Technology/Engineering, High School

Learning Standards for a Full First-Year Course

I. Content Standards

(Suggested learning activities related to the high school Technology/Engineering learning standards are listed on pages 98–99.)

1. Engineering Design

Central Concepts: Engineering design involves practical problem solving, research, development, and invention/innovation, and requires designing, drawing, building, testing, and redesigning. Students should demonstrate the ability to use the engineering design process to solve a problem or meet a challenge.

1.1 Identify and explain the steps of the engineering design process: identify the problem, research the problem, develop possible solutions, select the best possible solution(s), construct prototypes and/or models, test and evaluate, communicate the solutions, and redesign.

1.2 Understand that the engineering design process is used in the solution of problems and the advancement of society. Identify examples of technologies, objects, and processes that have been modified to advance society, and explain why and how they were modified.

1.3 Produce and analyze multi-view drawings (orthographic projections) and pictorial drawings (isometric, oblique, perspective), using various techniques.

1.4 Interpret and apply scale and proportion to orthographic projections and pictorial drawings (e.g., ¼" = 1'0", 1 cm = 1 m).

1.5 Interpret plans, diagrams, and working drawings in the construction of prototypes or models.

2. Construction Technologies

Central Concepts: The construction process is a series of actions taken to build a structure, including preparing a site, setting a foundation, erecting a structure, installing utilities, and finishing a site. Various materials, processes, and systems are used to build structures. Students should demonstrate and apply the concepts of construction technology through building and constructing either full-size models or scale models using various materials commonly used in construction. Students should demonstrate the ability to use the engineering design process to solve a problem or meet a challenge in construction technology.

2.1 Identify and explain the engineering properties of materials used in structures (e.g., elasticity, plasticity, R value, density, strength).

2.2 Distinguish among tension, compression, shear, and torsion, and explain how they relate to the selection of materials in structures.

2.3 Explain Bernoulli's principle and its effect on structures such as buildings and bridges.

2.4 Calculate the resultant force(s) for a combination of live loads and dead loads.

2.5 Identify and demonstrate the safe and proper use of common hand tools, power tools, and measurement devices used in construction.

2.6 Recognize the purposes of zoning laws and building codes in the design and use of structures.

3. Energy and Power Technologies—Fluid Systems

Central Concepts: Fluid systems are made up of liquids or gases and allow force to be transferred from one location to another. They can also provide water, gas, and/or oil, and/or remove waste. They can be moving or stationary and have associated pressures and velocities. Students should demonstrate the ability to use the engineering design process to solve a problem or meet a challenge in a fluid system.

3.1 Explain the basic differences between open fluid systems (e.g., irrigation, forced hot air system, air compressors) and closed fluid systems (e.g., forced hot water system, hydraulic brakes).

3. Energy and Power Technologies—Fluid Systems (cont.)

3.2 Explain the differences and similarities between hydraulic and pneumatic systems, and explain how each relates to manufacturing and transportation systems.
3.3 Calculate and describe the ability of a hydraulic system to multiply distance, multiply force, and effect directional change.
3.4 Recognize that the velocity of a liquid moving in a pipe varies inversely with changes in the cross-sectional area of the pipe.
3.5 Identify and explain sources of resistance (e.g., 45º elbow, 90º elbow, changes in diameter) for water moving through a pipe.

4. Energy and Power Technologies—Thermal Systems

Central Concepts: Thermal systems involve transfer of energy through conduction, convection, and radiation, and are used to control the environment. Students should demonstrate the ability to use the engineering design process to solve a problem or meet a challenge in a thermal system.

4.1 Differentiate among conduction, convection, and radiation in a thermal system (e.g., heating and cooling a house, cooking).
4.2 Give examples of how conduction, convection, and radiation are considered in the selection of materials for buildings and in the design of a heating system.
4.3 Explain how environmental conditions such as wind, solar angle, and temperature influence the design of buildings.
4.4 Identify and explain alternatives to nonrenewable energies (e.g., wind and solar energy conversion systems).

5. Energy and Power Technologies—Electrical Systems

Central Concepts: Electrical systems generate, transfer, and distribute electricity. Students should demonstrate the ability to use the engineering design process to solve a problem or meet a challenge in an electrical system.

5.1 Explain how to measure and calculate voltage, current, resistance, and power consumption in a series circuit and in a parallel circuit. Identify the instruments used to measure voltage, current, power consumption, and resistance.
5.2 Identify and explain the components of a circuit, including sources, conductors, circuit breakers, fuses, controllers, and loads. Examples of some controllers are switches, relays, diodes, and variable resistors.
5.3 Explain the relationships among voltage, current, and resistance in a simple circuit, using Ohm's law.
5.4 Recognize that resistance is affected by external factors (e.g., temperature).
5.5 Compare and contrast alternating current (AC) and direct current (DC), and give examples of each.

6. Communication Technologies
Central Concepts: Applying technical processes to exchange information can include symbols, measurements, icons, and graphic images. Students should demonstrate the ability to use the engineering design process to solve a problem or meet a challenge in a communication technology.

6.1 Explain how information travels through the following media: electrical wire, optical fiber, air, and space.
6.2 Differentiate between digital and analog signals. Describe how communication devices employ digital and analog technologies (e.g., computers, cell phones).
6.3 Explain how the various components (source, encoder, transmitter, receiver, decoder, destination, storage, and retrieval) and processes of a communication system function.
6.4 Identify and explain the applications of laser and fiber optic technologies (e.g., telephone systems, cable television, photography).
6.5 Explain the application of electromagnetic signals in fiber optic technologies, including critical angle and total internal reflection.

7. Manufacturing Technologies
Central Concepts: Manufacturing processes can be classified into six groups: casting/molding, forming, separating, conditioning, assembling, and finishing. Students should demonstrate the ability to use the engineering design process to solve a problem or meet a challenge in a manufacturing technology.

7.1 Describe the manufacturing processes of casting and molding, forming, separating, conditioning, assembling, and finishing.
7.2 Identify the criteria necessary to select safe tools and procedures for a manufacturing process (e.g., properties of materials, required tolerances, end-uses).
7.3 Describe the advantages of using robotics in the automation of manufacturing processes (e.g., increased production, improved quality, safety).

II. Steps of the Engineering Design Process

Students should be provided opportunities for hands-on experiences to design, build, test, and evaluate (and redesign, if necessary) a prototype or model of their solution to a problem. Students should have access to materials, hand and/or power tools, and other resources necessary to engage in these tasks. Students may also engage in design challenges that provide constraints and specifications to consider as they develop a solution to a problem.

Steps of the Engineering Design Process*
1. Identify the need or problem
2. Research the need or problem
   - Examine current state of the issue and current solution(s)
   - Explore other options via the Internet, library, interviews, etc.
3. Develop possible solution(s)
   - Brainstorm possible solution(s)
   - Draw on mathematics and science
   - Articulate the possible solution(s) in two and three dimensions
   - Refine the possible solution(s)

Steps of the Engineering Design Process (cont.)

4. Select the best possible solution(s)
    - Determine which solution(s) best meet(s) the original requirements
5. Construct one or more prototypes and/or models
    - Model the selected solution(s) in two and three dimensions
6. Test and evaluate the solution(s)
    - Does it work?
    - Does it meet the original design constraints?
7. Communicate the solution(s)
    - Make an engineering presentation that includes a discussion of how the solution(s) best meet(s) the needs of the initial problem or need
    - Discuss societal impact and tradeoffs of the solution(s)
8. Redesign
    - Modify the solution(s) based on information gathered during the tests and presentation

**The Engineering Design Process is also listed under the first content standard of the Engineering Design subtopic in this course.*

III. Mathematical Skills

Students are expected to know the content of the *Massachusetts Mathematics Curriculum Framework,* through grade 8. Below are some specific skills from the *Mathematics Framework* that students in this course should have the opportunity to apply:

- ✓ Construct and use tables and graphs to interpret data sets.
- ✓ Solve simple algebraic expressions.
- ✓ Perform basic statistical procedures to analyze the center and spread of data.
- ✓ Measure with accuracy and precision (e.g., length, volume, mass, temperature, time)
- ✓ Use both metric/standard international (SI) and U.S. Customary (English) systems of measurement.
- ✓ Convert within a unit (e.g., centimeters to meters, inches to feet).
- ✓ Use common prefixes such as *milli-, centi-,* and *kilo-*.
- ✓ Use scientific notation, where appropriate.
- ✓ Use ratio and proportion to solve problems.

The following skills are not detailed in the *Mathematics Framework*, but are necessary for a solid understanding in this course:

- ✓ Determine the correct number of significant figures.
- ✓ Determine percent error from experimental and accepted values.
- ✓ Use appropriate metric/standard international (SI) units of measurement for mass (kg); length (m); time (s); power (W); electric current (A); electric potential difference/voltage (V); and electric resistance (Ω).
- ✓ Use the Celsius and Fahrenheit scales.

What It Looks Like in the Classroom

A Look at Energy-Efficient Homes

Adapted from *Standards for Technological Literacy*, p. 197

Technology/Engineering, High School

The city of Westlake and the surrounding areas experienced an accelerated growth in the construction industry, especially in new home construction. The local high school technology teacher, Mr. Morales, thought it would be helpful for his students, as future consumers, to have an in-depth understanding of the housing industry and to know about the latest developments in home construction techniques, materials, and practices.

Mr. Morales decided to organize a lesson where students were invited to participate in designing an energy-efficient home for a family of four. He guided the students to consider all forms of energy and not to limit their imaginations. Students were instructed to consider costs of using energy-efficient designs and how those costs might affect the resale value of a home.

He instructed the students in his technology class to individually design, draw, and build a scale model of a residential home using heating and cooling systems that were energy-efficient, aesthetically pleasing, functional, marketable, and innovative. The house also had to accommodate a family of four with a maximum size of 2100 square feet. Each student had to work within a budget of $150,000, and had nine weeks to complete the project.

The students began by researching homes in their city that already incorporated features that were required in their project. They conducted library and Internet searches to learn about the latest materials and techniques available in the housing industry. Students also interviewed local architects and building contractors to learn about current practices and how these professionals were integrating innovative features. For example, the students learned about incorporating increased day lighting, which takes into account the home's orientation, into the design of the home. They also learned about designing and installing environmentally sound, energy-efficient systems and incorporating whole-home systems that are designed to provide house maintenance, home security, and indoor air-quality management.

The students then began the process of sketching their homes. Many students had to gather additional research as they realized they needed more information to complete their sketches. Using their sketches, the students built scale models of their homes out of mat board.

A group of building industry professionals from across the area was invited to evaluate students' work and provide feedback on their ideas in several categories, including design, planning, innovation, energy conservation features, drawing presentation, model presentation, and exterior design.

As a result of this experience, the students learned firsthand what it takes to design a home for the 21st century. Students also learned how to successfully plan and select the best possible solution from a variety of design ideas in order to meet criteria and constraints, as well as how to communicate their results using graphic means and three-dimensional models.

WHAT IT LOOKS LIKE IN THE CLASSROOM

Assessment Strategies

- Students can research building codes and zoning laws in the community, then each can write a detailed informational report.
- Students can compare construction efficiency for various house designs, evaluating the advantages and disadvantages of each design (e.g., ranch vs. colonial, lumber vs. steel framework). They can then create a chart illustrating the differences.
- Students can create an engineering presentation illustrating the design and efficiency of the prototype, using appropriate visual aids (e.g., charts, graphs, presentation software). The presentation should include any other factors that impact the design of the house (e.g., site, soil conditions, climate).
- Students will use a rubric to assess design specification, heat efficiency, and final prototype of the design challenge.

Engineering Design Learning Standards

High School

1.2 Understand that the engineering design process is used in the solution of problems and the advancement of society. Identify examples of technologies, objects, and processes that have been modified to advance society, and explain why and how they were modified.

1.3 Produce and analyze multi-view drawings (orthographic projections) and pictorial drawings (isometric, oblique, perspective), using various techniques.

1.4 Interpret and apply scale and proportion to orthographic projections and pictorial drawings (e.g., ¼" = 1'0", 1 cm = 1 m).

1.5 Interpret plans, diagrams, and working drawings in the construction of prototypes or models.

Construction Technologies Learning Standards

High School

2.1 Identify and explain the engineering properties of materials used in structures (e.g., elasticity, plasticity, R value, density, strength).

2.6 Recognize the purposes of zoning laws and building codes in the design and use of structures.

Energy and Power Technologies—Thermal Systems Learning Standards

High School

4.2 Give examples of how conduction, convection, and radiation are considered in the selection of materials for buildings and in the design of a heating system.

4.3 Explain how environmental conditions such as wind, solar angle, and temperature influence the design of buildings.

Suggested Learning Activities for High School Technology/Engineering Learning Standards

Please note: The number(s) in parentheses following each suggested learning activity refer to the related high school Technology/Engineering learning standard(s).

1. Engineering Design

- Create an engineering design presentation using multimedia, oral, and written communication. (1.1)
- Choose the optimal solution to a problem, clearly documenting ideas against design criteria and constraints, and explain how human values, economics, ergonomics, and environmental considerations have influenced the solution. (1.1)
- Visit a local industry in any area of technology and describe the research and development processes of the company. (1.1, 1.5)
- Have students utilize library/Internet resources to research the patent process. (1.1, 1.2, 1.5)
- Create pictorial and multi-view drawings that include scaling and dimensioning. (1.2, 1.3, 1.4, 1.5)
- Create plans, diagrams, and working drawings in the construction of a prototype. (1.2, 1.3, 1.4, 1.5)

2. Construction Technologies

- Demonstrate the transmission of loads for buildings and other structures. (2.1, 2.2, 2.6)
- Construct a truss and analyze to determine whether the members are in tension, compression, shear, and/or torsion. (2.1, 2.3, 2.4, 2.5)
- Given several types of measuring tools and testing tools, give students a challenge and have them evaluate the effectiveness of a tool for the given challenge. (2.2)
- Construct and test geometric shapes to determine their structural advantages depending on how they are loaded. (2.3, 2.5, 2.6)
- Using a chart from the state building code, students should be able to correctly use the stress-strain relationship to calculate the floor joist size needed. (2.4, 2.6)
- Design and conduct a test for building materials (e.g., density, strength, thermal conductivity, specific heat, moisture resistance). (2.4, 2.5)
- Calculate the live load for the second floor of a building and show how that load is distributed to the floor below. (2.5, 2.6)
- Identify ways to protect a watershed (e.g., silt barriers, hay bales, maintenance of watershed areas). (2.5)

3. Energy and Power Technologies—Fluid Systems

- Demonstrate how appropriate selection of piping materials, pumps, and other materials is based on hydrostatic effects. (3.1, 3.5)
- Demonstrate how a hydraulic brake system operates in an automobile. (3.1, 3.5)
- Design a private septic system while considering the type of soil in the leach field. (3.1, 3.4)
- Identify similar and differing elements of a public sewer system and a private septic system. (3.1, 3.4)
- Explain engineering control volume concepts as applied to a domestic water system. Does the amount of water entering a residence equal the amount of water leaving the residence? (3.5)
- Design an airfoil or spoiler to demonstrate Bernoulli's principle. (3.3)
- Create a hydraulic arm powered by pistons that is capable of moving in three dimensions. (3.4)

Suggested Learning Activities for High School Technology/Engineering Learning Standards

3. Energy and Power Technologies—Fluid Systems (cont.)

- Have students do a simple calculation with velocity and cross-sectional pipe size. Velocity times cross-sectional area is a constant. As the pipe size changes, the velocity will have to change as well. For example, if the pipe changes from a 2-inch diameter to a 1-inch diameter, the velocity will quadruple. (3.5)

4. Energy and Power Technologies—Thermal Systems

- Create a model (e.g., the multi-layer wall of a building) to test the concept of conduction, and compute heat losses. (4.1, 4.2, 4.4)
- Design and build a hot water solar energy system consisting of a collector, hoses, pump (optional), and storage tank. After the system has been heated, calculate the heat gains achieved through solar heating. (4.1)
- Design and build a model to test heat losses through various materials and plot the results. (4.2, 4.5)
- Design and build a solar cooker for various food substances. Each student should design a solar cooker for her or his specific food. (4.1, 4.2)
- Design an awning for a business based upon seasonal changes and the angles of the sun. (4.2)

5. Energy and Power Technologies—Electrical Systems

- Design and create an electrical system containing a source, a switch, and multiple loads. Be able to measure the voltage and current at each load. (5.2)
- Design and create an electrical system with either motors, all operating at different speeds, or lamps, all operating at different intensities. (5.2, 5.3)
- Create schematics for series, parallel, and combination (series-parallel) circuits, and construct each type of circuit from its schematic. (5.4)

6. Communication Technologies

- Give an example of each of the following types of communication: human to human (talking), human to machine (telephone), machine to human (facsimile machine), and machine to machine (computer network). (6.4)
- Create prototypes for the following specific types of communication: human to human (e.g., talking, telephone), human to machine (e.g., keyboard, cameras), machine to human (e.g., CRT screen, television, printed material), machine to machine (e.g., CNC, internetworking). (6.2, 6.3, 6.4)
- Define size and focal length for a lens and explain their applications in light theory. (6.5)
- Research a communication technology and the impact that lasers or fiber optics have had on that technology. (6.4, 6.5)

7. Manufacturing Technologies

- Design a system for mass producing a product. (7.1, 7.2)
- Design, build, and program a robotic device capable of moving through three axes. (7.3)