, Technology & Engineering, Environmental Literacy and Sustainability (STEELS) Standards

In September of 2019, the Pennsylvania State Board of Education directed the Pennsylvania Department of Education (PDE) to begin the process of updating Pennsylvania's *Academic Standards for Science and Technology Education* to align them with current research and best practices. Between February and March 2020, 14 meetings were held in person and virtually to engage stakeholders from across Pennsylvania and gain input for developing new standards. Approximately 960 stakeholders (consisting of elementary and secondary educators, administrators, higher education faculty, business and industry representatives, community not-for-profit organization representatives, students, and parents) provided feedback. A public call for applicants to serve on the content and steering committees to revise the standards was posted online in April 2020. Applicants were selected through a multi-reviewer process based on their depth and breadth of expertise in curriculum and standards development, their understanding of the existing Pennsylvania and national standards documents, and their understanding of current research related to the respective content areas. Two committees were formed: a) a content committee consisting of 60 members who reviewed the previous standards and developed the content for the new standards, and b) a steering committee which consisted of 17 members who reviewed the items developed by the content committee and provided feedback. Three of the members on the steering committee served as liaisons between the steering and content committees to help communicate concerns and provide clarity about any feedback. Each selected committee member was approved by the State Board of Education.

During June and July of 2020 the committees met over a series of online meetings. First they reviewed research-based articles on standards along with other standards and framework documents compiled by PDE, such as *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* [7], the *Next Generation Science Standards* (NGSS) [2], the *STEL* [1], *A Framework for P-12 Engineering Learning: A Defined and Cohesive Educational Foundation for P-12 Engineering* [8], the International Society for Technology in Education's *(ISTE) Standards for Students* [9], as well as science and T&E standards related documents from other states (e.g., Massachusetts) and countries (e.g., England). Additionally, the committees reviewed the most recent Pennsylvania standards and feedback from the stakeholder meetings. The committees then worked in groups to identify key content and cross-cutting connections that they believed were evident across the documents. They were also encouraged to consider Pennsylvania Career Ready Skills [10] and Pennsylvania specific contexts that may relate to the documents reviewed.

Over nine full days the committees worked to develop a draft of the standards. For the first three days the committee members were intermingled according to content area and grade level to deliberate on the essential elements that should be included in the new standards. The committees made a good faith effort to incorporate criteria from the various sources reviewed to capture the essential concepts of science and T&E education that would be most relevant to Pennsylvania's students. It was decided that the STEELS should be organized according to content area and grade bands (K-2, 3-5, 6-8, and 9-12), with each standard demonstrating a clear progression across the grade bands.

Once a consensus for the format of the standards was reached, content committee members were split into grade band specific groups to start writing the respective standards documents. The elementary (K-2 and 3-5) standards content committee had a mix of individuals from science and T&E education backgrounds. In regard to T&E education, this committee had representation from two educators who taught elementary engineering, and two higher education faculty members who had degrees in T&E education and taught integrated STEM elementary methods courses at their universities. The secondary (6-8 and 9-12) content committee included a mix of science and T&E educators. Specifically, five T&E teachers and three teacher preparation faculty members were among the secondary grades committee members. One of these committee members was a physics teacher who taught pre-engineering courses. The PDE content advisors for T&E education and science education attended the online content committee meetings as observers because PDE wanted to ensure the standards reflected the ideas of the committee members who were selected to represent stakeholders from across the Commonwealth. At the end of each day the content committees would share their progress to the entire group and the steering committee (which included two T&E teacher preparation faculty members) would meet to review the work of the content committees. The steering committees looked for overlap among the documents, gaps in areas like equity and inclusion, and provided comments for the content committees to consider each day as they developed the standards. At the conclusion of the nine-day standards writing meetings, the standards document was reviewed by PDE to prepare it to post for public comment.

Following a 30-day public comment period required by Pennsylvania rules and regulations, additional revisions were made during the fall of 2021 by the committee members in collaboration with PDE to address concerns from the public. The final draft document was sent to the Pennsylvania Board of Education to review and examine the extent to which the public comments were addressed. The Board of Education provided additional recommendations that were also addressed by the committee members in collaboration with PDE. During the fall of 2021 the committees also worked on completing the foundations boxes that would accompany each of the standards. This included specifying the STEL T&E practices that best aligned to the content that appear in the foundation box for each standard. It also included aligning each T&E standard with disciplinary core ideas (DCI) from the NGSS, the International Society for Technology in Education (ISTE) Standards for Students, the National Assessment of Educational Progress (NAEP) Technology and Engineering Literacy assessment targets, NGSS related science and engineering practices (SEP), and Pennsylvania Career Ready Skills. Additionally, descriptors (clarifying statements), Pennsylvania specific contexts/connections, and connections to Pennsylvania English language arts and mathematics standards were also identified [Fig. 8]. The final amendments to the standards documents were adopted by the Board of Education in January of 2022, and after approval from the Attorney General, the standards documents were published online in July of 2022 [Fig. 1]. The following section describes the content of the standards in more detail.

Date	Task(s) Completed
September 2019	Pennsylvania Board of Education (BOE) grants approval to update the standards.
February -March 2020	Stakeholder meetings held across the state.
April 2020	Call for content and steering committee applicants posted online.
June-July 2020	Committees meet online to develop the standards.
September 2020	BOE votes to adopt the proposed format for the standards.
September 2020-May 2021	Committee members and PDE representatives meet online to refine the standards and get it into a full draft document for public review.
June 2021	Draft of standards posted online for 30-day public comment period.
September-December 2021	Standards revised to address public comments and recommendations from the BOE. Criteria for the foundations boxes developed and aligned.
January 2022	Standards documents adopted by the BOE.
July 2022	Standards documents approved by the Independent Regulatory Review Commission and the Attorney General. Final documents published online.
July 2025	Public schools required to align curricula and instruction with the new standards by the start of the 2025-2026 academic year.

Fig. 1. Timeline for the development of the standards.

Rationale for the structure of the STEELS

As previously mentioned, the content and steering committees reviewed numerous state and national level standards and frameworks from a variety of content areas. Upon review of these documents, the committees opted to model the STEELS after the NGSS [2] and the STEL [1]. The STEELS reflect a focus on multi-dimensional learning which was deemed an important focus among all committees (e.g., disciplinary core ideas, practices, cross-cutting concepts or context areas). The STEELS also include connections to Pennsylvania Career Ready Skills, a Pennsylvania specific context, and connections to standards from other content areas (e.g., math).

One of the reasons that the content and steering committees elected to model the T&E standards within the STEELS after the STEL was due to the strong foundation of peer-reviewed research that guided the development the STEL [1]. The STEL were the result of a multi-year project to re-envision the former STL [4]. Additionally, the content and steering committees believed the process used to develop the STEL resulted in a document that represented the views of a broad spectrum of stakeholders involved with P-12 T&E education. Hundreds of T&E educators, industry partners, and other stakeholders across the world participated in multiple rounds of feedback to guide the development of the STEL [1,11]. More details about the rigorous process utilized to develop the STEL are described in the literature [11,12]. Studies have established that the STEL adequately represent developmentally appropriate features of the Nature of Engineering Knowledge framework [13], and have helped to improve technological and engineering literacy internationally [14]. The STEL were also chosen as a model because of their applicability to Pennsylvania T&E contexts and the peer-reviewed supplemental resources that were readily available. These resources included alignments of the STEL with standards from other content areas, alignments of the domains of learning with student outcomes for each benchmark, and documentation of the coherent progression of each benchmark across grade levels [12,15]. While the STEL provided an excellent foundation for developing state level standards, additional edits were made by the committees to ensure the standards were relevant to Pennsylvania specific T&E applications.

Similar to discussions that occurred during the development of the STEL [11], the content committees debated whether to elevate the context areas (formerly the designed world standards of the STL [4]) to the level of strands (core disciplinary standards) or leave them as overarching T&E contexts where the strands and practices could be applied. After thoughtful debate it was determined that leaving the T&E context areas as contexts would direct educators to focus on the core strands (standards) which were identified as the most essential concepts (e.g., the design process) of T&E education. The committee discussed that with previous T&E standards it was not uncommon for educators to gravitate to the standards related to the context area of the lesson instead of focusing on core components like the design process as the driver of the lesson. The secondary grades content committee decided to condense the eight STEL core standards and benchmarks into four strands (core disciplinary standards) so that teachers did not view the core standards they were expected to cover as a daunting task [Fig. 2]. For the K-2 and 3-5 grade band T&E standards within the STEELS, the elementary content committee opted to keep all eight core standards from the STEL [6].

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

Fig. 2. Examples of how the STEL core standards were condensed for the T&E strands in the STEELS 6-8 and 9-12 grade bands.

In the K-2 and 3-5 grade band standards, the elementary content committee originally proposed adopting standards that reflected the NGSS. The T&E content specialists serving on this committee voiced their concerns about the limited focus that the NGSS had on engineering. Science specialists on the committee were concerned about overwhelming elementary educators with too many standards they would need to address, especially in content areas where elementary educators traditionally have limited time dedicated for this instruction, limited preparation to teach these concepts, and low self-efficacy toward teaching these concepts [16]. The T&E content specialists advocated that the PK-2 and 3-5 grade band benchmarks from the STEL covered a much broader spectrum of T&E concepts and in greater depth than the three broad engineering design standards that were part of the NGSS at these grade bands. The elementary content committee ultimately decided to integrate the STEL standards.

Organization of the STEELS

Like the STEL, the T&E standards within the STEELS feature an overlapping, multi-dimensional perspective. As Reed et al. [12, p. 4] described, the structure of the standards "should be thought of as a set of three spinning octagons where standards, practices, and contexts can be rotated and aligned to develop a particular unit or lesson." Each of the T&E strands (core disciplinary standards), shown in the innermost grey octagon, represent core concepts that all students should study and apply within various T&E practices, across a multitude of contexts. Within each strand, there are detailed standards according to grade band (K-2, 3-5, 6-8, and 9-12). The gold octagon in the middle represents T&E practices derived from 21st Century Skills and engineering habits of mind [1]. The practices reflect the knowledge, skills, and dispositions that students need in order to successfully apply the strands in the different T&E context areas. The outermost blue octagon in Fig. 3 represents the eight major contexts in which T&E concepts can potentially be applied. While this is not all-inclusive, it does provide local school district curriculum developers and teachers flexibility in how the standards are addressed [12]. Unlike the strands and standards, it is not expected that students master all eight contexts. Furthermore, these contexts may evolve over time as new technologies emerge. The T&E standards within the STEELS allow for that type of flexibility to remain relevant to students, schools, communities, and society. Regardless of the context, curriculum developers and educators should always start with the strands and standards, and then consider the contexts in which those core T&E concepts may be applied. This could involve interdisciplinary contexts and multiple practices and/or contexts.

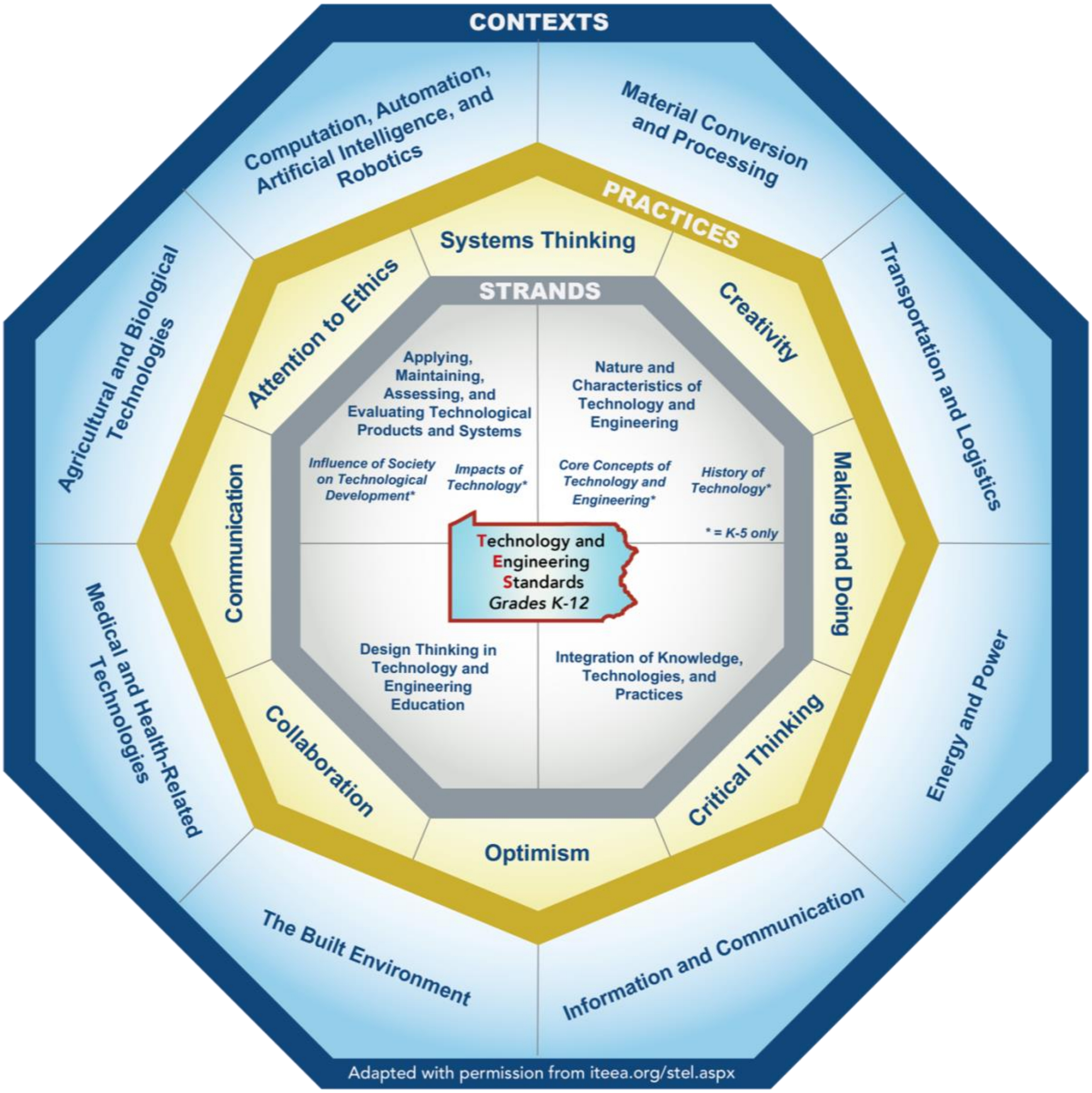

Fig. 3. Organization graphic depicting the T&E standards within the STEELS [6].

As described previously, the T&E standards for grade bands K-2 and 3-5 within the STEELS included all eight core standards from the STEL. The T&E standards for grade bands 6-8 and 9-12 reduced the core STEL standards down to four T&E strands within the STEELS. Fig. 4

provides a closer look at the middle octagon of the graphic. This helps depict which strands were combined in developing the 6-8 and 9-12 grade band standards, and reinforces the information presented in Fig. 2. In addition to the core standards from the STEL, the STEELS also incorporated the Engineering, Technology and the Application of Science (ETS) standards from the NGSS [2] within the appropriate T&E strands of the STEELS.

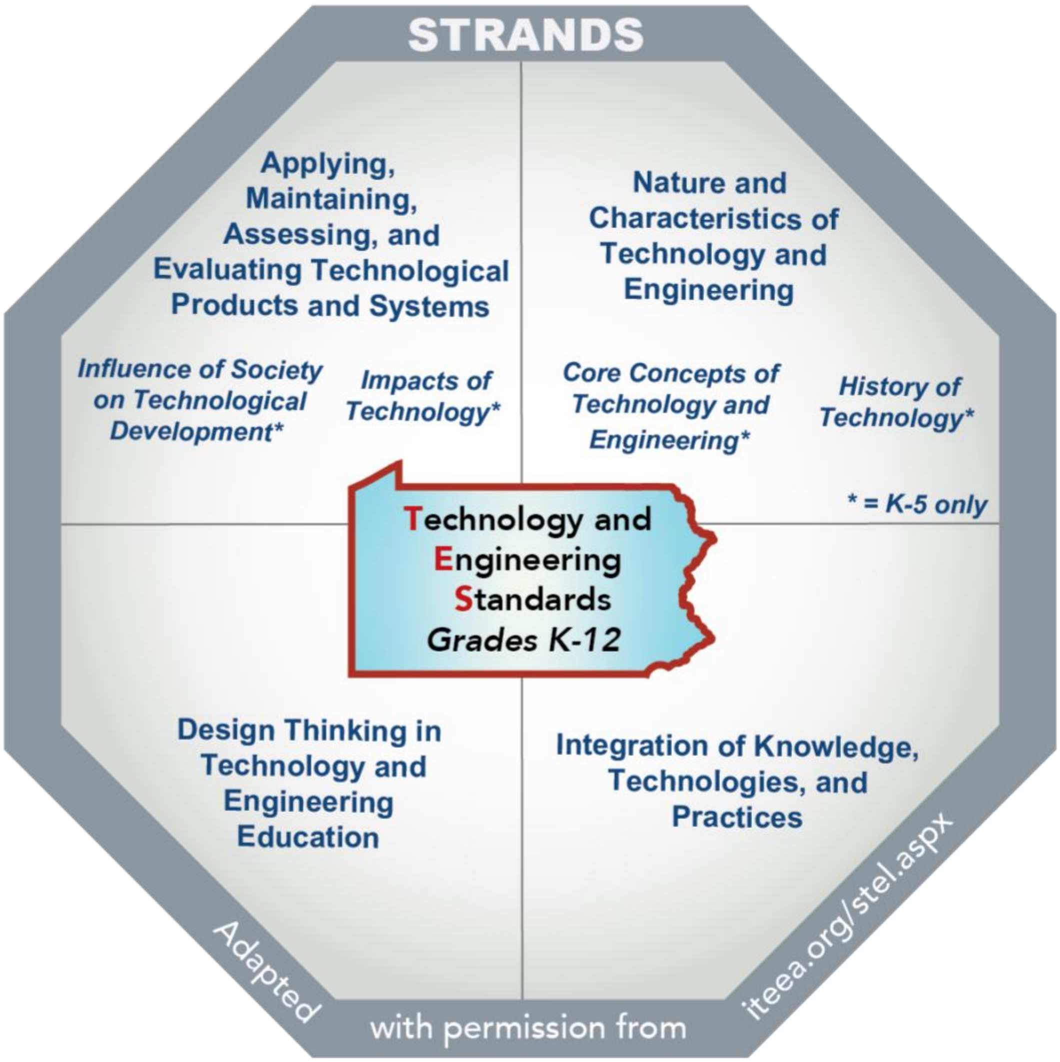

Fig. 4. A closer look at the core T&E strands within the STEELS [6].

A closer look at the T&E standards

After determining the structure of the strands (core disciplinary standards), the committees closely examined the STEL benchmarks related to each comparable Pennsylvania strand. The committees modified and reordered a few of the STEL benchmarks to reduce redundancy and make them more user friendly for Pennsylvania's educators. The elementary committee opted to keep 30 benchmarks at the K-2 grade band and 34 benchmarks at the 3-5 grade band like the

STEL had. At the secondary level, the 6-8 grade band standards featured 37 benchmarks in the STEL, which were increased to 38 in the STEELS. Moreover, at the 9-12 grade band, the STEL have 41 benchmarks as do the STEELS. It should be noted that the STEELS refer to benchmarks as standards, which are numbered according to the core strand with which they align. An example of a modification that was made to a STEL benchmark is presented in Fig. 5.

STEL benchmark	Pennsylvania standard
6-8.4L: Analyze how the creation and use of technologies consumes renewable and non-renewable resources and creates waste.	**3.5.6-8.D:** Analyze how the creation and use of technologies consumes renewable, non-renewable, and inexhaustible resources; creates waste; and may contribute to environmental challenges.

Fig. 5. Example of how a benchmark from the STEL was modified for the T&E standards within the STEELS (grade band 6-8).

Similar to the STEL, each standard within the STEELS demonstrates a coherent progression as students advance through the grade bands. Note how in Fig. 6 the related standards intentionally increase in complexity as exemplified by the verbs used for each grade band. Like the STEL, the T&E standards in the STEELS also align with one or more of the domains of learning – cognitive, psychomotor, and/or affective. Each of these three domains are correlated to the T&E dimensions of knowing, thinking, and/or doing, and the student outcomes of knowledge, skills, or dispositions [12].

Strand	K-2	3-5	6-8	9-12
Applying, Maintaining, Assessing, and Evaluating Technological Products and Systems	3.5.K-2.D **Select** ways to reduce, reuse, and recycle resources in daily life.	3.5.3-5.F **Classify** resources used to create technologies as either renewable or nonrenewable.	3.5.6-8.D **Analyze** how the creation and use of technologies consumes renewable, nonrenewable, and inexhaustible resources; creates waste; and may contribute to environmental challenges.	3.5.9-12.C **Develop** a solution to a technological problem that has the least negative environmental and social impact.

Fig. 6. Example of the progression of a STEELS T&E standard across grade bands.

When examining the standards, the committees also placed an increased emphasis on safety in regard to engineering design considerations and laboratory practices. The committees believed this was important due to the essential making and doing aspect of T&E education, the increased popularity of interdisciplinary makerspaces and Fab Labs in schools [17], and the rise in out of content area educators being tasked with teaching engineering practices [18-20]. A content analysis by P-12 safety specialists determined the STEL had the greatest emphasis on safety in comparison to other science and engineering standards and frameworks [21], many of which were reviewed in the development of the STEELS. The content committees ensured that safety concepts remained a key focus throughout the Pennsylvania standards, and the standards aligned with state legislation pertaining to safety in school laboratory activities.

In addition to safety, the content and steering committees made it priority to pay attention to equity and access in the development of the T&E strands, standards, practices, and context areas. To assist with this an educator with expertise in equity in access served on the steering committee and provided valuable feedback to the content committees. Moreover, the committees also focused on ensuring the standards promoted multi-dimensional and interdisciplinary learning opportunities. The connections to the Pennsylvania Career Ready Skills, Pennsylvania specific contexts, and the Pennsylvania Core Standards from other content areas all reflect these efforts.

Additionally, the content committees wrote exemplars to demonstrate how the standards could be applied to reflect this focus on multi-dimensional teaching and learning. The following is one example related to the T&E standards within the STEELS:

> Students can apply standard 3.5.9-12.AA., safely apply an appropriate range of making skills to a design thinking process, in the context of Bio-Related Technologies by designing and making a device that will safely capture an invasive pest. One example specific to Pennsylvania is the spotted lantern fly. The spotted lantern fly is native to China and was first spotted in Pennsylvania in Berks County during 2014. It feeds on plants that are important to Pennsylvania's economy and has increasingly caused a lot of damage in the state. Students can utilize the Technology and Engineering Practice of Making and Doing to study the spotted lantern fly and safely use appropriate materials and processes to build a device to catch the invasive pest. This addresses the Technology and Engineering habit of mind – Creativity. (See example design solution in Fig. 7).

Fig. 7. Example of a student solution to the spotted lantern fly design challenge. Photo Credit: Dr. Dave Shernoff, Rutgers University [22].

Accompanying resources to support educators in implementing the STEELS

PDE recognized that the release of new science and T&E standards for the first time in two decades was going to require a lot of support and a robust repository of resources to help school districts and educators. These resources will be essential for enhancing educators' understanding of the standards and assisting with integration into curricula and instruction. In anticipation of this, and in consultation with the various stakeholders on the content and steering committees, PDE is helping guide the committee members in the ongoing follow-up work to develop accompanying resources being posted on the STEELS Hub. This can be accessed on the Standards Aligned System (SAS) website [6].

- **Implementation Guide**: Includes suggested actions and a timeline for multi-county intermediate units, school curriculum directors, administrators, and educators to be fully prepared to implement the standards by the 2025-2026 academic year deadline.
- **Foundations Boxes**: Provides additional details for each standard, including clarifying statements and cross-cutting connections. These foundation boxes also show which NGSS related science and engineering practices (SEP) and National Assessment of Educational Progress (NAEP) Technology and Engineering Literacy assessment targets are best aligned with each standard. These boxes closely resemble the format of those created for the NGSS [Fig. 8].
- **Curriculum Frameworks**: Provides a roadmap for curriculum development.

- **Instructional Resources**: Examples of lesson plans aligned with the new standards, teaching observation rubrics, and other resources to assist educators and school districts.
- **Curriculum Resources**: Vetted resources from national standards documents aimed to assist educators and school districts in developing standards-aligned curriculum while also meeting the needs specific to their community and students.
- **Research Resources**: Articles and reports related to NGSS and STEL research studies.
- **Professional Learning**: Recorded training sessions covering topics such as an overview of the standards, unpacking the foundation boxes, multi-dimensional teaching and learning, integrating cross-cutting connections, and other valuable information to assist educators.
- **Assessment Resources**: Resources pertaining to state assessment items to help local school districts develop curricula, formative assessments, and summative assessments to better prepare students for success on the required state assessments.
- **Safety Guide**: Work is underway to release an updated safety guide to assist school districts and educators in designing safer learning environments and providing safer multi-dimensional, hands-on laboratory/field-based instruction aligned with the STEELS.

Science, Technology & Engineering, and Environment Literacy & Sustainability (STEELS)

Grades 9–12

3.5.9-12.EE Technology and Engineering: Integration of Knowledge, Technologies, and Practices

Students who demonstrate understanding can *connect technological and engineering progress to the advancement of other areas of knowledge and vice versa.*

Clarifying Statement: For instance, cloud data storage aided the connectivity of physical devices, known as the Internet of Things (IoT). This advancement has enabled real-time mathematical, economic, medical, and other applications of data collection, analysis, and production. These advancements in turn are being applied to a multitude of areas, including the emerging field of "Smart Highways," infrastructure integrated with sensors to collect data on road conditions and weather to better aid in the decision-making process of road crews and local authorities.

Assessment Boundary: N/A

Science and Engineering Practices (SEP)	Disciplinary Core Ideas (DCI)	Technology and Engineering Practices (TEP)
Obtaining, Evaluating, and Communicating Information Obtaining, evaluating, and communicating information in 9–12 builds on K–8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs. • Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.	**ETS1.A: Defining and Delimiting Engineering Problems** • Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. **NAEP D.12.1** • Advances in science have been applied by engineers to design new products, processes, and systems, while improvements in technology have enabled breakthroughs in scientific knowledge.	**Systems Thinking** • Designs and troubleshoots technological systems in ways that consider the multiple components of the system. **Optimism** • Shows persistence in addressing technological problems and finding solutions to those problems.

Pennsylvania Context: Examples of Pennsylvania context include but are not limited to Pennsylvanian inventors and inventions.

Pennsylvania Career Ready Skills: Establish and pursue goals or post-secondary education, employment, and living within the community.

Connections to Other Standards Content and Practices

Standard Source	Possible Connections to Other Standard(s) or Practice(s)
PA Core Standards: Reading and Writing in Science and Technical Areas	CC.1.2.3.G: Use information gained from text features to demonstrate understanding of a text. CC.1.2.4.G: Interpret various presentations of information within a text or digital source and explain how the information contributes to an understanding of text in which it appears. CC.1.2.5.G: Draw on information from multiple print or digital sources, demonstrating the ability to locate an answer to a question quickly or to solve a problem efficiently. CC.1.4.3.V: Conduct short research projects that build knowledge about a topic. CC.1.4.4.V: Conduct short research projects that build knowledge through investigation of different aspects of a topic. CC.1.4.5.V: Conduct short research projects that use several sources to build knowledge through investigation of different aspects of a topic. CC.1.4.3.W: Recall information from experiences or gather information from print and digital sources; take brief notes on sources and sort evidence into provided categories.
PA Core Standards: Reading and Writing in Science and Technical Areas (continued)	CC.1.4.4.W: Recall relevant information from experiences or gather relevant information from print and digital sources; take notes and categorize information, and provide a list of sources. CC.1.4.5.W: Recall relevant information from experiences or gather relevant information from print and digital sources; summarize or paraphrase information in notes and finished work, and provide a list of sources.
PA Core Standards and Practices: Math	MP.7: Look for and make use of structure.
Integrated Standards for Science, Environment & Ecology, and Technology & Engineering Standards Grades K–12	N/A

Fig. 8. Example of a foundations box for a grade band 9-12 T&E standard within the STEELS [6].

Insight gained from the STEELS development process

One of the challenges that the committees faced was ensuring that the standards were applicable to *ALL* students across the Commonwealth. Pennsylvania is a relatively large state serving 500 school districts and 1.7 million students annually. Furthermore, Pennsylvania is a diverse state in regard to ethnicity, socioeconomic status, geography, technologies and access to technologies, industries, and other characteristics. During the standards development meetings there was a lot of discussion around how specific standards would be viewed by school districts, educators, students, and parents in varying parts of the state. There was also a lot of discussion about the feasibility of implementing specific standards based on the resources that schools had. Equity and access were considered throughout the standards development process. One example is in regard to agricultural connections. The committee included examples of connections for students in rural regions where they have a greater understanding of farms, but also provided examples related to urban farming for students in suburban and urban areas to connect with better. The flexibility of the context areas of the standards helped in providing examples of these diverse applications for students from all regions to learn similar core concepts.

Organization and preparation work leading up to the committee meetings was a valuable lesson learned from the STEL development [11], and also held true with this STEELS development process. Like the STEL development process, a good chunk of time during the first two days was spent by the content committees determining what was most important to teach in T&E education. The committees did not spend as much time engaging in similar conversations pertaining to science, probably due to the well-established epistemology of science education and its disciplines (e.g., biological sciences, physical sciences, earth sciences). Due to the rapidly evolving nature of T&E education, it historically has not had a well-established epistemology like other content areas, which often leaves room for debate about the key concepts that should be emphasized in standards. While these initial conversations were critical to determining what T&E education looked like in Pennsylvania and what would best meet the needs of the stakeholders, it did take away from time that could have been spent developing the standards and other resources. Loveland and Love [11] described a similar experience from the STEL writing retreat in 2020. It is recommended for future T&E standards development projects that these types of details be fleshed out prior to the writing sessions to maximize working time. There were a number of documents provided in advance for committee members to review and easily access during the meetings which was very beneficial. The insight learned from this project is also applicable to the creation of supplemental documents, such as the forthcoming STEELS safety guide to accompany the standards, which is described in the next section.

Another benefit of these meetings was that they served as a forum for a diverse group of stakeholders to have important conversations which they may not have otherwise. An example of this is in regard to teacher preparation and PD. As the standards were starting to take shape, teachers and school district personnel expressed concerns about supporting teachers in implementing these standards. Teacher educators voiced concerns about updating their curriculum and accreditation standards to prepare future teachers for providing instruction aligned with these new standards. This spurred great conversations with PDE representatives who were involved with the curriculum division, not the teacher preparation and certification divisions. It became apparent from these conversations that educators, administrators, school districts, intermediate units, and teacher preparation programs would all need PD resources. The interesting benefit of these conversations between these stakeholders was that they gained a greater understanding of the educational ecosystem and how each stakeholder plays a unique and important role in delivering standards-based instruction. Some of the PD resources that educators and school systems have asked for are already available on the STEELS Hub located on the SAS website [6]. PDE, universities, and professional associations like the Technology and Engineering Education Association of Pennsylvania (TEEAP) have hosted webinars and conference sessions providing overviews of the standards and walking viewers through examples of standards-aligned lessons. A shared community of resources for educators to post exemplar lessons would be beneficial. Universities will play a critical role in the standards implementation as they can help provide the resources (e.g., grant funded) and faculty expertise (content and pedagogical) to model exemplar lessons for teachers to integrate multi-dimensional learning. A number of other resources are needed to support the implementation of the standards and prepare teachers with the content and pedagogical knowledge needed to deliver integrative instruction [23]. Love and Roy [24] suggested a number of research-supported PD resources that would be beneficial to assist with the implementation of the STEL. Those resources, such as teacher preparation standards, would also be applicable at the state level to support the release of new standards.

Next steps

While much work has already commenced to develop the supplemental resources that educators and school districts will rely on to integrate the standards with fidelity, there are additional needs that will emerge as school districts implement the standards. One exciting result of this standards development project is the recent decision by PDE to include T&E as a testable subject area on their state assessments that all fifth and eighth-grade students must take. While the STEELS in Pennsylvania now mirror the inclusion of engineering similar to the NGSS and STEL, the development of the STEELS helped to demonstrate the breadth and depth of T&E concepts that cannot be fully covered in other already packed content areas (e.g., science education). The STEELS also demonstrate the interdisciplinary nature of T&E content, which provides opportunities for students to apply concepts they learn in other content areas in higher order systems thinking and design-based T&E contexts. For these reasons, 25% of the fifth and eighth-grade science state assessment in Pennsylvania will include explicit T&E questions directly correlated with the T&E standards within the STEELS. This makes Pennsylvania one of the few, if not the only, states in the U.S. to include T&E education as a state tested subject similar to other core content areas. This should incentivize school districts to provide high-quality T&E instruction aligned with the standards. It will also provide valuable data about the technological and engineering literacy of Pennsylvania's students.

Another result of the STEELS standards work was the realization that the state guideline document for safety in science and T&E education needs to also be revised. The most recent version of this document was originally published in 2002 and revisions were made in 2013 [25]. With the interdisciplinary nature of the new STEELS, safety specialists from science and T&E education met in December of 2022 to begin envisioning what an interdisciplinary safety guide may look like to help elementary and secondary educators provide safer hands-on integrative science and T&E instruction. This project will include supplemental instructional resources to demonstrate how safety plays an integral role in delivering standards-aligned multi-dimensional instruction. It is projected that a new comprehensive safety guide will be available on the STEELS Hub [6] by the standards implementation deadline (2025-2026 academic year).

Final thoughts

Standards documents come with challenges as they call for frequent updates to remain current with emerging technologies and practices. They also prompt a ripple effect to update accompanying curricula and assessments. The STEL were created as a non-prescriptive guide, to provide flexibility for states and local school districts to tailor the standards to what met their specific needs and adapt over time to keep up with technological advances. From this standards development process in the Commonwealth of Pennsylvania, it is clear that the STEL provided the necessary foundation to create state standards (and subsequent curricular and instructional resources) that will guide relevant and authentic learning experiences for the next generation of innovators and problem-solvers educated by Pennsylvania's public education system.

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