Pennsylvania Technology and Engineering Standards (Grades 6-12)

Contents

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Introduction

The *Pennsylvania Technology and Engineering Standards (Grades 6-12)* define the knowledge, skills, and abilities necessary for establishing literacy in technology and engineering literacy. Students develop a practical understanding of how humans are influenced by science and technology. Four core disciplinary standards describe practices in technology and engineering and include specific benchmarks for students in grade bands 6-8 and 9-12. Technology and engineering (T&E) education has a rich history rooted in hands-on, minds-on learning. Over more than 100 years, the field has evolved from manual arts to T&E education, continually adapting to provide relevant and authentic learning experiences that prepare the next generation of innovators and problem solvers. These continual changes make T&E education unique from many content areas in that T&E is rapidly evolving to provide students with the latest design thinking skills, technical skills, and many other competencies. However, such changes do not come without caution as they call for frequent updates to standards, curricula and assessments. The standards build upon previous standards documents and current research in T&E education. The *Pennsylvania Technology and Engineering Standards (Grades 6-12)* define the knowledge, skills, and abilities necessary for establishing technology and engineering literacy. Students develop a practical understanding of the fields of technology and engineering in order to make informed decisions about technology and better contribute to its design, development, and use. The standards describe core practices in technology and engineering in addition to four core disciplinary standards with a set of specific benchmarks for grade bands 6-8 and 9-12.

Pennsylvania's Vision for T&E

Businesses and industries are growing in Pennsylvania, and they want skilled and well-educated workers who are prepared for the 21st century economy. Students need to be equipped with the knowledge and skills to enter the workforce and be successful in a science and technology-driven global economy. To best prepare students for the 21st century economy, Pennsylvania will establish an equitable and innovative culture so every student can be included in technology and engineering education. The *Pennsylvania Technology and Engineering Standards (Grades 6-12)* were established on the following foundational beliefs:

- Every student is capable of engineering and technological literacy.
- Engineering and technology should be explored through an integrated and active learning process.
- Iteration and reflection are critical components of the learning process.
- Success depends upon the partnerships between educators, students, families, postsecondary education providers and institutions, legislators, businesses and industries.

As T&E fields evolve, so will the teaching of T&E concepts. The *Pennsylvania Technology and Engineering Standards (Grades 6-12)* document should be used by local schools to develop rigorous, authentic T&E learning experiences that are relevant to all students. The standards describe eight core disciplinary standards with a set of specific benchmarks for two grade bands—6-8, and 9-12—as well as technology and engineering practices to be applied across a range of contexts. The following section provides a brief overview of the development of the standards, their structure, a definition of T&E education, and a description of technological and engineering literacy followed by an overview of the standards and benchmarks, including how to use them, the standards by grade-level band, and a few examples of how the standards could potentially be applied in the learning environment.

Development of the Standards

The *Pennsylvania Technology and Engineering Standards (Grades 6-12)* are based on peer-reviewed research and other national standards documents. Most notably, the *Standards for Technological and Engineering Literacy: The Role of Technology and Engineering in STEM Education (STEL)* are the most recently updated standards developed by the International Technology and Engineering Educators Association (ITEEA) in a joint project with its Council on Technology and Engineering Teacher Education (CTETE). Hundreds of T&E educators, industry partners, and other stakeholders across the world contributed to the development of the STEL. While the STEL provides an excellent foundation for state standards, additional edits were made to ensure the standards in this document were relevant to Pennsylvania-specific T&E applications. The process outlined below incorporated feedback from various stakeholders to develop the current *Pennsylvania Technology and Engineering Standards (Grades 6-12)*.

In September 2019, the State Board of Education directed the Pennsylvania Department of Education (PDE) to begin the process of updating *Academic Standards for Science and Technology* (2002) and *Academic Standards for Environment and Ecology* (2002) to align them with current research and best practices. The standards currently in use in Pennsylvania classrooms are the *Academic Standards for Science and Technology*, which were approved by the State Board of Education in 2002. From February through March 2020, over 14 stakeholder engagement sessions were held across the state and virtually; the public was invited to attend and provide input. Of the more than 960 members of the public who provided input at these sessions, most were elementary and secondary educators, school administrators, postsecondary educators, student teachers, business and industry representatives, community not-for-profit organization representatives, parents and students. Their feedback was captured in a report that summarized the current research and best practices regarding science, environment, ecology, technology and engineering standards (see Ferguson et al., 2020).

In April 2020, PDE solicited applications from interested members of the public to serve on committees to review and revise the standards. Applicants were selected through a multi-reviewer process on the basis of their depth and breadth of expertise in curriculum and standards development, understanding of the existing standards and current research, equity and access in education and meeting the needs of diverse learners and overall education experience. Each selected committee member was approved by the State Board of Education in May 2020.

In June and July, the committees met to review the stakeholder input as well as research-based frameworks and guidelines—such as the National Research Council's (NRC) *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (2012), North American Association for Environmental Education's (NAAEE) *K–12 Environmental Education: Guidelines for Excellence* (2019), International Technology and Engineering Educators Association's (ITEEA) *Standards for Technological and Engineering Literacy* (STEL) (2020), International Society for Technology in Education's (ISTE) *Standards for Students* (2019), National Council for Agricultural Education (NCAE) *Agriculture, Food and Natural Resources (AFNR) Career Cluster Content Standards* (2015) and other national and international frameworks. Committee members also conducted close reads to share relevant information from Pennsylvania-specific documents, such as Pennsylvania's *Academic Standards for Science and Technology* (2002) and *Academic Standards for Environment and Ecology* (2002) to inform the development of the revised standards. Committee members collaborated to identify key content within those research-informed frameworks and other key national and international standards in science, environment, ecology, technology, engineering and agriculture.[1] They sought to identify cross-content connections while adding sustainability, PA Career Ready Skills and other PA-specific contexts.

Over nine full-day convenings, the committee members discussed the essential elements of academic standards. Attention to equity and access surfaced as foundational in the development of the standards. Equity in the context of the standards can be defined as a foundation of knowledge and skills critical for and accessible to all students, as well as "a characteristic of the instructional environment that increases the capacity for everyone to participate in meaningful learning" (Windschitl, Thompson, & Braaten, 2018, p. 12). This begins with standards that are crafted to allow for the individual and personalized experiences, knowledge and skills students bring with them to the classroom.

Following recommendations from current research to ensure equitable opportunities exist for all students and research indicating how students learn best, committee members drafted these revised standards based on the committees' commitment to equity and inclusivity to open doors to STEM fields for all students. Therefore, the practices embedded in the standards provide an equitable on-ramp for all students as they transition their developing and experience-based notions of the scientific world to conceptions that are scientifically based.

The committees worked to incorporate criteria from these various sources in a good faith effort to capture the essential concepts of T&E education that are most relevant to Pennsylvania students. The *Pennsylvania Technology and Engineering Standards (Grades 6-12)* reflect the work of the committees.

[1] Content and steering committee members reviewed over 30 research-based frameworks, guidelines and Pennsylvania-specific documents, such as the Pennsylvania Environmental Literacy Plan and the 22 Pa. Code Chapter 4 Academic Standards and Assessment.

What Is Technology and Engineering Education (T&E)?

Before teaching or planning T&E instruction, one must fully understand what technology and engineering education encompasses. T&E education has had numerous name changes throughout its history to reflect current societal and educational needs. Early manual and industrial arts courses focused on developing technical skills in students. There was a shift to a focus on the application of technology skills and the engineering process to prepare all students to be technologically literate users and consumers of various technologies through adaptive, design-based thinking. Since formally changing its name to technology education in 1985, the field has long faced an identity crisis, often mistaken as synonymous with digital or educational technologies (Dugger, 2013). While T&E systems can utilize digital technology, they are not confined to solely that form of technology. There are many technologies that contribute to the broad spectrum of T&E education and help us develop solutions to address human needs and wants. T&E education can be defined as the "combined disciplinary study of the engineered (human-designed) world, the goal of which is to develop individuals with a breadth of knowledge and capabilities who see the interactions between technology, engineering, and society and can use, create, and assess current and emerging technologies" (ITEEA, 2020, p. 162). Furthermore, Dugger and Naik (2001) clarified that T&E education is "concerned with the broad spectrum of technology, which encompasses but is not limited to, such areas as design making, problem solving, technological systems, resources and materials, criteria and constraints, processes, controls, optimization and trade-offs, invention, and many other human topics dealing with innovation" (p. 31). When viewing T&E education through this lens, it accurately represents the broader purview of the technologies and core concepts that are essential to preparing technologically and engineering literate citizens.

> *T&E education is "concerned with the broad spectrum of technology, which encompasses but is not limited to, such areas as: design, making, problem solving, technological systems, resources and materials, criteria and constraints, processes, controls, optimization and trade-offs, invention, and many other human topics dealing with innovation"*

What Is Technological and Engineering Literacy?

"Literacy" requires more than possessing knowledge; literacy requires being able to *apply* knowledge. A technologically and engineering literate person is able to apply the knowledge, concepts, skills, and practices learned in the classroom to real-life situations.

After understanding the breadth of T&E education, one can gain better insight into what it means to be technologically and engineering literate. Technological and engineering literacy is "the ability to understand, use, create, and assess the human-designed environment in increasingly sophisticated ways over time" (ITEEA, 2020, p. 161). One of the main goals of T&E education programs should be to enhance all students' technological and engineering literacy.

Structure of the Standards

Like the STEL, the *Pennsylvania Technology and Engineering Standards (Grades 6-12)* were created to provide a common set of expectations for what students should learn and be able to do. Additionally, the standards were designed to be developmentally appropriate for students and promote interdisciplinary connections with other school subjects. The standards provide a coherent and increasingly complex progression from grades 6 to 12 to help guide local school districts in developing appropriate curricula to meet the needs of their students. For terms related to the standards, see Appendix A.

Informed by the STEL (ITEEA, 2020), there are multiple organizers in the *Pennsylvania Technology and Engineering Standards*. They are:

- **Core Disciplinary Standards:** Four core disciplinary standards cut across grades 6-8 and 9-12.
  - **Nature and Characteristics of Technology and Engineering**
    - The field of technology and engineering requires knowledge of both natural and man-made worlds. These worlds have been heavily impacted by the history of man. The study of technology and engineering draws upon concepts, tools, and processes from all facets of the human experience.
  - **Integration of Knowledge, Technologies and Practices**
    - Technology and engineering are interdisciplinary subject areas relating to other STEM disciplines and beyond. Technology and engineering developments impact and are impacted by the transfer of technology from other fields. Similarly, technology and engineering knowledge and practices advance and are advanced by other fields of study.
  - **Design Thinking in Technology and Engineering Education**
    - Design thinking is an iterative human-centered process for creative problem-solving to meet human needs and wants. Design, itself, is a fundamental human activity. There is no single correct solution to design problems as solutions can always be improved and refined. The process of making solutions to complex problems is inherent to technology and engineering education.
  - **Applying, Maintaining, Assessing and Evaluating Technological Products and Systems**
    - Technological and engineering literate people are better equipped to learn about and use products and systems. Maintenance of these products and systems is crucial in keeping technology working and in repairing issues. All citizens of our digital world should possess the ability to gather, synthesize, and analyze information before drawing conclusions and making judgment about a technological product, system, or process.

- **Benchmarks**—These are key concepts that guide students' understanding of technology and engineering and are applicable across context areas and offer a set of specific benchmarks for each grade band.
- **Descriptors—**Describe what all students should know and be able to do in technology and engineering education for that particular core disciplinary standard. Descriptors provide deeper detail and explanation to each of the benchmarks.[2]
- **Key Practices**—Eight technology and engineering-based knowledge and skills to be applied across a range of contexts. The student-centered set of practices reflect the knowledge and skills students need in order to successfully apply the core disciplinary standards in the different context areas (ITEEA, 2020).
- **Pennsylvania (PA) Career Ready Skills:** Stakeholder engagement sessions captured stakeholder feedback regarding the dispositions all students should learn and be able to do as a part of a comprehensive K-12 science program. Using the student dispositions recommended by stakeholders, the Pennsylvania Career Ready Skills Continuum,[3] and research on habits of mind and the inclusion of dispositions in exemplar academic standards, committee members proposed lists of habits of mind relevant to the academic disciplines and the needs of Pennsylvania learners.
- **PA Connection:** A suggested PA-focused example to use in the classroom to promote relevance and a connection to Pennsylvania.
- **Connections to Other Content Areas**: As technology and engineering is inherently an integrative field, a variety of other content areas provide complementary standards to address similar ideas. These standards should not be used in the place of the technology and engineering standards, but rather can be used in the classroom to deepen student learning through highlighting the interrelation between technology and engineering and other content areas.

An overview of the Practices, T&E and PA Career Ready Skills and T&E Contexts is provided in Table 1.

[2] T&E descriptors are similar to the Performance Expectations described in the Pennsylvania Integrated Standards for Science, Environment, Ecology, Technology and Engineering (Grades K-5) as they are statements of what students should know and be able to do with what they know.

[3] The Pennsylvania Career Ready Skills are social-emotional learning progressions that support the development of a student's career preparedness.

Table 1. Overview of the Practices, T&E and PA Career Ready Skills, and T&E Contexts

Technology and Engineering Practices	Key Technology and Engineering and PA Career Ready Skills	Technology and Engineering Contexts
Making and Doing	Creativity	Computation, Automation, Artificial Intelligence, and Robotics
Safety	Persistence	Material Conversion and Processing
Systems Thinking	Collaboration	Transportation and Logistics
Optimization	Communication	Energy and Power
Integrating Concepts	Conscientiousness	Information and Communication
Problem-Solving	Empathy	The Built Environment
		Bio-Related Technologies

Overview of a T&E Standard

As illustrated below, the standards for each Core disciplinary standard are organized in six main sections: (1) benchmark, (2) descriptor, (3) key practices, (4) Key Technology and Engineering and PA Career Ready Skills, (5) PA connections and (6) connections to other content area standards. Appendix C provides an example of a completed standard.

T&E Standard Structure

Core Disciplinary Standard			
Benchmark			
Descriptor			
Key Practices		**Key Technology and Engineering and PA Career Ready Skills**	
PA Connections			
Connections to Other Content Areas			
Math	**Science/EE**	**ELA**	**Other**

Additional Considerations and Accompanying Documents

When using the Pennsylvania *Technology and Engineering Standards*, it is important to consider some overarching factors that are critical to all T&E instruction.

Equity and access: Equity and access must be taken into account when planning and providing instructional opportunities for students. Exemplars for middle and high school are provided for at least one item from each organizer (standards, practices, PA Career Ready Skills, and contexts) and should be intentionally and appropriately incorporated into each lesson, activity, and/or unit (See Appendices C and D). It is the expectation that every Pennsylvania student have equitable access to T&E education from K to grade 12. It is imperative that educators follow recommendations from current research to ensure equitable opportunities exist for all students.

Equity and access must be taken into account when planning and providing instructional opportunities for students. It is the expectation that every Pennsylvania student have equitable access to T&E education from K to grade 12. It is imperative that educators follow recommendations from current research to ensure equitable opportunities exist for all students.

PA Career Ready Skills: The Pennsylvania Career Ready Skills are social-emotional learning progressions that support the development of a student's career preparedness. By design, the PA Career Ready Skills reflect priorities to ensure youth are career ready and prepared to meet the demands of the 21st century workforce. The PA Career Ready Skills are grouped into three domains: self-awareness and self-management, establishing and maintaining relationships, and social problem-solving skills. A crosswalk of the proposed habits of mind and the PA Career Ready Skills shows where they align (see Appendix D). Educators can use this table in conjunction with the PA Career Ready Skills to identify ways to integrate teaching science, environment, ecology technology and engineering with related employability skills at any grade level. (See Appendix E for an intersection of Pennsylvania's Career Ready Skills, dispositions and habits of mind.)

Additionally, student and instructor safety are critical considerations prior to and during any T&E lesson. A risk and hazards analysis should be performed in the planning and preparation of any T&E lesson. Instructors should work in conjunction with their administration, special education department, and district safety specialist to ensure the safest learning environment and to confirm that safe instruction is occurring. The Pennsylvania Department of Education's *Safety Guidelines for Elementary and Technology Education Teachers* and professional association safety resources from the International Technology & Engineering Educators Association (ITEEA), National Science Teaching Association (NSTA), Association for Career and Technical Education (ACTE), and other professional associations should be used to inform the planning of safer instruction while addressing the valuable hands-on nature of these standards.

Technology and Engineering Academic Standards[4]

These standards are written in such a way that knowledge and skills progress across the grade bands. The intent is to assist teachers in scaffolding instruction in increasingly sophisticated ways as students advance in their study and understanding of technology and engineering. While maintaining age appropriateness, the standards are progressively more rigorous at the higher grade levels. While the core standards and benchmarks address similar ideas at both grades, levels of specificity and complexity build across the grade bands.

Grades 6-8

Nature and Characteristics of Technology and Engineering

1. Consider historical factors that have contributed to the development of technologies and human progress.
2. Engage in a research and development process to simulate how inventions and innovations have evolved through systematic tests and refinements.
3. Differentiate between inputs, processes, outputs, and feedback in technological systems.
4. Demonstrate how systems thinking involves considering relationships between every part, as well as how the systems interact with the environment in which it is used.
5. Create an open-loop system that has no feedback path and requires human intervention.
6. Create a closed-loop system that has a feedback path and requires no human intervention.
7. Predict outcomes of a future product or system at the beginning of the design process.
8. Apply informed problem-solving strategies to the improvement of existing devices or processes or the development of new approaches.

[4] The language of the standards is adapted, informed by or taken from the: International Technology and Engineering Educators Association (ITEEA) (2020). *Standards for technological and engineering literacy: The role of technology and engineering in STEM education.* Pennsylvania State Board of Education. (2002). *Academic standards for science and technology;* Pennsylvania Department of Education (2002). *Safety guidelines for elementary and technology education teachers;* Pennsylvania Department of Education (n.d.). *Pennsylvania career ready skills continuum.*

9. Explain how technology and engineering are closely linked to creativity, which can result in both intended and unintended innovations.
10. Compare how different technologies involve different sets of processes.

Integration of Knowledge, Technologies, and Practices

1. Compare, contrast, and identify overlap between the contributions of science, technology, engineering, and mathematics in the development of technological systems.
2. Analyze how different technological systems often interact with economic, environmental, and social systems.
3. Adapt and apply an existing product, system, or process to solve a problem in a different setting.
4. Demonstrate how knowledge gained from other content areas affects the development of technological products and systems.

Applying, Maintaining, Assessing and Evaluating Technological Products and Systems

1. Examine the ways that technology can have both positive and negative effects at the same time.
2. Analyze how the creation and use of technologies consumes renewable, non-renewable, and inexhaustible resources; creates waste; and may contribute to environmental challenges.
3. Consider the impacts of a proposed or existing technology and devise strategies for reducing, reusing, and recycling waste caused by its creation.
4. Analyze examples of technologies that have changed the way people think, interact, live, and communicate.
5. Hypothesize what alternative outcomes (individual, cultural, and/or environmental) might have resulted had a different technological solution been selected.
6. Analyze how an invention or innovation was influenced by the context and circumstances in which it is developed.
7. Evaluate trade-offs based on various perspectives as part of a decision process that recognizes the need for careful compromises among competing factors.
8. Research information from various sources to use and maintain technological products or systems.
9. Use tools, materials, and machines to safely diagnose, adjust, and repair systems.
10. Use devices to control technological systems.
11. Design methods to gather data about technological systems.
12. Interpret the accuracy of information collected.

13. Use instruments to gather data on the performance of everyday products.

Design Thinking in Technology and Engineering Education

1. Apply a technology and engineering design thinking process.
2. Develop innovative products and systems that solve problems and extend capabilities based on individual or collective needs and wants.
3. Illustrate the benefits and opportunities associated with different approaches to design.
4. Create solutions to problems by identifying and applying human factors in design.
5. Evaluate and assess the strengths and weaknesses of various design solutions given established principles and elements of design.
6. Refine design solutions to address criteria and constraints.
7. Defend decisions related to a design problem.

Grades 9-12

Nature and Characteristics of Technology & Engineering

1. Evaluate how technology and engineering have been powerful forces in reshaping the social, cultural, political, and economic landscapes throughout history.
2. Relate how technological and engineering developments have been evolutionary, often the result of a series of refinements to basic inventions or technological knowledge.
3. Identify and explain how the evolution of civilization has been directly affected by, and has in turn affected, the development and use of tools, materials, and processes.
4. Analyze how the Industrial Revolution resulted in the development of mass production, sophisticated transportation and communication systems, advanced construction practices, and improved education and leisure time.
5. Investigate the widespread changes that have resulted from the Information Age, which has placed emphasis on the processing and exchange of information.
6. Analyze the rate of technological and engineering development and predict future diffusion and adoption of new innovations and technologies.
7. Demonstrate the use of conceptual, graphical, virtual, mathematical, and physical modeling to identify conflicting considerations before the entire system is developed and to aid in design decision making.
8. Analyze the stability of a technological system and how it is influenced by all of the components in the system, especially those in the feedback loop.
9. Troubleshoot and improve a flawed system embedded within a larger technological, social, or environmental system.
10. Use project management tools, strategies, and processes in planning, organizing, and controlling work.

11. Implement quality control as a planned process to ensure that a product, service, or system meets established criteria.

Integration of Knowledge, Technologies, and Practices

1. Assess how similarities and differences among scientific, technological, engineering, and mathematical knowledge and skills contributed to the design of a product or system.
2. Develop a plan that incorporates knowledge from science, mathematics, and other disciplines to design or improve a technological product or system.
3. Analyze how technology transfer occurs when a user applies an existing innovation developed for one function for a different purpose.
4. Evaluate how technology enhances opportunities for new products and services through globalization.
5. Connect technological and engineering progress to the advancement of other areas of knowledge and vice versa.

Applying, Maintaining, Assessing, and Evaluating Technological Products and Systems

1. Develop a solution to a technological problem that has the least negative environmental and social impact.
2. Develop a device or system for the marketplace.
3. Evaluate ways that technology and engineering can impact individuals, society, and the environment.
4. Critique whether existing or proposed technologies use resources sustainably.
5. Critically assess and evaluate a technology that minimizes resource use and resulting waste to achieve a goal.
6. Evaluate a technological innovation that arose from a specific society's unique need or want.
7. Evaluate how technology and engineering advancements alter human health and capabilities.
8. Evaluate a technological innovation that was met with societal resistance impacting its development.
9. Use various approaches to communicate processes and procedures for using, maintaining, and assessing technological products and systems.
10. Synthesize data and analyze trends to make decisions about technological products, systems, or processes.
11. Interpret laws, regulations, policies, and other factors that impact the development and use of technology.

Design Thinking in Technology and Engineering Education

1. Apply a broad range of design skills to a design thinking process.
2. Implement and critique principles, elements, and factors of design.

3. Evaluate and define the purpose of a design.
4. Conduct research to inform intentional inventions and innovations that address specific needs and wants.
5. Analyze and use relevant and appropriate design thinking processes to solve technological and engineering problems.
6. Implement the best possible solution to a design using an explicit process.
7. Apply principles of human-centered design.
8. Optimize a design by addressing desired qualities within criteria and constraints while considering trade-offs.
9. Use a design thinking process to design an appropriate technology for use in a different culture.
10. Apply appropriate design thinking processes to diagnose, adjust, and repair systems to ensure precise, safe, and proper functionality.
11. Recognize and explain how their community and the world around them informs technological development and engineering design.
12. Safely apply an appropriate range of making skills to a design thinking process.

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Appendix A. Glossary

Assessing: The collection of relevant data and information about a technology, including its trade-offs and impact on other systems.

Benchmarks: These are key concepts that guide students' understanding of technology and engineering and are applicable across context areas and offer a set of specific benchmarks for each grade band.

Bio-Related Technology: Bio-related technologies include any technology that uses living organisms to make or modify products and the technologies that improve upon the life and function of living things.

Computation, Automation, Artificial Intelligence and Robotics: Within technology and engineering, this context is focused upon the role of computational thinking as it relates to the automation of physical systems and devices through design, programming and troubleshooting.

Connections to Other Content Areas: As technology and engineering is inherently an integrative field, a variety of other content areas provide complementary standards to address similar ideas.

Contexts: Areas of study within technology and engineering that provide more specific applications of standards and skills. These are the settings in which technology and engineering teaching and learning occur.

Descriptors: Describe what all students should know and be able to do in technology and engineering education for that particular core disciplinary standard. Descriptors provide deeper detail and explanation to each of the benchmarks.

Design Thinking: An iterative human-centered process for creative problem-solving to meet human needs and wants.

Energy and Power: The ability to do work and the rate at which that work is done. This includes designing, building, and troubleshooting systems that convert and harness and utilize energy and power.

Evaluating: The assignment of a judgment of the value, worth, or usability of a technology based on collected and observed information.

Exemplars: Excellent samples of ideas or concepts.

Habits of mind: Identified as "dispositions" in the Science and Technology and Environment and Ecology Standards: A National Landscape Scan and Pennsylvania Stakeholder Feedback report, these traits are what students should tend to when engaging in science and engineering practices alone and with others. Stakeholder feedback emphasized that students should develop habits of mind regarding science, environment and ecology and technology and engineering. Therefore, the committee created a list of habits of mind that students need in the classroom and in the workforce. Appendix E presents a crosswalk of the committee's habits of mind with Pennsylvania's Career Ready Skills to show the relationships between and overlap of each.

Information and Communication: A large field of technology and engineering dealing with the collection, analysis and dissemination of information and ideas.

Integrating Concepts: The use of technology and engineering studies as an opportunity to delve into and explore concepts from other fields of study including, but not limited to, science and mathematics.

Key Practices: Eight technology and engineering-based knowledge and skills to be applied across a range of contexts.

Making and Doing: The act of creation that results in a tactile solution made with one's own hands. This includes designing, building, and producing. The main skill and practice within technology and engineering education.

Material Conversion and Processing: Production of physical goods from raw materials to finished products. This includes the manufacturing processes and project management involved in making those goods.

Optimization: The process of evaluating and adjusting a design or system to ensure functionality and maximum efficiency within criteria and constraints. Often this includes developing effective solutions that utilize the fewest resources.

PA Career Ready Skills: The Pennsylvania Career Ready Skills are social-emotional learning progressions that support the development of a student's career preparedness. By design, the PA Career Ready Skills reflect priorities to ensure youth are career ready and prepared to meet the demands of the 21st century workforce. The PA Career Ready Skills are grouped into three domains: self-awareness and self-management, establishing and maintaining relationships and social problem-solving skills.

Pennsylvania (PA) connections: Provide opportunities for students to connect standards to local or regional phenomena to increase student engagement. PA connections provide PA-related examples that teachers can use to implement a curriculum designed to master said standard.

Problem-Solving: The process of gathering information about a problem, developing and enacting a plan of action, and evaluating the results in order to address an unmet need or want.

Safety: The act of making choices and developing behaviors that keep one protected from and/or minimize the risk of danger or injury.

Science and Technology and Environment and Ecology Standards: A National Landscape Scan and Pennsylvania Stakeholder Feedback (Pennsylvania Landscape Report): Commissioned by the Pennsylvania State Board of Education, this report captures the current research and best practices regarding science standards as well as the feedback from 14 stakeholder engagement sessions held across the commonwealth.

Systems Thinking: A system of thought that considers the problem as a whole in addition as the result of many parts and components. Systems thinking considers all variables impacting and being impacted by the system.

The Built Environment: The human-made environment including structures in which humans work and live. The built environment also includes roadways, infrastructure, cities, and other spaces built in the man-made world. Beyond just the structures, it also considers the relationship between the built environment and the natural environment in design, construction and use of these spaces.

Transportation and Logistics: The study of a wide variety of components and devices that operate on land, in water, in the air, and in space. This includes the management of the information necessary to keep these systems running and interacting smoothly.

Appendix B. Example of a Standard

<table>
<tr><th colspan="4">Standard: 4. Design Thinking in Technology and Engineering Education</th></tr>
<tr><td colspan="4">Benchmark: 4H.F: Implement the best possible solution to a design using an explicit process.</td></tr>
<tr><td colspan="4">Descriptor: Students should be able to express a rationale, based on testing and analysis of evidence, to support their selection of a design solution that optimizes criteria and constraints. Identifying strengths and combining key features may enhance design solutions.</td></tr>
<tr><td colspan="2">Key Practices:
• Optimization
• Integrating Concepts
• Problem Solving</td><td colspan="2">Key Technology and Engineering and PA Career Ready Skills:
• Creativity
• Persistence
• Collaboration</td></tr>
<tr><td colspan="4">PA Connections: You may not have heard of TAIT Towers, but you’ve probably experienced something related to their work. TAIT is actually a group of companies, but their headquarters are in Lititz, PA. They design and construct large products for live experiences such as concerts, theme parks, theater shows, and cruise ship performances. They have a long list of clients, including Taylor Swift, Elton John, Cirque Du Soleil, NASA, and the Olympics. Regardless of the client and project, they strive to exceed client expectations by creating the best possible solution to meet the project’s goals. That means their teams of expert designers, fabricators, and installers work together to solve the problem following what is called a “project cycle,” which starts with a scope of work detailing the design criteria and constraints. They do conceptual brainstorming and create design matrices to narrow down the best design concept. Using 3D modeling software, they convert the idea into drawings, select materials, and validate the design using engineering calculations. Designs are often modeled and tested before building the full scale and unique version that will eventually be installed for or by the client.</td></tr>
<tr><th colspan="4">Connections to Other Content Areas:</th></tr>
<tr><td>Math. S-IC.2: Decide if a specified model is consistent with results from a given data-generating process (e.g., using simulation).</td><td>Science/EE. HS-ETS1-4: Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.</td><td>ELA. ELA-Literacy.W.9-10.7: Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; and synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.</td><td>Other</td></tr>
</table>

Appendix C. Middle School Exemplars

This new structure of standards requires a much different method for implementation in comparison to past documents where single standards and benchmarks were often copied and pasted verbatim. Following this new structure, at least one item from each organizer (standards, practices, PA Career Ready Skills and contexts) should be intentionally and appropriately incorporated into each lesson, activity and/or unit. There is an expectation that standards are integrated with practices and PA Career Ready Skills within the area of contexts. All four domains should be integrated together to address the concept being taught.

- Teams of middle school students apply **standard/benchmark 1M.F,** *create a closed-loop system that has a feedback path and requires no human intervention*, within a **Computation, Automation, Artificial Intelligence, and Robotics context** during a design challenge on developing robotic rescues. Students are given a scenario of a flooded area that needs supplies delivered and people extracted. They design and build an unmanned aerial vehicle (UAV), or drone, which can be programmed to deliver a payload of ping pong balls to a target supplies site. Students must include a preliminary design report and journal outlining the process used in design and development of their solution. This activity also expands upon the **Technology and Engineering Practice of Making and Doing** while encouraging the **Technology and Engineering habit of mind - Creativity**.
- Middle school students can apply **standard/benchmark 2M.D,** *explain how knowledge gained from other content areas affects the development of technological products and systems,* within a **Material Conversion and Processing context** by using mathematics to precisely measure in English and metric measurements when laying out parts in a manufacturing design process. Manufacturing for global use requires the use of different measuring systems, which leads to the need for conversion of measurements. This activity also expands upon the **Technology and Engineering Practice of Integrating Concepts** while encouraging the **Technology and Engineering habit of mind - Communication**.
- Middle school students can address **standard/benchmark 3M.B,** analyze how the creation and use of technologies consumes renewable, non-renewable, and inexhaustible resources, creates waste, and may contribute to environmental challenges, in the **context of Communication and Information**. Challenge students to create a three-dimensional and interactive exhibit that would educate the school community about fracking—what it is, why it is used, how it works, and impacts of this technology. **Technology and Engineering Practices of Making and Doing** and **Safety** can be highlighted as students develop solutions using appropriate tools and materials. As they do their research and ponder strategies for developing accurate and informative exhibits, **Technology and Engineering PA Career Ready Skills** related to **empathy, conscientiousness, and communication** will be fostered.
- Middle school students can address **standard/benchmark 3M.D,** *analyze examples of technologies that have changed the way people think, interact, live, and communicate*, in the **context of Bio-Related Technologies**. Engage students in a research and development project to identify ways that bio-related technologies improve human lives. Have them present what they learned to peers during an “Ignite” type of presentation—use of 10 slides (usually just pictures) set up to automatically advance every 15 seconds resulting in a fast-paced 2.5-minute talk. **Technology and Engineering Practices of making/doing** and

integrating concepts can be highlighted. **Technology and Engineering habits of mind** related to **empathy, conscientiousness,** and **communication** can be nurtured as students discover how some amazing innovations are helping people to cope with illnesses or disabilities, and they find creative ways to share their findings with peers.

- Middle school students can address **standard/benchmark 3M.F,** *analyze how an invention or innovation was influenced by the context and circumstances in which it is developed,* in the **context of Bio-Related Technologies** and/or **The Built Environment**. Set up a design scenario that clearly describes a set of unique circumstances in which a design problem must be solved. For example, establish a situation whereby students must design and model an outdoor dining area at a restaurant that would creatively meet social distancing guidelines and make customers as comfortable as possible during a pandemic. **Technology and Engineering Practices of making/doing, problem-solving,** and **integrating concepts** can be stressed. **Technology and Engineering habits of mind** related to **creativity, empathy,** and **conscientiousness** will be practiced as students probe factors that affect people's comfort and safety and brainstorm design strategies that could be employed to address them.
- Waste management is a huge challenge in today's world and it is the perfect topic to explore with middle school students while supporting **standard/benchmark 3M.G,** *evaluate trade-offs based on various perspectives as part of a decision process that recognizes the need for careful compromises among competing factors*. In the **context of Bio-Related Technologies** and/or **Material Conversion and Processing,** students can study the process of trash collection and processing by following how it travels from home to its final destination in their community. Pose questions for them to explore such as: (1) How does trash impact the local environment? (2) How much trash is recycled and how does this facility operate? (3) How efficient is the waste management system? (4) How are recycled materials processed and converted into new products? Promote students' engagement in this process more effectively by asking them to work as a collaborative team to develop a plan to help improve the community's waste issues. Take it one step further by having students propose how some materials can be recycled into a new, functional product by creating a prototype, optimizing the design based on material use, and analyzing the trade-offs. Emphasize **Technology and Engineering Practices of making/doing, problem-solving,** and **optimization**. Promote **Technology and Engineering habits of mind** related to **creativity, collaboration,** and **conscientiousness** during this team project.
- Students could use a Kill-A-Watt monitor to measure how much power assorted technological devices use. They could then determine which have "ghost" loads and which don't. They could compare and contrast the power output of the same type of product from different companies to determine the most energy-efficient one (i.e., the most optimized one). This activity connects to **standard/benchmark 3M.L,** *interpret the accuracy of information collected*, in the **context of Energy and Power**. **Technology and Engineering Practices of safety, optimization,** and **integrating concepts** can easily be addressed as these items are tested and evaluated. Engaging in this activity will promote students' **Technology and Engineering habits of mind** in **communication** and **conscientiousness** as they compare and contrast consumer products, document their findings, and share their conclusions with peers.

- Middle school students can address **standard/benchmark 3M.K,** *design methods to gather data about technological systems,* in the **context of Energy and Power** and/or **The Built Environment**. Students work in small groups to design a way to analyze the performance of assorted materials to contain heat or cold in a structure (e.g., a box representing a house or lunch sack) to determine which material has the best insulating properties in order to optimize a design solution. Students document their data and communicate their findings using charts or graphs. Through this activity, **Technology & Engineering Practices of making/doing, optimizing,** and **problem-solving** are strengthened. Students will work on **Technology & Engineering habits of mind** related to **creativity, collaboration,** and **communication** through this activity.
- **Standard/benchmark 3M.H,** *research information from various sources to use and maintain technological products or systems,* is an ideal one to address in the **context of Energy and Power**. Provide pairs of students with a simple electronics kit that requires them to follow written instructions to solder a working circuit or assemble reusable electronic circuit kits. Have students modify the written instructions to more clearly communicate the process using words and pictures with an emphasis on safely doing so. Expect them to seek additional information from other sources to better understand and explain information. And ask them to draw the system chart for this device to communicate inputs, processes, and outputs. Emphasize **Technology & Engineering Practices of making/doing, safety,** and **systems thinking** and call attention to **Technology & Engineering habits of mind** such as **persistence, collaboration,** and **communication** while working with their partners and troubleshooting the circuit.
- Students can apply **standard/benchmark 3M.I,** *use tools, materials, and machines to safely diagnose, adjust, and repair systems,* within a **Material Conversion and Processing context** as they learn to use and maintain technological systems. Students could be assigned to develop safety reinforcement artifacts (e.g., posters, commercials, infographics, public service announcements) to remind and encourage their peers that systems need to be adjusted or repaired and tools and equipment must be used safely. This objective and activity addresses material conversion and processing safety as well as Pennsylvania safety regulations in school labs. This activity also expands upon the **Technology & Engineering Practice of Making and Doing** while encouraging the **Technology & Engineering habit of mind - Communication**.
- Students could apply **standard/benchmark 4M.B,** develop innovative products and systems that solve problems and extend capabilities based on individual or collective needs and wants, within a **Bio-Related Technologies context,** by being introduced to various physical challenges faced by military veterans. Providing middle school students with the opportunity to design, test, build, and automate a device that performs an important function for these veterans could help students practice using knowledge of sensors, controllers, various materials, machines, and techniques as they work to build a solution to extend the capabilities of individuals. This activity also expands upon the **Technology & Engineering Practices of Making and Doing and Problem-Solving** while encouraging the **Technology & Engineering habit of mind - Empathy.**

Appendix D. High School Exemplars

- Students can apply **standard/benchmark 2H.B.,** *develop a plan that incorporates knowledge from science, mathematics, and other disciplines to design or improve a technological product or system*, in the **context of The Built Environment** to investigate structural properties of building materials. The deflection and moment of inertia for various materials (e.g., wood strips) can be tested while using appropriate safety practices. Students can then calculate the deflection of different size beams made of the same material, graph their results, and safely test the accuracy of their calculations. Students should be able to identify relationships between the amount of deflection and the size of the material. They should also be able to calculate and analyze the moment of inertia. As an extension, students could be tasked with designing beams by safely using various **Materials Conversion and Processing** techniques (e.g., cardboard/recyclable products, molding plastic, casting metal, building a wood form to pour a concrete beam) and applying the aforementioned mathematics and physics concepts to inform their knowledge of materials used in designing structures. This new knowledge about the properties of various materials should inform their planning related to the built environment. This would address the **Technology and Engineering Practices of Making and Doing and Safety,** and the **Technology and Engineering habit of mind- Persistence** (adapted from Hughes, A. J., & Merrill, C. (2020). Concrete beam design: Pouring the foundation to engineering in T&E classrooms. *Technology and Engineering Teacher, 79*(4), 8-13).
- Students can apply **standard/benchmark 1H.G.,** *demonstrate the use of conceptual, graphical, virtual, mathematical, and physical modeling to identify conflicting considerations before the entire system is developed and to aid in design decision making, by safely studying and reverse engineering an existing product to gain a better understanding of how it works and improving it*. Such products could include items utilized by persons with disabilities, small children, or elderly people. For example, students may identify a handle used to operate a door or sink as a product that needs improved. They should collect data to develop a mathematical model representing the use of the product. Using that data, students could then reverse engineer the product to gain a better idea of how it works, and then using 3D design software create a virtual model of a new or improved handle. Lastly, a physical model can be created using advanced manufacturing techniques (e.g., CNC or 3D printing) and tested to see how well it works with the target audience. This **Material Conversion and Processing context** would address the **Technology and Engineering Practice of Making and Doing** while encouraging the **Technology and Engineering habit of mind - Empathy.**
- Students can address **standard/benchmark 3H.A.,** *develop a solution to a technological problem that has the least negative environmental and social impact,* in the **contexts of Transportation and Logistics** and **Computation, Automation, Artificial Intelligence, and Robotics**. They can be introduced to the concept of automation and tasked with researching the environmental and social impacts of automated systems. Specifically, they can research transportation systems in Pennsylvania and consider the benefits of automating forms of transportation for Pennsylvania residents (e.g., self-driving electric cars

on the turnpike). Then students could be introduced to microcontrollers (middle school) or more complex microcomputers (high school) and sensors that they must program to safely perform specific tasks. This could result in programming line followers, reed switches, and magnets to sense when a vehicle reaches a specified marker representing a traffic light or turnpike toll plaza. Considerations in designing these types of automated systems address the **Technology and Engineering habit of mind - Empathy and Creativity**. The physical computing aspect of designing and creating a prototype of an automated transportation system relates to the **Technology and Engineering Practice of Safety and Making and Doing.**

- Students can apply **standard/benchmark 4H.M.,** *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.**

Appendix E. Intersection of Pennsylvania's Career Ready Skills, Dispositions, and Habits of Mind

Stakeholder engagement sessions captured stakeholder feedback regarding the dispositions all students should learn and be able to do as a part of a comprehensive K-12 science program. Using the student dispositions recommended by stakeholders, the Pennsylvania Career Ready Skills Continuum, and research on habits of mind and the inclusion of dispositions in exemplar academic standards, committee members proposed lists of habits of mind relevant to the academic disciplines and the needs of Pennsylvania learners. Appendix E presents a crosswalk of the committee's habits of mind with the Pennsylvania Career Ready Skills to show the relationships and overlap of each. Educators can use this resource in conjunction with the PA Career Ready Skills Continuum to identify ways to integrate teaching science, environment and ecology, and technology and engineering with related employability skills at any grade level.

Habits of Mind/Dispositions Aligned to Pennsylvania Career Ready Skills
Domain of Pennsylvania Career Ready Skills
A. Self-Awareness and Self-Management (Recognize and regulate emotions) *Related employability skills:* Respect, Dependability and Reliability, Communication, Professionalism, Teamwork, Integrity, Business Fundamentals, Adaptability, Initiative, Planning and Organizing
B. Establishing and Maintaining Relationships (Communicate and collaborate amongst diversity) *Related employability skills:* Problem-Solving, Decision Making, Critical Thinking, Integrity, Teamwork, Adaptability, Professionalism, Communication, Respect
C. Social Problem-Solving Skills (Demonstrate empathy and respectful choice) *Related employability skills:* Teamwork, Integrity, Communication, Respect, Customer Focus, Critical Thinking, Professionalism, Reading, Writing, Problem-Solving

PA Career Ready Skills Domains That Align to Each of the Dispositions/Habits of Mind

Science Core Ideas and Practices

Dispositions/ Habits of Mind	Domain A: Self-Awareness and Self-Management	Domain B: Establishing and Maintaining Relationships	Domain C: Social Problem-Solving Skills
Resilience or grit			
Intellectual curiosity			
Empathy			○

Dispositions/ Habits of Mind	Domain A: Self-Awareness and Self-Management	Domain B: Establishing and Maintaining Relationships	Domain C: Social Problem-Solving Skills
Integrity	○	○	○
Self-efficacy			
Adaptability	○	○	
Initiative	○		
Open-minded			
Drive			
Ownership			
Advocate			
Ethical			
Self-awareness/self-management	○		
Establishing and maintaining relationships		○	
Social problem-solving		○	○

Environment and Ecology Core Ideas and Practices

Dispositions/ Habits of Mind	Domain A: Self-Awareness and Self-Management	Domain B: Establishing and Maintaining Relationships	Domain C: Social Problem-Solving Skills
Patience			
Teamwork	○	○	○
Trial and error			
Individual resiliency			
Critical thinking		○	○
Collaboration		○	
Recognizing rights and responsibilities			
Recognizing efficacy and developing agency	○		
Accepting personal responsibility			

Dispositions/ Habits of Mind	Domain A: Self-Awareness and Self-Management	Domain B: Establishing and Maintaining Relationships	Domain C: Social Problem-Solving Skills
Working with flexibility, creativity and openness		○	
Self-awareness/Self-management	○	○	
Establishing and maintaining relationships		○	
Social problem-solving			○

Technology and Engineering Practices

Dispositions/ Habits of Mind	Domain A: Self-Awareness and Self-Management	Domain B: Establishing and Maintaining Relationships	Domain C: Social Problem-Solving Skills
Creativity			
Persistence (goal directed) and perseverance			
Empathy		○	○
Collaboration		○	
Communication	○	○	○
Attention to ethics			
Systems thinking			
Critical thinking		○	○
Self-awareness/Self-management	○	○	
Establishing and maintaining relationships		○	
Social problem-solving			○

The Pennsylvania Career Ready Skills Continuum is available from PDE at: https://www.education.pa.gov/K-12/CareerReadyPA/CareerReadySkills/Toolkit/Pages/Continuum.aspx