TENNESSEE DEPARTMENT OF EDUCATION
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Energy and the Environment (PLTW)

Primary Career Cluster:	Science, Technology, Engineering, and Mathematics (STEM)
Consultant:	Bethany King Wilkes, (615) 532-2844, Bethany.Wilkes@tn.gov
Course Code:	~~TBD~~0886
Prerequisite(s):	None
Credit:	N/A
Grade Level:	8
Graduation Requirement:	N/A
Coursework and Sequence:	This is ~~the first~~a course in the *Project Lead the Way (PLTW)* middle school sequence of coursework.
Necessary Equipment:	Visit www.pltw.org for more information.
Aligned Student Organization(s):	Technology Student Association (TSA):http://www.tntsa.org Amanda Hodges, (615) 532-6270, Amanda.Hodges@tn.gov
Coordinating Work-Based Learning:	N/A
Available Student Industry Certifications:	N/A
Dual Credit or Dual Enrollment Opportunities:	N/A
Teacher Endorsement(s):	001, 013, 014, 015, 016, 017, 018, 047, 070, 078, 081, 101, 210, 211, 212, 213, 214, 230, 231, 232, 233, 400, 401, 402,413, 414, 415, 416, 417, 418, 440, 470, 477
Required Teacher Certifications/Training:	*Project Lead the Way* training is required
Teacher Resources:	http://www.tn.gov/education/cte/doc/STEMResourceList.pdf

Course Description

This is a course in the series of *Project Lead the Way (PLTW)* curriculum. For more information, visit the PLTW website at http://www.pltw.org/.

Program of Study Application

These courses build knowledge and skills related to the following career clusters:

1) Architecture & Construction
2) Information Technology (IT)
3) Manufacturing
4) Science, Technology, Engineering & Mathematics (STEM)
5) Transportation, Distribution, & Logistics

Course Standards

The course standards outlined below are the copyrighted property of *Project Lead the Way*. Teachers must participate in *Project Lead the Way* training in order to be able to teach this course. This course is one in a series of PLTW middle school courses. The lesson numbers below reflect the recommended sequence.

Lesson 3.1 Investigating Energy (14 days)

Understandings

1) Two types of energy exist: potential (stored energy) and kinetic (energy in motion).
2) Energy sources can be renewable, exhaustible, or inexhaustible. There are advantages and disadvantages to each.
3) The six main forms of energy include solar or light radiation, thermal, electrical, mechanical, chemical, and nuclear.
4) Energy efficiency and conservation are necessary in order to minimize pollution, improve business/economy, reduce dependence on foreign sources, and reduce our carbon footprint to create a sustainable world.
5) Energy can be transferred, or moved, from one object to another.
6) Energy can be transformed, or changed, from one form to another.
7) The second law of thermodynamics states that not all energy is 100 percent efficient when it is converted from one form to another.
8) Work is measured in Joules and is defined as force acting over a distance. Power is measured in Watts and is defined by how fast work is done.
9) Engineers, designers, and engineering technologists are high demand for the development of future technology to meet societal needs and wants.

Knowledge and Skills

It is expected that students will:

- Describe the differences between, and the advantages and disadvantages of exhaustible, inexhaustible, renewable, and non-renewable energy sources.
- Describe the six main forms of energy; including solar or light radiation, thermal, electrical, mechanical, chemical, and nuclear.
- Differentiate between potential and kinetic energy.
- Identify global energy uses and explain trends toward future demands.
- Demonstrate ways to increase the efficiency of energy used in homes and at school.
- Calculate financial savings and explain effects of our carbon footprint as a result of using energy efficiently.
- Use the design process to design, model, and test a wind turbine for efficiency.
- Calculate power and work by measuring force, distance, and time using the wind turbine model.

- Describe the roles and responsibilities of STEM professionals for high demand technological careers.

Lesson 3.2 Sustainable Energy (15 days)

Understandings
There are events and issues that challenge us to use energy wisely and to develop alternate forms of energy, including economic and population growth, natural disasters, and conflicts with countries that provide the United States with oil.

1) Fossil fuel use and greenhouse gas emissions can be reduced by using innovative means to implement renewable and inexhaustible energy sources.
2) Energy sources can be used to produce electricity and hydrogen, energy carriers that provide the greatest diversity and lowest impact on the environment.
3) Decisions regarding the implementation of alternative energy sources involve the weighing of tradeoffs between predicted positive and negative effects on the environment and financial burden.
4) Careers in sustainable engineering will be created because our planet needs environmentally sustainable solutions to support population growth and preserve our limited natural resources.

Knowledge and Skills
It is expected that students will:

- Graph data that represents energy consumption, energy imports, and energy production.
- Recognize that alternative energies are not always available in every location.
- Recognize that the solution to our energy needs now and in the future will include conservation and wise use of resources as well as a wide variety of sources.
- Describe the roles and responsibilities of STEM careers that help solve environmental problems.
- Identify alternative forms of energy, explain why they are alternative, and identify the advantages and disadvantages of each.
- Identify challenges in transferring alternative energies from where they are produced to where they are consumed.
- Research an alternative energy solution used for a specific purpose that will reduce the nation's dependency on fossil fuels.

Lesson 3.3 Making a~~A~~n Impact (16 days)

Understandings

1) Water plays a critical role in our daily lives; it should be used wisely and users should be conscientious about conserving water.
2) Environmental engineering focuses on developing a sustainable future, preventing pollution, and assessing the environmental impact of integrated waste management systems.
3) The seven steps of integrated waste management include reduce, reuse, recycle, compost, incineration that creates usable energy, landfills, and incineration with no usable energy created.
4) Engineers must consider a product's life cycle when designing because every product has an impact on the environment.
5) Every individual impacts the environment through the choices they make in energy consumption and garbage disposal.

6) Using energy efficiently will reduce the need for new power plants and utility infrastructure and will reduce the need to burn fossil fuels to produce energy, thereby reducing greenhouse gas emissions that contribute to climate change.
7) Heat transfer occurs through conduction, convection, and radiation.

Knowledge and Skills
It is expected that students will:

- Calculate daily water consumption for a building such as a home or school and recommend water conservation strategies.
- Identify ways that individuals can reduce the effect on the environment through their energy choices and garbage disposal.
- Identify how STEM professionals are involved in integrated waste management and other environmental careers.
- Understand the difference between energy conservation and energy efficiency and be able to calculate both.
- Differentiate between conduction, convection, and radiation as forms of energy transfer.
- Compare the temperature of different materials to determine which are better at preventing heat transfer.
- Design an experiment to investigate the prevention of heat transfer.
- Evaluate a design to reduce heat transfer by weighing the amount of ice remaining; propose improvements for the design.

TENNESSEE DEPARTMENT OF EDUCATION
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Engineering Design I

Primary Career Cluster:	Science, Technology, Engineering, and Mathematics (STEM)
Consultant:	Bethany King Wilkes, (615) 532-2844, Bethany.Wilkes@tn.gov
Course Code:	6139
Prerequisite(s):	*Principles of Engineering & Technology* (5924) (recommended); *Algebra I* (3102); and *Physical Science* (3202) or *Biology* (3210)
Co-requisite:	*Geometry* (3108)
Credit:	1
Grade Level:	10
Graduation Requirement:	This course satisfies one of three credits required for an elective focus when taken in conjunction with other STEM courses.
Programs of Study and Sequence:	This is the second course in the *Engineering* program of study.
Necessary Equipment:	Equipment lists can be found at http://www.tn.gov/education/cte/ScienceTechnologyEngineeringMathematics.shtml.
Aligned Student Organization(s):	Skills-USA: http://www.tnskillsusa.com Brandon Hudson, (615) 532-2804, Brandon.Hudson@tn.gov Technology Student Association (TSA): http://www.tntsa.org Amanda Hodges, (615) 532-6270, Amanda.Hodges@tn.gov
Coordinating Work-Based Learning:	If a teacher has completed work-based learning training, he or she can offer appropriate ~~student~~ placement ~~can be offered~~. To learn more, please visit http://www.tn.gov/education/cte/wb/.
Available Student Industry Certifications:	~~None~~Students may be qualified to sit for the American Design Drafting Association (ADDA) Certification Exam upon completion of the *Engineering Design* program of study.
Dual Credit or Dual Enrollment Opportunities:	There are no known dual credit/dual enrollment opportunities for this course. If interested in developing, reach out to a local postsecondary institution to establish an articulation agreement.
Teacher Endorsement(s):	013, 014, 015, 016, 017, 018, 047, 070, 078, 081, 210, 211, 212, 213, 214, 413, 414, 415, 416, 417, 418, 230, ~~231~~, 232, 233, 470, 477, 519, 531, 595, 596
Required Teacher Certifications/Training:	Teachers who have never taught this course must attend training provided by the Department of Education.
Teacher Resources:	http://www.tn.gov/education/cte/ScienceTechnologyEngineeringMathematics.shtml~~doc/STEMResourceList.pdf~~

Course Description

Engineering Design I is a fundamental course in the STEM cluster for students interested in developing their skills in preparation for careers in engineering and technology. The course covers essential knowledge, skills, and concepts required for postsecondary engineering and technology fields of study. Upon completion of this course, proficient students are able to describe various engineering disciplines, as well as admissions requirements for postsecondary engineering and engineering technology programs in Tennessee. They will also be able to identify simple and complex machines; calculate various ratios related to mechanisms; explain fundamental concepts related to energy; understand Ohm's Law; follow the steps in the engineering design process to complete a team project; and effectively communicate design solutions to others. Standards in this course are aligned with Tennessee Common Core State Standards in English Language Arts & Literacy in Technical Subjects and Tennessee Common Core State Standards in Mathematics.*

Note: Students are expected to use engineering notebooks to document procedures, design ideas, and other notes for all projects throughout the course.

Program of Study Application

This is the second course in the *Engineering* program of study. For more information on the benefits and requirements of implementing this program in full, please visit the STEM website at http://www.tn.gov/education/cte/ScienceTechnologyEngineeringMathematics.shtml.

Course Standards

Safety

1) Accurately read and interpret safety rules, including but not limited to rules published by the National Science Teachers Association (NSTA), rules pertaining to electrical safety, Occupational Safety and Health Administration (OSHA) guidelines, and state and national code requirements. Be able to distinguish between the rules and explain why certain rules apply. (TN CCSS Reading 3, 4, 6)

2) Identify and explain the intended use of safety equipment available in the classroom. For example, demonstrate how to properly inspect, use, and maintain safe operating procedures with tools and equipment. Incorporate safety procedures and complete safety test with 100 percent accuracy. (TN CCSS Reading 3, 4)

Career Exploration

3) In teams, use an online editing tool to develop an informational paper or infographic illustrating various engineering disciplines (e.g., civil, mechanical, electrical, chemical, biomedical, computer, agricultural, industrial, and aerospace). The descriptions should contain definitions, job roles, professional societies, and applicable licenses and/or certifications associated with each discipline. Use a variety of sources to gather data, cite each source, and briefly describe why the chosen source is reliable. (TN CCSS Reading 1, 7, 8; TN CCSS Writing 2, 6, 8)

4) Research the postsecondary institutions (colleges of applied technology, community colleges, and four-year universities) in Tennessee and other states that offer engineering or engineering

technology programs. Write an informative paper or develop an infographic identifying admissions criteria, the postsecondary programs of study, and the secondary courses that will prepare individuals to be successful in a postsecondary engineering or engineering technology program. (TN CCSS Reading 1, 5; TN CCSS Writing 4)

Engineering Design Process

5) Compare and contrast the following engineering design process with the following eight common practices of science and engineering (Achieve, 2013). Based on observations, write a brief paper explaining how the engineering design process and the practices overlap. Present findings to the class and refine the paper based on feedback. (TN CCSS Reading 2, 5; TN CCSS Writing 2, 5)

Engineering Design Process	Science and Engineering Practices
a) Identify the problem	a) Asking questions (for science) and defining problems (for engineering)
b) Identify criteria and specify constraints	b) Developing and using models
c) Brainstorm possible solutions	c) Planning and carrying out investigations
d) Research and generate ideas	d) Analyzing and interpreting data
e) Explore alternative solutions	e) Using mathematics and computational thinking
f) Select an approach	f) Constructing explanations (for science) and designing solutions (for engineering)
g) Write a design proposal	g) Engaging in argument from evidence
h) Develop a model or prototype	h) Obtaining, evaluating, and communicating information
i) Test and evaluate	
j) Refine and improve	
k) Create or make a product	
l) Communicate results	

Problem-Solving Format

6) Apply a problem-solving format for assigned engineering problems. The format should include the *problem statement* with illustration (e.g., free body diagram), what is *given,* what the student is asked to *find,* a list of assumptions, a list of equations to be used to solve the problem, and the step-by-step solution. (TN CCSS Reading 3; TN CCSS Writing 4)

Engineering Drawing**

7) Define the differences in technique among freehand sketching, manual drafting, and computer-aided drafting (CAD), and describe the skills required for each. Create a two-dimensional orthographic (multiview) drawing incorporating labels, notes, and dimensions, using sketching/geometric construction techniques. Apply basic dimensioning rules and properly use different types of lines (e.g., object, hidden, center). The orthographic projections should

include principle views of a simple object from top, front, and right sides. (TN CCSS Reading 3, 4, 5, 7; TN CCSS Writing 4; TN CCSS Math~~,~~ G-MG)

8) Building on the knowledge of a two-dimensional drawing, create complex~~simple~~ isometric (3-D pictorial) drawings, properly using lines (e.g., object, hidden, center), labels, and dimensioning techniques. (TN CCSS Reading 3, 4, 5, 7; TN CCSS Writing 4; TN CCSS Math~~,~~ G-MG)

9) Use CAD software to create simple two-dimensional and three-dimensional drawings, accurately incorporating labels, notes, dimensioning, and line types to design drawings. Perform basic operations such as creating, saving files, opening files, storing files, and printing. (TN CCSS Reading 3, 4, 5, 7; TN CCSS Writing 4; TN CCSS Math~~,~~ G-MG)

**Students who successfully completed Principles of Engineering and Technology *will already have foundational skills in Engineering Drawing, however these concepts should be reviewed. If students have not taken the* Principles *class, please cover these standards in full.*

Work, Force, Power & Machines

~~7)~~10) Drawing on relevant technical documents, define and identify at least one application for each of the six simple machines listed below. Describe each with sketches and proper notation in an engineering notebook.

a. Inclined plane
b. Wedge
c. Lever
d. Wheel and axle
e. Pulley
f. Screw

In addition, define a combination of two or more simple machines working together as a compound machine, and identify at least one application of the compound machine. (TN CCSS Reading 1; TN CCSS Writing 2, 4, 7)

~~8)~~11) In teams, document the process of completing a simple project, such as building or using one or more simple machines. Participate in and describe each engineering design process step in an engineering notebook. Create a physical prototype or model based on the constraints specified in the project and the data gathered in the process of development. (TN CCSS Reading 3, TN CCSS Writing 2, 7)

~~9)~~12) Calculate force, work, and power, and apply these formulae to solve engineering problems as outlined by the instructor. Articulate specific scenarios in which an engineer must calculate force, work, and power. (TN CCSS Reading 3, 4, 5; TN CCSS Math N-Q)

~~10)~~13) Calculate the ideal mechanical advantage and actual mechanical advantage, and explain to classmates what this concept means in the context of engineering. Given a specified engineering problem, calculate the efficiency of a machine when the ideal mechanical advantage and actual mechanical advantage are known. (TN CCSS Reading 5; TN CCSS Math N-Q, A-SEE, A-CED, A-REI)

Mechanisms

~~11)~~14) Explain the definition of a mechanism. Interpret technical information in design problems to identify types of mechanisms such as:

a. Linkages
b. Cam and follower
c. Bearings
d. Gears
e. Sprockets and chain
f. Drives

Explain the typical application and operation in systems of the components listed above, citing measurement and/or observed evidence to support explanations. (TN CCSS Reading 1, 4, 5; TN CCSS Writing 2)

~~12)~~15) Create equations that describe relationships to solve engineering problems using formulae such as gear ratio, speed ratio, torque, and torque ratio. For example, understand that if a gear ratio is 2, the input gear must make two complete revolutions to every one revolution that the output gear makes. (TN CCSS Reading 4, 5; TN CCSS Math A-CED)

Energy

~~13)~~16) Write an explanatory text defining energy, in particular its use in engineering, drawing on engineering texts and other technical documents. In addition, identify and explain the different forms of energy. The explanation should include the categorization of various forms of energy such as potential or kinetic. (TN CCSS Reading 2, 4, 5; TN CCSS Writing 2, 4)

~~14)~~17) Draw on engineering texts and other technical documents to synthesize and explain the concept of heat. Include definitions of the different temperature scales such as Fahrenheit, Celsius, and Kelvin. Furthermore, explain the three forms of heat transfer: conduction, convection, and radiation. (TN CCSS Reading 2, 4; TN CCSS Writing 2, 4, 8)

~~15)~~18) Understand and solve problems in specific engineering contexts involving conversion from one unit of energy such as British Thermal Units (Btu), Joule (J), and Calorie (cal) to another. Use this information to calculate the heat needed to change temperature. (TN CCSS Reading 3, 4, 5; TN CCSS Math N-Q)

~~16)~~19) Research print and electronic sources published by government, nonprofit, or engineering organizations to define different renewable energy sources such as biomass, hydroelectric power, geothermal, wind, and solar, as well as nonrenewable energy sources such as petroleum, natural gas, coal, and nuclear energy. In teams, create and deliver a presentation justifying the use of one energy source for their local community; the presentation must contain at least one summary table or graphic. In addition, the presentation should provide an analysis demonstrating the advantage of their selected source over others. (TN CCSS Reading 1, 2, 4, 7, 9; TN CCSS Writing 1, 4, 5, 7, 8, 9)

Electrical Systems

~~17)~~20) Write a technical report describing the subatomic particles (e.g., nucleus, proton, neutron, and electron) that make up an atom. Moreover, cite technical texts to explain how the particles relate to electricity, including characteristics that make materials either conductors or insulators, and explain the relationship between the flow of charge and electrical current at the subatomic and atomic level. (TN CCSS Reading 2, 4, 5; TN CCSS Writing 2, 9)

~~18)~~21) Write an explanatory paper defining, comparing, and contrasting voltage, current, and resistance, incorporating appropriate graphic illustrations (such as diagrams) to complement the narrative. Identify sources of voltage as well. For example, a battery is a source of voltage, and one end of the battery represents a positive charge, while the other end represents a negative charge. (TN CCSS Reading 4, 5, 7; TN CCSS Writing 2, 9; TN CCSS Math N-Q)

~~19)~~22) Calculate voltage, current, and/or resistance in a DC circuit using Ohm's law (V = IR). Explain how Ohm's Law relates voltage, current, and resistance, citing technical examples for illustration. For example, if voltage remains constant and resistance decreases, the current will increase. Given a physical circuit, demonstrate how to measure each using a digital multimeter. Where unexpected behavior is observed, cite specific evidence to explain the observations. Prepare an informative report comparing calculated values with measured values and include an explanation of any sources of error. (TN CCSS Reading 1, 4, 5, 9; TN CCSS Writing 2, 4, 7; TN CCSS Math N-Q)

~~20)~~23) Explain how series and parallel circuits function, including identification of their chief components, characteristics, and differences. Solve problems involving series and parallel circuits including calculating equivalent resistance and calculating voltage and/or current through elements within a circuit. (TN CCSS Reading 3, 4, 5; TN CCSS Writing 4; TN CCSS Math N-Q, A-SEE, A-CED)

Computer Software for Engineering Problem Solving

~~21)~~24) Use computer tools, such as spreadsheet software (e.g., Microsoft Excel), analytical/scientific software (e.g., MATLAB), and/or programming software (e.g., Microsoft Visual Basic) to solve at least one problem from the content described in the standards above. Examples may include the use of spreadsheets to input data from experimental tests and create graphs for presentation, or the use of MATLAB to solve a system of equations. (TN CCSS Reading 5, 7; TN CCSS Writing 9)

Team Project

~~22)~~25) As a team, identify a problem in the school or community. Draft a problem statement to guide a project incorporating engineering concepts from at least three of the content sections (i.e., electrical systems, energy, mechanisms, etc.) outlined above. Follow the engineering design process to solve the problem. Each team will develop a paper following the format of a typical technical report (see components of the report below). Upon completion of the report, create and deliver a presentation for a CTSO event using appropriate citation conventions. Refine the report as would a team of engineers by incorporating feedback from the presentation.

The written report should include, but is not limited to:

a) Background
b) Problem definition
c) Design constraints
d) Methodology
e) Data analysis (e.g., charts, graphs, calculations)
f) Results/Problem solution (including engineering drawings)
g) Conclusions and recommendations for future research.

(TN CCSS Reading 1, 3, 4, 5, 7, 9; TN CCSS Writing 2, 5, 6, 7, 8, 9)

Standards Alignment Notes

*References to other standards include:

- TN CCSS Reading: Common Core State Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects; Reading Standards for Literacy in Science and Technical Subjects 6-12; Grades 9-10 Students (page 62).
    - Note: While not directly aligned to one specific standard, students who are engaging in activities outlined above should be able to also demonstrate fluency in Standard 10 at the conclusion of the course.
- TN CCSS Writing: Common Core State Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects; Writing Standards for Literacy in History/Social Studies, Science, and Technical Subjects 6-12; Grades 9-10 Students (pages 64-66).
    - Note: While not directly aligned to one specific standard, students who are engaging in activities outlined above should be able to also demonstrate fluency in Standards 3 and 10 at the conclusion of the course.
- TN CCSS Math: Common Core State Standards for Mathematics; Math Standards for High School: Number and Quantity, Algebra, Functions, Geometry, Statistics and Probability.
    - Note: The standards in this course are not meant to teach mathematical concepts. However, the concepts referenced above may provide teachers with opportunities to collaborate with mathematics educators to design project-based activities or collaborate on lesson planning. While not aligned to one specific conceptual category, students who are engaging in the activities outlined above should be able to demonstrate quantitative, algebraic, functional, geometric, and statistical reasoning as applied to specific technical concepts. In addition, students will have the opportunity to practice the habits of mind as described in the eight Standards for Mathematical Practice.
- P21: Partnership for 21st Century Skills Framework for 21st Century Learning
    - Note: While not all standards are specifically aligned, teachers will find the framework helpful for setting expectations for student behavior in their classroom and practicing specific career readiness skills.
- Achieve: Next Generation Science Standards. (2013). “A Science Framework for K-12 Science Education.”
- International Technology and Engineering Educators Association (ITEEA). (2013). http://www.iteea.org/.

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Engineering Design II

Primary Career Cluster:	Science, Technology, Engineering, and Mathematics (STEM)
Consultant:	Bethany King Wilkes, (615) 532-2844, Bethany.Wilkes@tn.gov
Course Code:	6140
Prerequisite(s):	*Engineering Design I* (6139); *Algebra I* (3102); *Physical Science* (3202); and *Biology* (3210) or *Chemistry* (3221)
Credit:	1
Grade Level:	11
Graduation Requirement:	This course satisfies one of three credits required for an elective focus when taken in conjunction with other STEM courses.
Programs of Study and Sequence:	This is the third course in the *Engineering* program of study.
Necessary Equipment:	~~Refer to the equipment list found on the STEM website linked below.~~ Equipment lists can be found at http://www.tn.gov/education/cte/ScienceTechnologyEngineeringMathematics.shtml.
Aligned Student Organization(s):	Skills USA: http://www.tnskillsusa.com Brandon Hudson, (615) 532-2804, Brandon.Hudson@tn.gov Technology Student Association (TSA): http://www.tntsa.org Amanda Hodges, (615) 532-6270, Amanda.Hodges@tn.gov
Coordinating Work-Based Learning:	If a teacher has completed work-based learning training, he or she can offer appropriate ~~student~~ placement ~~can be offered~~. To learn more, please visit http://www.tn.gov/education/cte/wb/.
Available Student Industry Certifications:	Students may be qualified to sit for the American Design Drafting Association (ADDA) Certification Exam upon completion of the *Engineering Design* program of study. ~~Not applicable~~
Dual Credit or Dual Enrollment Opportunities:	There are no known dual credit/dual enrollment opportunities for this course. If interested in developing, reach out to a local postsecondary institution to establish an articulation agreement.
Teacher Endorsement(s):	013, 014, 015, 016, 017, 018, 047, 070, 078, 081, 210, 211, 212, 213, 214, 413, 414, 415, 416, 417, 418, 230, ~~231,~~ 232, 233, 470, 477, 519, 531, 595, 596
Required Teacher Certifications/Training:	Teachers who have never taught this course must attend training provided by the Department of Education.
Teacher Resources:	http://www.tn.gov/education/cte/ScienceTechnologyEngineeringMathematics.shtml ~~doc/STEMResourceList.pdf~~

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Course Description

Engineering Design II is an applied course in the STEM career cluster for students interested in further developing their skills as future engineers. This course covers knowledge, skills, and concepts required for postsecondary engineering and technology fields of study. Upon completion of this course, proficient students are able to explain the differences between scientists and engineers, understand the importance of ethical practices in engineering and technology, identify components of control systems, describe differences between laws related to fluid power systems, explain why material and mechanical properties are important to design, create simple free body diagrams, use measurement devices employed in engineering, conduct basic engineering economic analysis, follow the steps in the engineering design process to complete a team project, and effectively communicate design solutions to others. Standards in this course are aligned with Tennessee Common Core State Standards in English Language Arts & Literacy in Technical Subjects and Tennessee Common Core State Standards in Mathematics.*

Note: Students are expected to use engineering notebooks to document procedures, design ideas, and other notes for all projects throughout the course.

Program of Study Application

This is the third course in the *Engineering* program of study. For more information on the benefits and requirements of implementing this program in full, visit the STEM website at http://www.tn.gov/education/cte/ScienceTechnologyEngineeringMathematics.shtml.

Course Standards

Safety

1) Accurately read and interpret safety rules, including but not limited to rules published by the National Science Teachers Association (NSTA), rules pertaining to electrical safety, Occupational Safety and Health Administration (OSHA) guidelines, and state and national code requirements. Be able to distinguish between the rules and explain why certain rules apply. (TN CCSS Reading 3, 4, 6)

2) Identify and explain the intended use of safety equipment available in the classroom. For example, demonstrate how to properly inspect, use, and maintain safe operating procedures with tools and equipment. Incorporate safety procedures and complete safety test with 100 percent accuracy. (TN CCSS Reading 3, 4)

Career Exploration

3) In teams, research various sources to determine the differences between engineers and scientists. Create a brochure that would be appealing to middle school students to educate them on the differences between the roles and activities of engineers and scientists. As an extension activity, prepare a presentation, using the brochures, to present to local middle school students. (TN CCSS Reading 1, 5, 7, 9; TN CCSS Writing 2, 4, 6, 8)

4) Research various engineering job responsibilities (such as research engineer, development engineer, testing engineer, design engineer, analysis engineer, systems engineer, manufacturing

engineer, operations and maintenance engineer, technical support engineer, sales engineer, and engineering manager) and present the characteristics of each. Also, describe how these job responsibilities are applied in industry. Use a variety of sources to gather data, cite each source, and briefly explain why each source is reliable. (TN CCSS Reading 1, 5, 7, 9; TN CCSS Writing 2, 4, 6, 8)

Engineering Ethics

5) Write an explanatory text defining ethics in the context of engineering practice, comparing and contrasting ethical standards with morals, personal standards, and legal standards. Include reasons and examples why ethical standards take precedence over personal and legal standards in engineering (TN CCSS Reading 1, 2; TN CCSS Writing 2, 4, 7)

6) Research print and electronic media to identify an issue related to ethics and engineering (for example, the decision to launch the space shuttle Challenger in cold temperatures). As a team, use the National Society of Professional Engineers (NSPE) Code of Ethics as a framework and develop a presentation displaying arguments on multiple sides of the selected issue or product. Teams should present their findings to the class and other audience members. (TN CCSS Reading 1, 2, 6, 7, 8, 9; TN CCSS Writing 1)

Control Systems

7) Prepare an explanatory text defining a system and identifying the components of a system (i.e., input, output, process, feedback) using a specific example such as: if an automobile is a system, the driver provides the input by turning the steering wheel to the left; the car converts input to process; the car then delivers the output by changing direction from straight to left. Convert the description to an illustration of the system. (TN CCSS Reading 1, 2, 4, 7; TN CCSS Writing 2, 4)

8) Define, compare, and contrast processors and controllers; further, define, compare, and contrast microcontrollers, computer-based controllers, and programmable logic controllers, citing examples of how each is used. (TN CCSS Reading 1, 2, 4, 5; TN CCSS Writing 2, 4, 7)

9) Define, compare, and contrast open-loop and closed-loop systems. Use responsible internet searches to find examples of both open- and closed-loop system diagrams, and explain why they are either open- or closed-loop. Use an online editing tool to develop an informational paper or infographic illustrate the difference between open- and closed-loop systems, supplying examples for each. (TN CCSS Reading 1, 2, 5, 7; TN CCSS Writing 2, 4, 6, 7, 8)

Fluid Power Systems

10) Define fluid power; define, compare, and contrast the two categories of fluid power: pneumatic and hydraulic. Compare and contrast hydrostatics and hydrodynamics. Compare and contrast fluid flow rate and fluid velocity. Compare and contrast the three types of air pressure: atmospheric, gauge, and absolute. Demonstrate the use of the appropriate formulae for each concept. (TN CCSS Reading 1, 2, 4, 5; TN CCSS Writing 2, 4, 7; TN CCSS Math N-Q)

11) Using various sources such as the internet and textbooks, research various applications of Bernoulli's principle and identify specific examples to demonstrate the principle. Develop and lead a lab activity to teach Bernoulli's principle to the class. (TN CCSS Reading 4, 5, 7)

12) Given a confined gas, explain the differences between the following laws: Boyle's, Charles', Avogadro's and Gay-Lussac's. Identify an online demonstration or prepare a demonstration of one (or more) of these laws and document each step of the law(s). Use an online editing tool to create a single written informative text with links to virtual demonstrations. (TN CCSS Reading 1, 2, 4, 5; TN CCSS Writing 2, 6, 7, 8; TN CCSS Math N-Q)

Materials and Mechanical Properties

13) Define the following and describe differences among terms dealing with strength and testing of materials (e.g., ductility, brittleness, hardness, elasticity, electrical conductivity, thermal conductivity, stress, strain, and shear stress). Explain why each factor is important to consider in a design. Research various sources and identify a demonstration of a design or material failing due to one of these characteristics; write an introduction to the topic and include the link to the video or demonstration. (TN CCSS Reading 1, 2, 4; TN CCSS Writing 2, 4, 7)

14) As a team, use an online editing tool to develop an informational paper or infographic illustrating how raw materials are processed to make products and systems, and how each of these materials or products are used in society. Students should identify milestone developments (e.g., cast iron, paper, battery, and fiberglass) made possible after specific materials were developed. Metals, ceramics, polymers, and composites should be included. Select a material that is one of the most valuable materials ever discovered or manufactured, and use the online editing tool to prepare a persuasive paper supporting the claim. (TN CCSS Reading 1, 2, 5, 7, 9; TN CCSS Writing 1, 4, 6, 7, 8, 9)

Statics, Kinematics and Trajectory Motion

15) Define a projectile. Define, compare, and contrast kinematics and kinetics. Explain why a projectile travels along a parabolic curve. Solve fundamental projectile motion problems such as the initial horizontal velocity, initial vertical velocity, time for projectile to reach maximum height, maximum height reached by projectile, total flight time of projectile, distance projectile will travel horizontally, and firing angle. For example, given initial horizontal and vertical velocity of a projectile, use a graphical tool (i.e., Microsoft Excel or MATLAB) to graph the path of the projectile by programming equations defining the path. (TN CCSS Reading 3, 4, 7; TN CCSS Math N-Q, A-SEE, A-CED, F-IF, F-BF)

16) Given a scenario of a stationary object with forces applied, construct a simple free body diagram, graphically illustrating the magnitude and direction of all forces acting upon the object. Demonstrate that the sum of the force vectors is equal to 0 for a stationary object. If the sum of the force vectors does not equal zero, explain the resulting motion of the object. (TN CCSS Reading 3, 4, 7; TN CCSS Writing 4; TN CCSS Math N-VM)

Introduction to ~~Measurement,~~ Statistics~~,~~ and Quality

~~17) Use physical measurement devices typically employed in engineering to collect and build a dataset. For example, calipers may be used to measure the width of pens in the classroom, generating a dataset. Tools should include, but are not limited to, fractional rule, metric rule, dial caliper, and micrometer. (TN CCSS Reading 1, 3, 7; TN CCSS Writing 4; TN CCSS Math N-Q)~~

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~~18)~~17) Given a dataset, calculate mean, mode, median, standard deviation, and range using algebraic/statistical reasoning and engineering software such as Microsoft Excel. Generate a graphical representation of the dataset including results of these statistics in a format suitable for a technical report. (TN CCSS Reading 1, 3, 4; TN CCSS Writing 4; TN CCSS Math A-SSE, S-ID)

~~19)~~18) In teams, prepare an informative report on the importance of quality management in the context of product design, process planning, and manufacturing implementation. For example, research and describe, through class discussion, the aspects of Joseph Juran's trilogy of quality planning, quality control, and quality improvement; sampled inspection during manufacturing and the use of the Taguchi method to minimize sampling; or the concept of 6-sigma in manufacturing. Prepare and deliver a presentation to the class, and incorporate visuals and information from print and electronic resources. (TN CCSS Reading 1, 2, 6, 7, 9; TN CCSS Writing 2, 4, 6, 7, 8, 9)

Engineering Economics

~~20)~~19) Assess the impact of materials costs and manufacturing/construction costs in the development and determination of the best design solution. Apply techniques of engineering economics to guide design decisions. For example, understand how to use value and interest; cash flow diagrams; cash flow patterns; equivalence of cash flow patterns; unusual cash flows; and interest periods to make design solution decisions. (TN CCSS Reading 2, 3, 7, 9; TN CCSS Writing 4, 6; TN CCSS Math S-IC, F-IF)

Projects

~~21)~~20) Explore how teams are formed in order to design solutions to engineering problems. Using a scholarly database such as the Education Resources Information Center (ERIC), or searching on the websites of research institutions or other organizations, investigate a well-known team of engineers (for example, the team that raised the Costa Concordia shipwreck) and report to the class on how they collaborated to solve an engineering problem. (TN CCSS Reading 2, 4; TN CCSS Writing 2, 4, 7)

~~22)~~21) As a team, identify a problem in the school or community; draft a problem statement to guide a project incorporating engineering concepts from at least three of the content sections outlined above (engineering economics **must** be included). Follow the engineering design process to solve the problem. Each team member will develop a paper following the format of a typical technical report (see components of the report below). Upon completion of the report, create and deliver a presentation for a CTSO event using appropriate citation conventions. Then, each team member will refine his/her report, incorporating feedback from the presentation.

The written report should include, but is not limited to:

a. Background
b. Problem definition
c. Design constraints
d. Methodology
e. Data analysis (e.g., charts, graphs, calculations)
f. Cost analysis (using engineering economics concepts)
g. Results/Problem solution (including engineering drawings)
h. Conclusions and recommendations for future research

(TN CCSS Reading 1, 3, 4, 5, 7, 9; TN CCSS Writing 2, 5, 6, 7, 8, 9)

Standards Alignment Notes

*References to other standards include:

- TN CCSS Reading: Common Core State Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects; Reading Standards for Literacy in Science and Technical Subjects 6-12; Grades 11-12 Students (page 62).
  - Note: While not directly aligned to one specific standard, students who are engaging in activities outlined above should be able to also demonstrate fluency in Standard 10 at the conclusion of the course.
- TN CCSS Writing: Common Core State Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects; Writing Standards for Literacy in History/Social Studies, Science, and Technical Subjects 6-12; Grades 11-12 Students (pages 64-66).
  - Note: While not directly aligned to one specific standard, students who are engaging in activities outlined above should be able to also demonstrate fluency in Standards 3 and 10 at the conclusion of the course.
- TN CCSS Math: Common Core State Standards for Mathematics; Math Standards for High School: Numbers and Quantity, Algebra, Functions, Statistics and Probability.
  - Note: The standards in this course are not meant to teach mathematical concepts. However, the concepts referenced above may provide teachers with opportunities to collaborate with mathematics educators to design project-based activities or collaborate on lesson planning. Students who are engaging in activities listed above should be able to demonstrate quantitative, algebraic, functional, and statistical reasoning as applied to specific technical concepts. In addition, students will have the opportunity to practice the habits of mind as described in the eight Standards for Mathematical Practice.
- P21: Partnership for 21st Century Skills Framework for 21st Century Learning
  - Note: While not all standards are specifically aligned, teachers will find the framework helpful for setting expectations for student behavior in their classroom and practicing specific career readiness skills.
- International Technology and Engineering Educators Association (ITEEA). (2013). http://www.iteea.org/.
- National Society of Engineers (NSPE) Code of Ethics. (2014). http://www.nspe.org/resources/ethics/code-ethics.

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TENNESSEE DEPARTMENT OF EDUCATION
FIRST TO THE TOP

Engineering Practicum

Primary Career Cluster:	Science, Technology, Engineering, and Mathematics (STEM)
Consultant:	Bethany King Wilkes, (615) 532-2844, Bethany.Wilkes@tn.gov
Course Code:	6141
Prerequisite(s):	*Engineering II*; *Algebra I* (3102); *Physical Science* (3202); and *Biology* (3210) or *Chemistry* (3221)
Credit:	1
Grade Level:	12
Graduation Requirement:	This course satisfies one of three credits required for an elective focus when taken in conjunction with other STEM courses.
Programs of Study and Sequence:	This is the fourth course in the *Engineering* program of study.
Necessary Equipment:	Equipment lists can be found at http://www.tn.gov/education/cte/ScienceTechnologyEngineeringMathematics.shtml. ~~Refer to the equipment list found on the STEM website linked below.~~
Aligned Student Organization(s):	Skills USA: http://www.tnskillsusa.com Brandon Hudson, (615) 532-2804, Brandon.Hudson@tn.gov Technology Student Association (TSA): http://www.tntsa.org Amanda Hodges, (615) 532-6270, Amanda.Hodges@tn.gov
Coordinating Work-Based Learning:	If a teacher has completed work-based learning training, he or she can offer appropriate ~~student~~ placement ~~can be offered~~. To learn more, please visit http://www.tn.gov/education/cte/wb/.
Available Student Industry Certifications:	Students may be qualified to sit for the American Design Drafting Association (ADDA) Certification Exam upon completion of the *Engineering Design* program of study. ~~None~~
Dual Credit or Dual Enrollment Opportunities:	There are no known dual credit/dual enrollment opportunities for this course. If interested in developing, reach out to a local postsecondary institution to establish an articulation agreement.
Teacher Endorsement(s):	013, 014, 015, 016, 017, 018, 047, 070, 078, 081, 210, 211, 212, 213, 214, 413, 414, 415, 416, 417, 418, 230, ~~231,~~ 232, 233, 470, 477, 519, 531, 595, 596
Required Teacher Certifications/Training:	Teachers who have never taught this course must attend training provided by the Department of Education.
Teacher Resources:	http://www.tn.gov/education/cte/ScienceTechnologyEngineeringMathematics.shtml~~doc/STEMResourceList.pdf~~

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Course Description

Engineering Practicum is a capstone course intended to provide students with the opportunity to apply the skills and knowledge learned in previous *Engineering* courses within a professional, working environment. In addition to developing an understanding of the professional and ethical issues encountered by engineers and technologists in the workplace, students learn to refine their skills in problem solving, research, communication, data analysis, teamwork, and project management. The course is highly customizable to meet local system needs: instruction may be delivered through school laboratory training or through work-based learning arrangements such as internships, cooperative education, service learning, mentoring, and job shadowing. Upon completion of the practicum, students will be prepared for postsecondary study in engineering and technology fields. Standards in this course are aligned with Tennessee Common Core State Standards for English Language Arts & Literacy in Technical Subjects and Tennessee Common Core State Standards in Mathematics.*****

Note: Mastery of the following standards should be attained while completing an engineering design project in a practicum setting. Students are expected to use engineering notebooks to document procedures, design ideas, and other notes for the project throughout the course. The project should follow the engineering design process learned in previous courses. Moreover, practicum activities may take the form of work-based learning opportunities (such as internships, cooperative education, service learning, and job shadowing) or in-class projects, depending on local availability. Work-based learning opportunities must follow policies outlined in the work-based learning guide found online at http://www.tn.gov/education/cte/wb/doc/WorkBasedLearningPoliciesApril2013.pdf.

Program of Study Application

This is the fourth course in the *Engineering* program of study. For more information on the benefits and requirements of implementing this program in full, please visit the STEM website at http://www.tn.gov/education/cte/ScienceTechnologyEngineeringMathematics.shtml.

Course Standards

Safety

1) Accurately read and interpret safety rules, including but not limited to rules published by the National Science Teachers Association (NSTA), rules pertaining to electrical safety, Occupational Safety and Health Administration (OSHA) guidelines, and state and national code requirements. Be able to distinguish between the rules and explain why certain rules apply. (TN CCSS Reading 3, 4, 6)

2) Identify and explain the intended use of safety equipment available in the classroom. For example, demonstrate how to properly inspect, use, and maintain safe operating procedures with tools and equipment. Incorporate safety procedures and complete safety test with 100 percent accuracy. (TN CCSS Reading 3, 4)

Career Exploration

3) Develop an informational annotated document, linked to bookmarked websites, illustrating the opportunities for students to investigate and experience engineering and technology while in school, focusing specifically on those programs offered by colleges and universities in

Tennessee. For example, opportunities include job shadowing, internships, co-op programs, volunteer and community service, and part-time employment. (TN CCSS Reading 5, 7, 9; TN CCSS Writing 2, 4, 6, 8)

Employment Research and Preparation

4) Research and select a company or organization for a work-based learning project in an engineering or technology area of choice. Cite specific textual evidence from the organization's literature, as well as independent news articles to summarize:
    a. The mission and history of the organization
    b. Headquarters and organizational structure
    c. Products or services provided
    d. Credentials required for employment and how they are obtained and maintained
    e. Policies and procedures
    f. Reports, newsletters, and other documents published by the organization
    g. Website and contact information

    (TN CCSS Writing 4, 7)

5) Search for the resumes of engineers and technologists retrieved from the websites of institutions, organizations, or professional networks. Discuss what is typically included in the resumes of engineering and technology professionals, compare and contrast several examples, and create a personal resume modeled after elements identified in the search. (TN CCSS Reading 1, 4, 5, 6; TN CCSS Writing 4)

6) Conduct a job search and simulate the experience by researching local employment options. In preparation for a future career in engineering or technology, complete an authentic job application form and compose a cover letter following guidelines specified in the vacancy announcement. (TN CCSS Reading 7; TN CCSS Writing 4)

7) Participate in a mock interview. Prior to the interview, prepare a paper that includes the following: tips on dress and grooming, most commonly asked interview questions, appropriate conduct during an interview, and recommended follow-up procedures. Upon completion of the interview, write a thank you letter to the interviewer in a written or email format. (TN CCSS Reading 2; TN CCSS Writing 2, 4, 7, 9)

Transferring Course Concepts to Practicum

8) Apply skills and knowledge from previous courses in an authentic work-based learning internship, job shadow, or classroom-based project. Where appropriate, develop, practice, and demonstrate skills outlined in previous courses. (TN CCSS Reading 2, 3)

9) Identify a problem faced by a local organization or company to define a project proposal. Incorporate organization or company interviews into the research, as well as engineering concepts from the prior three courses. Prepare a written project proposal including the problem definition; justification for why the problem is important to solve; design statement; criteria; constraints; information obtained through research; and deliverables. (TN CCSS Reading 3, 4, 7, 9; TN CCSS Writing 1, 5, 7)

10) Create and continually update a personal journal to document skills learned during the practicum and draw connections between the experience and previous course content by reflecting on:
    a. Tasks accomplished and activities implemented
    b. Positive and negative aspects of the experience
    c. How challenges were addressed
    d. Team participation in a learning environment
    e. Comparisons and contrasts between classroom and work environments
    f. Interactions with colleagues and supervisors
    g. Personal career development
    h. Personal satisfaction

    (TN CCSS Writing 2, 4)

Portfolio

11) Create a portfolio, or similar collection of work, that illustrates mastery of skills and knowledge outlined in the previous courses and applied in the practicum. The portfolio should reflect thoughtful assessment and evaluation of the progression of work involving the application of steps of the engineering design process (depending on the nature of the work-based learning project). The following documents will reside in the career portfolio:
    a. Career and professional development plan
    b. Resume
    c. List of responsibilities undertaken through the course
    d. Examples of visual materials developed and used during the course (such as graphics, drawings, models, presentation slides, videos, and demonstrations)
    e. Description of technology used, with examples if appropriate
    f. Periodic journal entries reflecting on tasks and activities
    g. Feedback from instructor and/or supervisor based on observations

    (TN CCSS Writing 4, 5)

Communication of Project Results

12) Apply all steps of the engineering design process to successfully generate a prototype, collect the relevant data, perform the necessary tests, interpret the results, make modifications to models or prototypes, and communicate results over the course of the project's duration. Produce a technical report documenting the findings of the project and justifying the final conclusions based on evidence obtained. (TN CCSS Reading 1, 2, 3, 4, 5, 7, 8, 9; TN CCSS Writing 1, 2, 4, 5, 6, 7, 8, 9)

13) Upon completion of the practicum, develop a technology-enhanced presentation showcasing highlights, challenges, and lessons learned from the experience. The presentation should be delivered orally, but supported by relevant graphic illustrations, such as diagrams, drawings, and models of project findings, and/or physical artifacts that represent the outcome of the project (i.e., a prototype or 3-D model). Prepare the presentation in a format that could be presented to both a technical and a non-technical audience, as well as for a career and technical student organization (CTSO) competitive event. (TN CCSS Reading 1, 3, 7, 9; TN CCSS Writing 2, 4, 5, 6, 9)

Standards Alignment Notes

*References to other standards include:

- TN CCSS Reading: Common Core State Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects; Reading Standards for Literacy in Science and Technical Subjects 6-12; Grades 11-12 Students (page 62).
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- TN CCSS Math: Common Core State Standards for Mathematics; Math Standards for High School: Numbers and Quantity, Algebra, Functions, Geometry, Statistics and Probability.
    - Note: The standards in this course are not meant to teach mathematical concepts. However, the concepts referenced above may provide teachers with opportunities to collaborate with mathematics educators to design project-based activities or collaborate on lesson planning. While not aligned to one specific conceptual category, students who are engaging in the activities outlined above should be able to demonstrate quantitative, algebraic, functional, geometric, and statistical reasoning as applied to specific technical concepts. In addition, students will have the opportunity to practice the habits of mind as described in the eight Standards for Mathematical Practice.
- P21: Partnership for 21st Century Skills Framework for 21st Century Learning
    - Note: While not all standards are specifically aligned, teachers will find the framework helpful for setting expectations for student behavior in their classroom and practicing specific career readiness skills.
- International Technology and Engineering Educators Association (ITEEA). (2013). http://www.iteea.org/.

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Flight and Space (PLTW)

Primary Career Cluster:	Science, Technology, Engineering, and Mathematics (STEM)
Consultant:	Bethany King Wilkes, (615) 532-2844, Bethany.Wilkes@tn.gov
Course Code:	~~TBD~~0887
Prerequisite(s):	None
Credit:	N/A
Grade Level:	8
Graduation Requirement:	N/A
Coursework and Sequence:	This is ~~the first~~a course in the *Project Lead the Way (PLTW)* middle school sequence of coursework.
Necessary Equipment:	Visit www.pltw.org for more information.
Aligned Student Organization(s):	Technology Student Association (TSA):http://www.tntsa.org Amanda Hodges, (615) 532-6270, Amanda.Hodges@tn.gov
Coordinating Work-Based Learning:	N/A
Available Student Industry Certifications:	N/A
Dual Credit or Dual Enrollment Opportunities:	N/A
Teacher Endorsement(s):	001, 013, 014, 015, 016, 017, 018, 047, 070, 078, 081, 101, 210, 211, 212, 213, 214, 230, 231, 232, 233, 400, 401, 402,413, 414, 415, 416, 417, 418, 440, 470, 477
Required Teacher Certifications/Training:	*Project Lead the Way* training is required
Teacher Resources:	http://www.tn.gov/education/cte/doc/STEMResourceList.pdf

Course Description

This is a course in the series of *Project Lead the Way (PLTW)* curriculum. For more information, visit the PLTW website at http://www.pltw.org/.

Program of Study Application

These courses build knowledge and skills related to the following career clusters:

1) Architecture & Construction
2) Information Technology (IT)
3) Manufacturing
4) Science, Technology, Engineering & Mathematics (STEM)
5) Transportation, Distribution, & Logistics

Course Standards

The course standards outlined below are the copyrighted property of *Project Lead the Way*. Teachers must participate in *Project Lead the Way* training in order to be able to teach this course. This course is one in a series of PLTW middle school courses. The lesson numbers below reflect the recommended sequence.

Lesson 4.1 History of Flight and Space (15 days)

Understandings

1) The aerospace industry uses engineers who specialize in many different types of engineering careers.
2) The history of aerospace studies has influenced how people meet the challenges of traveling through the atmosphere or in space.
3) Engineering designs in aerospace exploration evolve as they are developed.
4) Different types of vehicles result in different types of flight.

Knowledge and Skills

It is expected that students will:

- Describe the roles and responsibilities of STEM professionals for high demand technological careers, especially in the aerospace industry.
- Apply their knowledge of research techniques to investigate an aerospace topic.
- Describe the flight characteristics of kites, whirly gigs, model airplanes, hot air balloons, and model rockets.
- Write a script and develop a storyboard to explain an aerospace concept.

Lesson 4.2 Aeronautics (19 days)

Understandings

1) Forces working on an airplane in flight are lift, gravity, thrust, and drag.
2) In order to fly, an airplane must overcome gravity with sufficient lift and must overcome drag with sufficient thrust.
3) Newton's three laws of motion are observed in both spacecraft and aircraft.
4) Bernoulli's principle, which states that as the speed of a fluid increases, its pressure decreases, explains in part how an airfoil gains lift.
5) Changing a wing's angle of attack affects the speed of the air flowing over the wing and the amount of lift the wing creates.
6) Airfoils are tested for performance in a wind tunnel.
7) Aircraft have different purposes, but the majority of their components are similar.
8) Propulsion systems provide the thrust so aircraft can fly.

Knowledge and Skills
It is expected that students will:

- Describe how center of gravity affects an aerospace vehicle in distributing weight.
- Recognize the tools and purpose of aeronautic design and testing.
- Distinguish between the forces of lift, drag, weight, and thrust that affect an object moving through a fluid.
- Explain the importance of the forces that affect an object moving through a fluid.
- Explain how Newton's laws apply to flight and space.
- Explain how Bernoulli's principle affects flight.
- Identify the characteristics of an airfoil and how they compare and contrast with the characteristics of wings.
- Analyze the features and benefits of different types of wings.
- Research and design an airfoil that will create lift using a wing tester.
- Calculate fuel consumption and range of an airplane given speed and fuel capacity.
- Describe the major parts (fuselage, empennage, high lift devices, wings, undercarriage, propulsion, instruments, and controls) of aircraft and how they can affect the overall balance of an airplane during flight

Lesson 4.3 Traveling and Living in Space (11 days)

Understandings

1) Reliable, inexpensive rockets are the key to enabling humans to travel, work, visit, and commercially develop space.
2) There are many reasons for going into space, including colonization, intelligence surveillance, international diplomacy, natural resources, research, satellites, and advancing technology.
3) Humans must adjust their diets, hygiene, clothing, recreation, and sleep patterns in order to survive in space.
4) Engineers use technology on the moon to research, design, and build appropriate equipment to solve problems related to the topography and atmosphere found on the moon.

Knowledge and Skills
It is expected that students will:

- Discuss the history and development of rocketry, space flight, and living in space.
- Know that a rocket must overcome the forces of gravity and drag in order to escape the atmosphere.
- Explain the basic principles of flight and rocketry.
- Investigate how changes in various design characteristics of a rocket will affect the rocket's performance.
- List challenges that engineers face to provide safe travel and optimum living conditions in space.
- Explain how gravity relates to an object's orbit.
- Use a simulation to select optimal components for a lunar robot to save stranded astronauts on the moon.

Green Architecture (PLTW)

Primary Career Cluster:	Science, Technology, Engineering, and Mathematics (STEM)
Consultant:	Bethany King Wilkes, (615) 532-2844, Bethany.Wilkes@tn.gov
Course Code:	~~TBD~~0888
Prerequisite(s):	None
Credit:	N/A
Grade Level:	8
Graduation Requirement:	N/A
Coursework and Sequence:	This is ~~the first~~a course in the *Project Lead the Way (PLTW)* middle school sequence of coursework.
Necessary Equipment:	Visit www.pltw.org for more information.
Aligned Student Organization(s):	Technology Student Association (TSA):http://www.tntsa.org Amanda Hodges, (615) 532-6270, Amanda.Hodges@tn.gov
Coordinating Work-Based Learning:	N/A
Available Student Industry Certifications:	N/A
Dual Credit or Dual Enrollment Opportunities:	N/A
Teacher Endorsement(s):	001, 013, 014, 015, 016, 017, 018, 047, 070, 078, 081, 101, 210, 211, 212, 213, 214, 230, 231, 232, 233, 400, 401, 402,413, 414, 415, 416, 417, 418, 440, 470, 477
Required Teacher Certifications/Training:	*Project Lead the Way* training is required
Teacher Resources:	http://www.tn.gov/education/cte/doc/STEMResourceList.pdf

Course Description

This is a course in the series of *Project Lead the Way (PLTW)* curriculum. For more information, visit the PLTW website at http://www.pltw.org/.

Program of Study Application

These courses build knowledge and skills related to the following career clusters:

1) Architecture & Construction
2) Information Technology (IT)
3) Manufacturing
4) Science, Technology, Engineering & Mathematics (STEM)
5) Transportation, Distribution, & Logistics

Course Standards

The course standards outlined below are the copyrighted property of *Project Lead the Way*. Teachers must participate in *Project Lead the Way* training in order to be able to teach this course. This course is one in a series of PLTW middle school courses. The lesson numbers below reflect the recommended sequence.

Lesson 1 – Architectural Basics (16 days)

Understandings

1) The ability to measure accurately is important at school and at home, at work, and when pursuing hobbies.
2) Precision measuring tools are needed for accuracy, but tools must be used correctly to ensure that accurate measurements are taken.
3) Quality of workmanship and accurate measurements with precise instruments are necessary to successfully solve problems.
4) The use of scale is important in design in order to create a functional space that is proportional and aesthetically pleasing to the client.
5) Dimensioning and measuring are required for any architectural project as well as many careers in related fields.
6) Area and perimeter are used to find the square footage of a floor, a wall, or the length and width needed to build the exterior of a home.
7) When designing a home, standard rules must be followed in regards to traffic flow, room sizes and relationships, and the layout of kitchens and bathrooms.
8) A set of architectural plans includes: plot plan, foundation plan, floor plan, elevations, 3-D views, and construction details.

Knowledge and Skills

It is expected that students will:

- Demonstrate the proper use of a standard ruler and an architectural scale.
- Use proper notation in regards to dimensioning an architectural drawing. Calculate area and perimeter of a floor plan given dimensions.
- Measure a room and draw it to scale using common symbols.
- Identify the systems required in a residential home, including electrical, plumbing, heating, ventilation, and air conditioning.
- Describe the three areas of a house and the rooms that belong to them.
- Identify common roof styles.
- Describe the working triangle and its purpose.
- Identify and use appropriate symbols in a basic floor plan for a residential home.

- Read and interpret a blueprint of a floor plan.

Lesson 2 – Introduction to Sustainable Architecture (12 days)

Understandings

1) Sustainable building solutions are an important part of the world today as our resources are dwindling.
2) Many different processes are used to recycle a variety of materials.
3) Researching the various recycling processes helps one better understand the requirements and the complexity of recycling processes.
4) The air we breathe inside a room can contain contaminants and particles, making it potentially dangerous for humans.
5) The health consequences of poor indoor air quality include coughs, colds, cancer, and even death.
6) Building green refers to methods of fabricating both commercial and residential structures to reduce their impact on human health and the natural environment.
7) Architectural designs are created based on the needs of humans and function of the building in relationship to the climate, region, and culture.
8) Within a local community there can be a variety of construction materials and architectural styles depending on purpose.
9) Architects, engineers, designers, and engineering technologists are in high demand for the development of future technology to meet societal needs and wants.

Knowledge and Skills

It is expected that students will:

- Communicate, using a variety of media, the effects that daily living has on the environment.
- Describe the steps of the recycling system.
- List ways to improve indoor air quality.
- Explain the consequences of poor indoor air quality.
- Categorize concepts related to building eco-friendly.
- Identify the local home styles in the region and outside of the region.
- Describe different house styles and how they can be built green.
- Provide examples of STEM careers and the need for these professionals in our society.

Lesson 3 Architectural Challenge (17 days)

Understandings

1) The ability to measure precisely and accurately is important at school and at home, at work, and when pursuing hobbies.
2) Numerous symbols are part of architectural plans. It is important to be able to identify such symbols.
3) Wood frame construction is popular because it is economical and strong.
4) Using graph paper and an architectural scale can help in the visualization of a space before the start of the prototype phase.
5) Architecture today uses computer-aided design (CAD) systems to quickly generate and annotate working drawings.

6) Three-dimensional computer modeling uses descriptive geometry, geometric relationships, and dimensions to communicate an idea or solution to a technological problem.
7) Using alternative materials in construction is beneficial to our environment.
8) Architecture and construction emphasize using environmentally friendly practices in their career fields.
9) Architects and engineers use the design process when designing and building structures.
10) Shipping containers stack up as waste unless they are repurposed; they offer many benefits as construction materials that are strong, water proof, pest proof, recycled, easy to build with, etc.
11) Creating a functional and environmentally friendly home is considered sustainable housing that could be adapted for emergency shelter in disaster areas.

Knowledge and Skills
It is expected that students will:

- Demonstrate knowledge of measurement, construction, and design.
- Identify the parts of a wall section.
- Measure accurately using a tape measure and architectural scale.
- Read and interpret a blueprint of a floor plan.
- Construct a model of the framing of a wall section.
- Demonstrate use of the Design Process including a Design Brief, Sketching, and Decision Making Matrix.
- Use Autodesk Revit Architecture to create an architectural drawing.
- Design an environmentally friendly home

TENNESSEE DEPARTMENT OF EDUCATION
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Magic of Electrons (PLTW)

Primary Career Cluster:	Science, Technology, Engineering, and Mathematics (STEM)
Consultant:	Bethany King Wilkes, (615) 532-2844, Bethany.Wilkes@tn.gov
Course Code:	~~TBD~~0889
Prerequisite(s):	None
Credit:	N/A
Grade Level:	8
Graduation Requirement:	N/A
Coursework and Sequence:	This is ~~the third~~a course in the *Project Lead the Way (PLTW)* middle school sequence of coursework.
Necessary Equipment:	Visit www.pltw.org for more information.
Aligned Student Organization(s):	Technology Student Association (TSA):http://www.tntsa.org Amanda Hodges, (615) 532-6270, Amanda.Hodges@tn.gov
Coordinating Work-Based Learning:	N/A
Available Student Industry Certifications:	N/A
Dual Credit or Dual Enrollment Opportunities:	N/A
Teacher Endorsement(s):	001, 013, 014, 015, 016, 017, 018, 047, 070, 078, 081, 101, 210, 211, 212, 213, 214, 230, 231, 232, 233, 400, 401, 402,413, 414, 415, 416, 417, 418, 440, 470, 477
Required Teacher Certifications/Training:	*Project Lead the Way* training is required
Teacher Resources:	http://www.tn.gov/education/cte/doc/STEMResourceList.pdf

Course Description

This is a course in the series of *Project Lead the Way (PLTW)* curriculum. For more information, visit the PLTW website at http://www.pltw.org/.

Program of Study Application

These courses build knowledge and skills related to the following career clusters:

1) Architecture & Construction
2) Information Technology (IT)
3) Manufacturing
4) Science, Technology, Engineering & Mathematics (STEM)
5) Transportation, Distribution, & Logistics

Course Standards

The course standards outlined below are the copyrighted property of *Project Lead the Way*. Teachers must participate in *Project Lead the Way* training in order to be able to teach this course. This course is one in a series of PLTW middle school courses. The lesson numbers below reflect the recommended sequence.

Lesson 6.1 What is Electricity? (16 days)

Understandings

1) Electron flow is created as electrons are transferred between atoms.
2) As engineers design electrical systems, they must understand a material's tendency toward being a conductor or insulator.
3) Current, voltage, and resistance are measurable quantities that are used to explain electron flow in an electrical system.
4) Magnets play an important role in creating electromotive force which is used to make and convert electricity.
5) Generators are used to convert mechanical energy into electrical energy, while motors convert electrical energy into mechanical energy.

Knowledge and Skills

It is expected that students will:

- Identify the roles of protons, neutrons, and electrons in an atom.
- Explain how charges interact to hold an atom together.
- Identify metals, metalloids, and non-metals on the periodic table.
- Explain the relationship between current, voltage, and resistance.
- Describe the properties of a magnet including polarity and defining characteristics.
- Explain the role of an electromagnet in the function of a DC motor and generator.
- Describe how electron transfer between atoms and the flow of electricity are related.
- Evaluate whether a material is a conductor, insulator, or semiconductor based upon its number of valance electrons and its position on the periodic table.
- Identify an element based on the atomic number given a periodic table.
- Identify metals, metalloids, and non-metals on the periodic table.
- Measure voltage and current using a multimeter.
- Demonstrate the characteristics and functions of an electromagnet.
- Identify the primary parts of a DC motor and demonstrate how it functions.
- Identify the primary parts of a generator and demonstrate how it functions.
- Compare and contrast the characteristics of a basic motor and generator.

Lesson 6.2 Electronics (17 days)

Understandings

1) An electrical circuit is a system made up of conductors and electrical components that form a complete path for electrical current.
2) Engineers use circuit diagrams to communicate components and functions of electrical circuits.
3) A variety of electronic components are incorporated into electrical circuits by engineers to achieve specific functions.
4) When building or diagnosing circuits, it is important to be able to measure voltage, current, and resistance.
5) Ohm's Law explains the mathematical relationship between voltage, current, and resistance.
6) The transistor is an important electronic device because it allows a small amount of current to control a larger amount of current.
7) Engineers, designers, and engineering technologists are needed in high demand for the development of future technology to meet societal needs and wants.

Knowledge and Skills

It is expected that students will:

- Identify the characteristics of series, parallel, and combination electrical circuits.
- Identify standardized schematic symbols using a chart.
- Distinguish between the functions and operations of fixed resistors, variable resistors, and photo resistors.
- Construct series, parallel, and combination electrical circuits.
- Sketch circuit diagrams using standardized schematic symbols.
- Construct and test physical electrical circuits based upon circuit diagrams.
- Integrate DC sources, lamps, switches, diodes, light emitting diodes, resistors, and capacitors into electrical circuits to achieve specific functions.
- Determine the value of a fixed resistor based upon the color codes on those resistors.
- Measure voltage, current, and resistance using a multimeter.
- Mathematically calculate voltage, current, and resistance using Ohm's law.
- Design a circuit that uses a transistor as a switch.

Lesson 6.3 Digital Electronics (12 days)

Understandings

1) The relationship between the binary number system, decimal number system, and ACII characters make it possible for computers to communicate and process complex functions.
2) Computer processors are the key component of electronic devices and function based on logic.
3) Logic gates are depicted by their schematic symbol and truth table.
4) Digital wave forms that communicate binary digits are the means of communication within and among digital electronic devices.
5) Engineers decide upon inputs, outputs, and the logic necessary for an electronic device and communicate them using electronic circuit diagrams.
6) Engineers must decide on the necessary constraints and trade-offs in control systems.

Knowledge and Skills

It is expected that students will:

- Identify the relationship between the binary number system and the decimal number system.
- Describe the functions of NOT, AND, OR, NAND, NOR, and XOR gates.
- Convert binary numbers to Base-10.
- Convert ACII characters to binary.
- Interpret logic scenarios to determine outputs based upon possible conditions within those scenarios.
- Create truth tables for logic scenarios and match those gates to truth tables.
- Create a digital wave form and graph it for a binary sequence.
- Communicate using electronic circuit diagrams.
- Use transistors as switches to create circuits that function as AND and OR gates.
- Determine the logic, sensors, gates, outputs, and other components needed to emulate existing electronic devices that utilize logic.
- Design, construct, and test device solutions for emulating common electronic devices that utilize logic.

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Medical Detectives (PLTW)

Primary Career Cluster:	Science, Technology, Engineering, and Mathematics (STEM)
Consultant:	Bethany King Wilkes, (615) 532-2844, Bethany.Wilkes@tn.gov
Course Code:	~~TBD~~0890
Prerequisite(s):	None
Credit:	N/A
Grade Level:	8
Graduation Requirement:	N/A
Coursework and Sequence:	This is ~~the first~~a course in the *Project Lead the Way (PLTW)* middle school sequence of coursework.
Necessary Equipment:	Visit www.pltw.org for more information.
Aligned Student Organization(s):	Technology Student Association (TSA):http://www.tntsa.org Amanda Hodges, (615) 532-6270, Amanda.Hodges@tn.gov
Coordinating Work-Based Learning:	N/A
Available Student Industry Certifications:	N/A
Dual Credit or Dual Enrollment Opportunities:	N/A
Teacher Endorsement(s):	001, 013, 014, 015, 016, 017, 018, 047, 070, 078, 081, 101, 210, 211, 212, 213, 214, 230, 231, 232, 233, 400, 401, 402,413, 414, 415, 416, 417, 418, 440, 470, 477
Required Teacher Certifications/Training:	*Project Lead the Way* training is required
Teacher Resources:	http://www.tn.gov/education/cte/doc/STEMResourceList.pdf

Course Description

This is a course in the series of *Project Lead the Way (PLTW)* curriculum. For more information, visit the PLTW website at http://www.pltw.org/.

Program of Study Application

These courses build knowledge and skills related to the following career clusters:

1) Architecture & Construction
2) Information Technology (IT)
3) Manufacturing
4) Science, Technology, Engineering & Mathematics (STEM)
5) Transportation, Distribution, & Logistics

Course Standards

The course standards outlined below are the copyrighted property of *Project Lead the Way*. Teachers must participate in *Project Lead the Way* training in order to be able to teach this course. This course is one in a series of PLTW middle school courses. The lesson numbers below reflect the recommended sequence.

Lesson 8.1 What is a Medical Detective? (13 days)

Understandings

1) Patient health can be evaluated in a variety of ways, including collecting a patient's medical history and testing vital signs.
2) An epidemic is an infectious disease that spreads rapidly and sickens a large number of people.
3) Medical professionals use a sequential, logical process to evaluate, diagnose, and treat patients.
4) A variety of health care professionals and scientists investigate medical mysteries.

Knowledge and Skills

It is expected that students will:

- Measure vital signs including heart rate, blood pressure, and temperature.
- Demonstrate the use of technology as an important tool in the Biomedical Sciences.
- Explain the different ways a virus spreads through a population.
- Describe the spread of a viral illness after inoculation is introduced.
- Evaluate patient case files to diagnose the pathogen responsible for the patient's mystery illness.
- Describe the steps that a medical professional will take to diagnose and treat a patient.
- Provide examples how medical professionals contribute to the health and wellness of individuals.

Lesson 8.2 Mysteries of the Human Body Systems (17 days)

Understandings

1) The nervous system collects and interprets input from the outside world using specialized receptors.
2) The brain is a complex organ that is organized into specialized regions.
3) The expression of a genetic trait through families highlights the varying patterns of genetic inheritance.
4) The unique sequence of a person's DNA can be utilized for a variety of purposes including testing for a genetic disease.
5) A mutation in the sequence of nucleotides in DNA may cause a genetic disease.

Knowledge and Skills
It is expected that students will:

- Describe how the brain collects and interprets input.
- Compare and contrast the senses of hearing and sight, taste and smell and how they are collected and processed by the human body.
- Identify major regions of the human brain.
- Dissect a sheep's brain, accurately identifying and describing the function of the specified structures.
- Compare and contrast the brains of a human and sheep.
- Evaluate patient family history as part of a medical exam and create a pedigree.
- Determine the probability of a child inheriting a genetic disease.
- Use appropriate laboratory methods to isolate DNA from cheek cells.
- Analyze how changes in the huntingtin gene affect the resulting protein and nerve cell function.

Lesson 8.3 Murder Mystery (15 days)

Understandings

1) Body temperature can be used as one way to determine the approximate time of 1.death.
2) An autopsy can provide clues to the circumstances surrounding a mysterious 2.death.
3) Human DNA is a unique code of over three billion base pairs that provides a 3.genetic blueprint of an individual.

Knowledge and Skills
It is expected that students will:

- Know how to use patient and ambient temperature to identify the time of death.
- Know how to use the time of death information to identify suspects.
- List the steps of an autopsy.
- Analyze a portion of an autopsy report to determine the cause of death for a murder victim.
- Use DNA gel electrophoresis to compare DNA samples.
- Defend identification of suspect using physical evidence including time of death, cause of death, and DNA crime scene analysis

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Principles of Engineering and Technology

Primary Career Cluster:	Science, Technology, Engineering, and Mathematics (STEM)
Consultant:	Bethany King Wilkes, (615) 532-2844, Bethany.Wilkes@tn.gov
Course Code:	5924
Prerequisite(s):	None
Credit:	1
Grade Level:	9
Graduation Requirement:	This course satisfies one of three credits required for an elective focus when taken in conjunction with other STEM courses.
Programs of Study and Sequence:	This is the first course in the *Engineering* and *Technology* programs of study.
Necessary Equipment:	Equipment lists can be found at http://www.tn.gov/education/cte/ScienceTechnologyEngineeringMathematics.shtml. ~~Refer to the equipment list found on the STEM website linked below~~.
Aligned Student Organization(s):	Skills USA: http://www.tnskillsusa.com Brandon Hudson, (615) 532-2804, Brandon.Hudson@tn.gov Technology Student Association (TSA): http://www.tntsa.org Amanda Hodges, (615) 532-6270, Amanda.Hodges@tn.gov
Coordinating Work-Based Learning:	If a teacher has completed work-based learning training, he or she can offer appropriate ~~student~~ placement ~~can be offered~~. To learn more, please visit http://www.tn.gov/education/cte/wb/.
Available Student Industry Certifications:	Students may be qualified to sit for the American Design Drafting Association (ADDA) Certification Exam upon completion of the *Engineering Design* program of study.~~None~~
Dual Credit or Dual Enrollment Opportunities:	There are no known dual credit/dual enrollment opportunities for this course. If interested in developing, reach out to a local postsecondary institution to establish an articulation agreement.
Teacher Endorsement(s):	013, 014, 015, 016, 017, 018, 047, 070, 078, 081, 210, 211, 212, 213, 214, 413, 414, 415, 416, 417, 418, 230, ~~231,~~232, 233, 470, 477, 519, 531, 595, 596
Required Teacher Certifications/Training:	Teachers who have never taught this course must attend training provided by the Department of Education.
Teacher Resources:	http://www.tn.gov/education/cte/ScienceTechnologyEngineeringMathematics.shtml~~doc/STEMResourceList.pdf~~

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Course Description

Principles of Engineering and Technology is a foundational course in the STEM cluster for students interested in learning more about careers in engineering and technology. This course covers basic skills required for engineering and technology fields of study. Upon completion of this course, proficient students are able to identify and explain the steps in the engineering design process. They can evaluate an existing engineering design, use fundamental sketching and engineering drawing techniques, complete simple design projects using the engineering design process, and effectively communicate design solutions to others. Standards in this course are aligned with Tennessee Common Core State Standards for English Language Arts & Literacy in Technical Subjects and Tennessee Common Core State Standards in Mathematics.*

Program of Study Application

This is the first course in both the *Engineering* and the *Technology* programs of study. For more information on the benefits and requirements of implementing ~~this~~ these programs in full, please visit the STEM website at http://www.tn.gov/education/cte/ScienceTechnologyEngineeringMathematics.shtml.

Course Standards

Safety

1) Accurately read and interpret safety rules, including but not limited to rules published by the National Science Teachers Association (NSTA), rules pertaining to electrical safety, Occupational Safety and Health Administration (OSHA) guidelines, and state and national code requirements. Be able to distinguish between the rules and explain why certain rules apply. (TN CCSS Reading 3, 4, 6)

2) Identify and explain the intended use of safety equipment available in the classroom. For example, demonstrate how to properly inspect, use, and maintain safe operating procedures with tools and equipment. Incorporate safety procedures and complete safety test with 100 percent accuracy. (TN CCSS Reading 3, 4)

Introduction to Engineering & Technology

3) Research the definition of each term within STEM: Science, Technology, Engineering, and Mathematics. Use these definitions and additional print and electronic resources (such as textbooks, National Science Teacher Association's STEM Classroom newsletters, or the websites of organizations like *STEM Connector*) to develop a written argument describing why science, mathematics, and technology are different than engineering, yet each influences engineering. Incorporate proper citation conventions used in STEM fields (MLA, APA, or other) to cite sources of information retrieved. (TN CCSS Reading 1, 5; TN CCSS Writing 2, 9)

4) In teams, produce a timeline or infographic illustrating important events in history, in a given time period, that specifically involve engineering. Use a variety of sources to gather data, cite each source, and briefly describe why the chosen source is reliable. (TN CCSS Reading 1, 8; TN CCSS Writing 2, 8)

5) As a team, develop a written explanation of how society benefits from the contributions of engineers in at least three different engineering disciplines. Provide detailed descriptions of each discipline and describe the specific benefits derived from each. For example, describe how civil engineers improve the efficiency and safety of transportation networks through the construction of bridges, highways, and other public infrastructures. Documents should contain links to relevant websites to illustrate the ideas presented. (TN CCSS Reading 1, 2; TN CCSS Writing 2, 6, 7, 8)

Engineering Design Process

6) There are different versions of the engineering design process. For example, examine the following framework endorsed by the International Technology and Engineering Educators Association (ITEEA):
    a. Identify the problem
    b. Identify criteria and specify constraints
    c. Brainstorm possible solutions
    d. Research and generate ideas
    e. Explore alternative solutions
    f. Select an approach
    g. Write a design proposal
    h. Develop a model or prototype
    i. Test and evaluate
    j. Refine and improve
    k. Create or make a product
    l. Communicate results

    Citing this framework or other variations as approved by the instructor, compare and contrast what is involved at each step of the engineering design process. Explain why it is an iterative process and always involves refinement. (TN CCSS Reading 3, 4, 5; TN CCSS Writing 2, 4, 9)

7) In teams, evaluate an existing large-scale engineering design using the engineering design process. Produce a report on the chosen design, and assume the role of the engineering design team that produced the design. Document constraints that may have been faced by the design team, criteria for measuring the effectiveness of the design, and progress through each step of the engineering design process. Create and deliver a presentation appropriate for a career and technical student organization (CTSO) event. (TN CCSS Reading 3, 4, 5, 7; TN CCSS Writing 2, 4, 9)

8) Complete a simple design activity and apply the engineering design process to produce a model that an engineer would test. Define criteria for determining an effective design, describe constraints on the design, and document each step in an engineering notebook. At the completion of the design process, present the model to the class and critique the design of other classmates. (TN CCSS Reading 3, 4, 5, 7, 9; TN CCSS Writing 4, 7)

Fundamental Sketching and Engineering Drawing

9) Define the differences in technique among freehand sketching, manual drafting, and computer-aided drafting (CAD), and describe the skills required for each. Create a two-dimensional orthographic (multiview) drawing incorporating labels, notes, and dimensions, using sketching/geometric construction techniques. Apply basic dimensioning rules and properly use

different types of lines (e.g., object, hidden, center). The orthographic projections should include principle views of a simple object from top, front, and right sides. (TN CCSS Reading 3, 4, 5, 7; TN CCSS Writing 4; TN CCSS Math~~,~~ G-MG)

10) Building on the knowledge of a two-dimensional drawing, create simple isometric (3-D pictorial) drawings, properly using lines (e.g., object, hidden, center), labels, and dimensioning techniques. (TN CCSS Reading 3, 4, 5, 7; TN CCSS Writing 4; TN CCSS Math~~,~~ G-MG)

11) Use CAD software to create simple two-dimensional and three-dimensional drawings, accurately incorporating labels, notes, dimensioning, and line types to design drawings. Perform basic operations such as creating, saving files, opening files, storing files, and printing. (TN CCSS Reading 3, 4, 5, 7; TN CCSS Writing 4; TN CCSS Math~~,~~ G-MG)

Introduction to Measurement

12) Use physical measurement devices typically employed in engineering to collect and build a dataset. For example, calipers may be used to measure the width of pens in the classroom, generating a dataset. Tools should include, but are not limited to, fractional rule, metric rule, dial caliper, and micrometer. (TN CCSS Reading 1, 3, 7; TN CCSS Writing 4; TN CCSS Math N-Q)

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Class Project

~~12)~~13) As a class, identify a problem in the school or community that can be solved by an engineer. Follow the design process to solve the problem. The class will collaboratively develop a paper following the format of a typical technical report (see components of the report below). Upon completion of the report, create and deliver a presentation for a CTSO event using appropriate citation conventions learned in the course. Refine the report as would a team of engineers by incorporating feedback from the presentation.

The technical report should include, but is not limited to:

a) Background
b) Problem definition
c) Design constraints
d) Methodology
e) Data analysis (e.g., charts, graphs, calculations)
f) Results/Problem solution (including engineering drawings)
g) Conclusions and recommendations for future research

(TN CCSS Reading 1, 3, 4, 5, 7, 9; TN CCSS Writing 2, 5, 6, 7, 8, 9, 10)

Standards Alignment Notes

*References to other standards include:

- TN CCSS Reading: Common Core State Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects; Reading Standards for Literacy in Science and Technical Subjects 6-12; Grades 9-10 Students (page 62).

    - Note: While not directly aligned to one specific standard, students who are engaging in activities outlined above should be able to also demonstrate fluency in Standard 10 at the conclusion of the course.
- TN CCSS Writing: Common Core State Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects; Writing Standards for Literacy in History/Social Studies, Science, and Technical Subjects 6-12; Grades 9-10 Students (pages 64-66).
    - Note: While not directly aligned to one specific standard, students who are engaging in activities outlined above should be able to also demonstrate fluency in Standards 1, 3 and 10 at the conclusion of the course.
- TN CCSS Math: Common Core State Standards for Mathematics; Math Standards for High School: Number and Quantity, Algebra, Functions, Geometry, Statistics and Probability.
    - Note: The standards in this course are not meant to teach mathematical concepts. However, the concepts referenced above may provide teachers with opportunities to collaborate with mathematics educators to design project-based activities or collaborate on lesson planning. While not aligned to one specific conceptual category, students who are engaging in the activities outlined above should be able to demonstrate quantitative, algebraic, functional, geometric, and statistical reasoning as applied to specific technical concepts. In addition, students will have the opportunity to practice the habits of mind as described in the eight Standards for Mathematical Practice.
- P21: Partnership for 21st Century Skills Framework for 21st Century Learning
    - Note: While not all standards are specifically aligned, teachers will find the framework helpful for setting expectations for student behavior in their classroom and practicing specific career readiness skills.
- International Technology and Engineering Educators Association (ITEEA). (2013). http://www.iteea.org/.

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Robotics & Automated Systems

Primary Career Cluster:	Science, Technology, Engineering, and Mathematics (STEM)
Consultant:	Bethany King Wilkes, (615) 532-2844, Bethany.Wilkes@tn.gov
Course Code:	6143
Prerequisite(s):	*Principles of Engineering & Technology* (5924); *Digital Electronics* (5925); *Algebra I* (3102); *Geometry* (3108); *Physical Science* (3202); and *Chemistry* (3221) or *Physics* (3231)
Credit:	1
Grade Level:	11
Graduation Requirement:	This course satisfies one of three credits required for an elective focus when taken in conjunction with other STEM courses.
Programs of Study and Sequence:	This is the third course in the *Technology* program of study.
Necessary Equipment:	Equipment lists can be found at http://www.tn.gov/education/cte/ScienceTechnologyEngineeringMathematics.shtml.
Aligned Student Organization(s):	Skills-USA: http://www.tnskillsusa.com Brandon Hudson, (615) 532-2804, Brandon.Hudson@tn.gov Technology Student Association (TSA): http://www.tntsa.org Amanda Hodges, (615) 532-6270, Amanda.Hodges@tn.gov
Coordinating Work-Based Learning:	If a teacher has completed work-based learning training, he or she can offer appropriate ~~student~~ placement ~~can be offered~~. To learn more, please visit http://www.tn.gov/education/cte/wb/.
Available Student Industry Certifications:	None
Dual Credit or Dual Enrollment Opportunities:	There are no known dual credit/dual enrollment opportunities for this course. If interested in developing, reach out to a local postsecondary institution to establish an articulation agreement.
Teacher Endorsement(s):	013, 014, 015, 016, 017, 018, 047, 070, 078, 081, 210, 211, 212, 213, 214, 413, 414, 415, 416, 417, 418, 230, 231, 232, 233, 470, 477, 519, 531, 535, 537, 582, 595, 596
Required Teacher Certifications/Training:	Teachers who have never taught this course must attend training provided by the Department of Education.
Teacher Resources:	http://www.tn.gov/education/cte/ScienceTechnologyEngineeringMathematics.shtml~~doc/STEMResourceList.pdf~~

Course Description

Robotics & Automated Systems is an applied course for students who wish to explore how robots and automated systems are used in industry. Building on the content and critical thinking frameworks of *Principles of Engineering* and *Digital Electronics*, this course asks students to follow the engineering design process and apply basic programming skills to complete assignments and projects. Upon completion of this course, proficient students will have an understanding of the historical and current uses of robots and automated systems; programmable circuits, interfacing both inputs and outputs; ethical standards for engineering and technology professions; and testing and maintenance of robots and automated systems.

Note: Standards in this course are presented sequentially for students' learning progression; however, instructors may tailor the order of course standards to their specifications. Students are expected to use engineering notebooks to document procedures, design ideas, and other notes for all projects throughout the course.

Program of Study Application

This is the third course in the *Technology* program of study. For more information on the benefits and requirements of implementing this program in full, please visit the STEM website at http://www.tn.gov/education/cte/ScienceTechnologyEngineeringMathematics.shtml.

Course Standards

Safety

1) Accurately read and interpret safety rules, including but not limited to rules published by the National Science Teachers Association (NSTA), rules pertaining to electrical safety, Occupational Safety and Health Administration (OSHA) guidelines, and state and national code requirements. Be able to distinguish between the rules and explain why certain rules apply. (TN CCSS Reading 2, 3, 4, 5, 6)

2) Identify and explain the intended use of safety equipment available in the classroom. For example, demonstrate how to properly inspect, use, and maintain safe operating procedures with tools and equipment. (TN CCSS Reading 3, 4)

Robotics Overview

3) Research the historical use of robotics from textbooks, news media, and other informational texts. Create a presentation concerning the various uses of robotics. For example, explore areas such as the surgical field, space exploration, agriculture, and advanced manufacturing. (TN CCSS Reading 1, 2, 4, 7; TN CCSS Writing 4, 7)

4) Write a persuasive essay explaining why robots should be used in certain circumstances. Cite textual evidence to support claims (for example, assemble evidence from medical journals to support a claim that the use of robots has lowered costs and increased efficiency among medical providers). Other examples may derive from the areas identified in standard 3. During a class

discussion, defend original arguments and debate peer perspectives using claim(s) and counterclaim(s) developed in the persuasive essay. (TN CCSS Reading 1, 4, 7, 8; TN CCSS Writing 1, 4, 7, 9)

Career Exploration

5) Create a presentation illustrating industries, organizations, and careers in Tennessee and other states that use robotics (such as Nissan in Automotive Manufacturing). Include work activities involved, postsecondary education needed, and skills necessary for these careers. (These could range from industry certifications to degrees in robotics engineering.) (TN CCSS Reading 2, 4; TN CCSS Writing 2, 4, 7, 8)

6) Research the ethical considerations involved in developing new and modifying existing technologies. For example, investigate the National Society of Professional Engineers' (NSPE) Code of Ethics for Engineers or the Computer Ethics Institute's Ten Commandments ~~for~~ of Computer Ethics. Select an existing technology and describe the ethical dilemmas faced by both producers and consumers of that technology, such as trade-offs between individual versus societal benefits or unforeseen consequences to the environment. For example, examine why some workers and labor unions may view robots as a threat to their jobs. Present findings to the class in a format appropriate for a career and technical student organization (CTSO) event. (TN CCSS Reading 2, 4, 7; TN CCSS Writing 2, 4, 7, 9)

Programming

7) Create a flowchart of a program for a robotic system. Convert the flowchart into a working program. Test, modify, and optimize the program. Write a technical report evaluating the performance of the program. Support all claims with specific examples. (TN CCSS Reading 3, 4; TN CCSS Writing 1, 4)

8) Log, store, and export data received from two or more sensors (for example, vision/light, audio, and touch) in a robotic or automated system. Explain why these procedures would be useful and provide specific examples. (TN CCSS Reading 3, 4; TN CCSS Writing 4)

Engineering Design and Science & Engineering Practices

9) Compare and contrast the following engineering design process with the eight practices of science and engineering (Achieve, 2013). Based on observations, write a brief paper explaining how the engineering design process and the science and engineering practices overlap, and describe how they might be used in automated systems design. Present findings to the class and refine the paper based on feedback. (TN CCSS Reading 2; TN CCSS Writing 2, 5)

Engineering Design Process	Science and Engineering Practices
a) Identify the problem	a) Asking questions (for science) and defining problems (for engineering)
b) Identify criteria and specify constraints	b) Developing and using models
c) Brainstorm possible solutions	c) Planning and carrying out investigations
d) Research and generate ideas	d) Analyzing and interpreting data

e) Explore alternative solutions	e) Using mathematics and computational thinking
f) Select an approach	f) Constructing explanations (for science) and designing solutions (for engineering)
g) Write a design proposal	g) Engaging in argument from evidence
h) Develop a model or prototype	h) Obtaining, evaluating, and communicating information
i) Test and evaluate	
j) Refine and improve	
k) Create or make a product	
l) Communicate results	

Computers and Electronics

10) Create an explanatory presentation that describes the parts necessary to make a robot and distinguishes it from a computer and a non-robotic machine. Parts necessary to make a robot include: (1) having a microprocessor for a brain, (2) sensors for input and output, (3) controls, and (4) motors. The presentation should include an informative report that describes various types of sensors (for example, auditory, visual, heat, etc.) and a summary of how sensors provide input. It should also describe various types of output (for example, motors, mechanisms, speakers, light, etc.) and discuss how sensors provide output. (TN CCSS Writing 2, 4, 9)

11) Design, develop, and test a program to control a robotic system and robotic subsystems. The program should be able to receive data from a robot's input devices, process the data, and create outputs based on the inputs received. Present the robotic system to the class and provide details on the methodology used to design and develop the program, justifying selections as appropriate. (CCSS TN Writing 4, 5)

12) Utilize feedback loops in a robotic system. For example, create a demonstration scenario and program a robot that requires the following: start, stop, or change motion within a robotic or automated system based on sensor input, provided by two or more sensors (such as vision/light, audio, and touch). (TN CCSS Reading 3, 4; TN CCSS Writing 4, 5)

Mechanics

13) Use mechanical tools, such as motors, gears, and gear trains in the construction of a robotic or automated system. Identify where forces are acting upon various points on the system and document with simple diagrams. Use the concepts of force, torque, and mechanical advantage to calculate the force acting upon the points in the system. (TN CCSS Reading 3, 7; TN CCSS Writing 4; TN CCSS Math N-Q, A-REI)

14) Develop a system to demonstrate force, torque, work, and power acting upon or being done by a robotic or automated system. Justify the design by creating mathematical models that show the calculations. (TN CCSS Reading 3; TN CCSS Writing 4; TN CCSS Math N-Q, A-REI)

Testing, Maintenance, Documentation, and Quality Assurance

15) Use appropriate instruments to measure and record electrical, light, and audio outputs of a robotic system. Compare measured data to acceptable norms for the system. Document whether the system is performing within accepted parameters and cite evidence to support the claims. Perform maintenance or follow recommended procedures to correct malfunctions or underperformance within the system. Write a justification for any maintenance that is performed, citing data obtained from test results. (TN CCSS Reading 3, 4; TN CCSS Writing 1, 4)

16) Create a service and maintenance report on a robotic or automated system. The report should include text explaining the maintenance and corrective measures conducted. It should also include text justifying whether the system is functioning properly or recommending additional measures to correct any issues within the system. Finally, it should include text recommending quality-assurance policies and procedures to assure continuing operation of the system within acceptable parameters and text describing corrective procedures to be used when the system is malfunctioning or operating below optimal performance. (TN CCSS Reading 5; TN CCSS Writing 1, 2, 4, 5)

Projects

17) Working in a team, design and create a robotic solution to a given problem. Incorporate the engineering design process, as well as science and engineering practices, to develop a solution that meets the criteria for entries in a regional, state, or national robotics competition. Maintain an engineering notebook to document the details of the project. Write a technical paper (see components of the report below) and develop a presentation describing the solution and development process for the team solution.

    The technical paper should include, but is not limited to:
    a) Background
    b) Problem definition
    c) Design constraints
    d) Methodology
    e) Data analysis (e.g., charts, graphs, calculations)
    f) Results/Problem solution (include engineering drawings)
    g) Conclusions and recommendations for future research

    (TN CCSS Reading 1, 3, 4, 7, 9; TN CCSS Writing 2, 5, 6, 7, 8, 9)

Standards Alignment Notes

*References to other standards include:

- TN CCSS Reading: Common Core State Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects; Reading Standards for Literacy in Science and Technical Subjects 6-12; Grades 11-12 Students (page 62).
    - Note: While not directly aligned to one specific standard, students who are engaging in activities outlined above should be able to also demonstrate fluency in Standard 10 at the conclusion of the course.

- TN CCSS Writing: Common Core State Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects; Writing Standards for Literacy in History/Social Studies, Science, and Technical Subjects 6-12; Grades 11-12 Students (pages 64-66).
    - Note: While not directly aligned to one specific standard, students who are engaging in activities outlined above should be able to also demonstrate fluency in Standards 3 and 10 at the conclusion of the course.
- TN CCSS Math: Common Core State Standards for Mathematics; Math Standards for High School: Numbers and Quantity, Algebra.
    - Note: The standards in this course are not meant to teach mathematical concepts. However, the concepts referenced above may provide teachers with opportunities to collaborate with mathematics educators to design project-based activities or collaborate on lesson planning. Students who are engaging in activities listed above should be able to demonstrate quantitative and algebraic reasoning as applied to specific technical concepts. In addition, students will have the opportunity to practice the habits of mind as described in the eight Standards for Mathematical Practice.
- P21: Partnership for 21st Century Skills Framework for 21st Century Learning
    - Note: While not all standards are specifically aligned, teachers will find the framework helpful for setting expectations for student behavior in their classroom and practicing specific career readiness skills.
- Achieve: Next Generation Science Standards. (2013). "A Science Framework for K-12 Science Education."

Science of Technology (PLTW)

Primary Career Cluster:	Science, Technology, Engineering, and Mathematics (STEM)
Consultant:	Bethany King Wilkes, (615) 532-2844, Bethany.Wilkes@tn.gov
Course Code:	~~TBD~~0891
Prerequisite(s):	None
Credit:	N/A
Grade Level:	8
Graduation Requirement:	N/A
Coursework and Sequence:	This is ~~the third~~a course in the *Project Lead the Way (PLTW)* middle school sequence of coursework.
Necessary Equipment:	Visit www.pltw.org for more information.
Aligned Student Organization(s):	Technology Student Association (TSA):http://www.tntsa.org Amanda Hodges, (615) 532-6270, Amanda.Hodges@tn.gov
Coordinating Work-Based Learning:	N/A
Available Student Industry Certifications:	N/A
Dual Credit or Dual Enrollment Opportunities:	N/A
Teacher Endorsement(s):	001, 013, 014, 015, 016, 017, 018, 047, 070, 078, 081, 101, 210, 211, 212, 213, 214, 230, 231, 232, 233, 400, 401, 402,413, 414, 415, 416, 417, 418, 440, 470, 477
Required Teacher Certifications/Training:	*Project Lead the Way* training is required
Teacher Resources:	http://www.tn.gov/education/cte/doc/STEMResourceList.pdf

Course Description

This is a course in the series of *Project Lead the Way (PLTW)* curriculum. For more information, visit the PLTW website at http://www.pltw.org/.

Program of Study Application

These courses build knowledge and skills related to the following career clusters:

1) Architecture & Construction
2) Information Technology (IT)
3) Manufacturing
4) Science, Technology, Engineering & Mathematics (STEM)
5) Transportation, Distribution, & Logistics

Course Standards

The course standards outlined below are the copyrighted property of *Project Lead the Way*. Teachers must participate in *Project Lead the Way* training in order to be able to teach this course. This course is one in a series of PLTW middle school courses. The lesson numbers below reflect the recommended sequence.

Lesson 5.1 Applied Chemistry (6 days)

Understandings

1) Chemical engineering is concerned with design, construction and operation of machines that perform chemical reactions, separations or mixes, and fluid flow to solve problems and make useful products.
2) Chemical engineers apply the knowledge and discoveries of a chemist to solve real life problems.
3) Chemical engineers work in many industries including manufacturing, pharmaceuticals, healthcare, environmental, materials, and alternative energy.
4) Chemical engineers often work on teams with other engineers, scientists, and technologists

Knowledge and Skills

It is expected that students will:

- Describe the difference between a chemist and a chemical engineer.
- Describe how salt affects the melting point of ice.
- Describe how an adhesive bond holds two items together.
- Outline the steps required to clean up an oil spill.
- Apply science and engineering skills to make ice cream.
- Utilize the steps of the design process to create product.
- Work as a part of a team to solve an oil spill engineering simulation problem.

Lesson 5.2 Nanotechnology (10 days)

Understandings

1) Nanotechnology is building innovative tools to study and manipulate objects at the nanometer scale, one billionth of a meter.
2) Properties of materials, such as strength, color, and resistance can be changed by nanotechnology.
3) Molecules can be arranged using nanotechnology in a way that they do not normally occur in nature.

4) Nanotechnology will have an impact on many areas, including but not limited to electronics and computing, materials, manufacturing, energy, environment, health, medicine, national security, and space exploration.
5) Scanning Probe and Atomic Force microscopes are used to see and move individual atoms.
6) Engineers, designers, and engineering technologists are needed in high demand for the development of future technology to meet societal needs and wants.

Knowledge and Skills
It is expected that students will:

- Identify facts regarding nanotechnology including properties of materials at nanoscale.
- Describe the relative size of a nanometer.
- Describe how nano-products are used in society today.
- Identify tools and processes used to see and manipulate matter at the nanoscale.
- Discuss the impact that nanotechnology has on their lives today and will have in the future.
- Identify examples of nanotechnology-enhanced products.
- Describe engineering and engineering technology careers related to the advancement of nanotechnology.

Lesson 5.3 Applied Physics (29 days)

Understandings
1) Simple machines can make work easier by increasing mechanical advantage.
2) Mechanical advantage is the ratio of the force produced by a machine to the force applied to the machine.
3) Compound machines are made from a combination of several simple machines.
4) Energy cannot be created or destroyed but may be transferred into different types of energy.
5) Humans use their energy, along with simple machines, to do work by changing the state of energy of an object from potential to kinetic.
6) Prototyping is an important step in the design process and provides the designer with a scaled working model that can be used for testing.

Knowledge and Skills
It is expected that students will:

- Identify the six simple machines: the lever, pulley, wheel and axle, inclined plane, wedge, and screw.
- Identify a machine as something that helps use energy more efficiently.
- Describe work as the force applied over a distance.
- Explain the applications of the six simple machines.
- Distinguish between the three classes of levers.
- Determine mechanical advantage from assembled simple machines.
- Compare and contrast kinetic and potential energy.
- Predict the relative kinetic energy based on the mass and speed of the object.
- Recognize and demonstrate safety rules for using lab tools and machines.
- Build, test, and evaluate a model of a design problem.
- Analyze a product through testing methods and make modifications to the product.

TENNESSEE DEPARTMENT OF EDUCATION
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STEM Designers

Primary Career Cluster:	Science, Technology, Engineering, and Mathematics (STEM)
Consultant:	Bethany King Wilkes, (615) 532-2844, Bethany.Wilkes@tn.gov
Course Code:	0849~~TBD~~
Prerequisite(s):	None
Credit:	1
Grade Level:	8
Graduation Requirement:	None
Coursework and Sequence:	This is the third course in the *Middle School STEM* sequence of coursework.
Necessary Equipment:	~~Refer to the equipment list found on the STEM website linked below.~~ Equipment lists can be found at http://www.tn.gov/education/cte/ScienceTechnologyEngineeringMathematics.shtml.
Aligned Student Organization(s):	Technology Student Association (TSA): http://www.tntsa.org Amanda Hodges, (615) 532-6270, Amanda.Hodges@tn.gov
Coordinating Work-Based Learning:	N/A
Available Student Industry Certifications:	N/A
Dual Credit or Dual Enrollment Opportunities:	N/A
Teacher Endorsement(s):	001, 013, 014, 015, 016, 017, 018, 047, 070, 078, 081, 101, 210, 211, 212, 213, 214, 230, 231, 232, 233, 400, 401, 402, 413, 414, 415, 416, 417, 418, 440, 470, 477
Required Teacher Certifications/Training:	Teachers who have never taught this course must attend training provided by the Department of Education.
Teacher Resources:	http://www.tn.gov/education/cte/ScienceTechnologyEngineeringMathematics.shtml~~doc/STEMResourceList.pdf~~

Course Description

STEM Designers is a fundamental middle school course that trains students to define problems and methodically answer the question, *"What is the solution?"* Upon completion of this course, proficient STEM designers understand that engineering design is a process of developing solutions to problems and challenges in order to meet the needs of society. Students continue to apply the practices for science and engineering learned in *STEM Explorers* and *STEM Innovators*; however, *STEM Designers* places more emphasis on practices such as using mathematics and computational thinking; designing solutions; engaging in argument from evidence; and obtaining, evaluating, and communicating information. In addition to gaining a deep understanding of the relationship between engineering and design, students who complete this course will learn how both innovation and engineering design result in new technologies that benefit humans. Standards in this course are aligned with Tennessee Common Core State Standards in English Language Arts & Literacy in Technical Subjects and Tennessee Common Core State Standards in Mathematics.*

Note: Students are expected to use engineering notebooks to document procedures, design ideas, and other notes for all projects throughout the course.

Program of Study Application

This is the third course in the *Middle School STEM* sequence of coursework and prepares students for multiple programs of study in the STEM career cluster. For more information on the benefits and requirements of implementing STEM courses in full, please visit the CTE website at http://www.tn.gov/education/cte/ScienceTechnologyEngineeringMathematics.shtml.

Course Standards

Safety

1) Accurately read and interpret safety rules, including but not limited to rules published by the National Science Teachers Association (NSTA), rules pertaining to electrical safety, Occupational Safety and Health Administration (OSHA) guidelines, and state and national code requirements. Be able to distinguish between the rules and explain why certain rules apply. (TN CCSS Reading 3, 4)

2) Identify and explain the intended use of safety equipment available in the classroom. For example, demonstrate how to properly inspect, use, and maintain safe operating procedures with tools and equipment. Incorporate safety procedures and complete safety test with 100 percent accuracy. (TN CCSS Reading 3, 4)

Introduction to Engineering

3) Research the history of engineering using textbooks, the websites of professional societies, scholarly narratives, and explain how science, technology, and math have influenced its development. Create a timeline of important engineering milestones, noting the influence of science, technology, and math in the timeline. The timeline may be done via PowerPoint, Prezi, poster, or other graphic format. (TN CCSS Reading 1; TN CCSS Writing 2, 4, 7)

4) Research and illustrate the relationship between science, technology, engineering, and math using a flowchart, Venn diagram, or other graphic organizer. Provide an example of a design solution that incorporated at least three of the disciplines and articulate how they each contributed to the design. (TN CCSS Reading 1; TN CCSS Writing 2, 4)

5) Research how engineers in various disciplines (such as civil, mechanical, electrical, chemical, biomedical, computer, agricultural, industrial, and aerospace) benefit society through the products and solutions they design. Write a paper arguing for the discipline that has benefited society the most. Illustrate the claim with specific products and benefits. (TN CCSS Reading 1; TN CCSS Writing 1, 4, 7)

Engineering Design Process

6) Evaluate an existing engineering design, such as a local bridge or a famous building, providing evidence from exemplars and design rubrics to justify whether the design meets the specified criteria. Create a presentation explaining how the steps of the design process might have been used to create this feat of engineering, citing historical narratives, published interviews with the architects or engineers involved, and other informational resources. The typical steps of the design process include: identify the problem; identify criteria and specify constraints; brainstorm for possible solutions; research and generate ideas; explore alternative solutions; select an approach; write a design proposal, develop a model or prototype; test and evaluate; refine and improve; create or make a product; and communicate results. (TN CCSS Reading 3; TN CCSS Writing 1, 2, 4)

7) Practice exploring alternative solutions in the engineering design process by creating two solutions for an engineering problem. Test each solution and record the test data. Analyze the test data to determine the differences in the quality for the solutions. Write a conclusion that that argues which solution is best and explains why. Support the explanation with specific evidence obtained from test results. For example, create a solar vehicle that is designed travel as fast as possible. The two solutions should have a single variable that is changed, for example drive and axle gear ratio, wheel size, or solar panel angle.(TN CCSS Reading 1, 3; TN CCSS Writing 1, 4, 7, 9; TN CCSS Math 8.SP)

8) Use the engineering design process and the practices of science and engineering (see specific practices below) to develop a solution for a given engineering challenge. Chronologically document the entire process in an engineering notebook. The engineering notebook should have bound, dated, and numbered pages. Use permanent ink to document notes. For example, design a balsa or basswood bridge that has the best performance ratio, maximum capacity divided by mass of the bridge. Tests can be done of various basic structure designs before creating a final design. This test data should be included in the engineering notebook. A hand or digital sketch should be made of the design. Pictures can be taken throughout the process and included in the engineering notebook. At minimum, address the following science and engineering practices:
    a. Using mathematics and computational thinking
    b. Designing solutions
    c. Engaging in argument from evidence
    d. Obtaining, evaluating, and communicating information

    (TN CCSS Reading 3; TN CCSS Writing 4)

Fundamental Sketching and Engineering Drawing

9) Present a two-dimensional design idea using freehand sketching, manual drafting, and computer-aided drafting (such as SketchUp or AutoCad). Designs should be made to scale and include dimensions, labels, and notes. At least one of the designs presented should be an orthographic (multi-view) projection. Use basic dimensioning rules and apply understanding of the use of lines (e.g., object, hidden, center) to inform the design. Sketch principle views of a simple object from the top, bottom, front, back, left side, and right side. For example, create an orthographic projection of a CO_2 dragster or a floor plan for a home. (TN CCSS Reading 3, 4, 7; TN CCSS Writing 4; TN CCSS Math~~,~~ 8.G)

10) Present a 3-D design idea using freehand sketching, manual drafting, and computer-aided drafting (such as SketchUp, SolidWorks, or Inventor). Designs should be made to scale and include dimensions, labels, and notes. Use basic dimensioning rules and apply understanding of the use of lines (e.g., object, hidden, center). *For example, convert the 2-D design in the activity in the previous standard into a 3-D design in the 3-D version of the software used to create the 2-D design.*(TN CCSS Reading 3, 4, 7; TN CCSS Writing 4; TN CCSS Math~~,~~ 8.G)

11) Create a scaled model of a design concept. A digital or manual drafting design should be made of this model prior to building or producing the model. For example, create a digital 3-D design of a product and use a 3-D printer to create a physical model of the design. If a 3-D printer is not available, build a model from materials provided in the class. (TN CCSS Reading 3, 4, 7; TN CCSS Writing 4; TN CCSS Math 8.G)

Final Project

12) Work in groups to solve a community or school problem by applying the engineering design process and the practices of science and engineering. Build a prototype, if feasible, and write a technical report detailing the problem, the design process used, and the solution proposed. Include an evaluation of the quality of the solution, and give a presentation to the class. Be able to justify the final design solution with supporting evidence from the process, including graphic representations and visual aids as appropriate. (TN CCSS Reading 1, 3, 4, 7, 9; TN CCSS Writing 2, 5, 6, 7, 8, 9, 10)

Standards Alignment Notes

*References to other standards include:

- TN CCSS Reading: Common Core State Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects; Reading Standards for Literacy in Science and Technical Subjects 6-12; Grades 6-8 Students (page 62).
    - Note: While not directly aligned to one specific standard, students who are engaging in activities outlined above should be able to also demonstrate fluency in Standards 2, 5, 6, 8, and 10 at the conclusion of the course.
- TN CCSS Writing: Common Core State Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects; Writing Standards for Literacy in History/Social Studies, Science, and Technical Subjects 6-12; Grades 6-8 Students (pages 64-66).

    - Note: While not directly aligned to one specific standard, students who are engaging in activities outlined above should be able to also demonstrate fluency in Standard 3 at the conclusion of the course.
- TN CCSS Math: Common Core State Standards for Mathematics; Math Standards for Middle School.
    - Note: The standards in this course are not meant to teach mathematical concepts. However, the concepts referenced above may provide teachers with opportunities to collaborate with mathematics educators to design project-based activities or collaborate on lesson planning. Students who are engaging in activities listed above should be able to demonstrate mathematical reasoning as applied to specific technical concepts. In addition, students will have the opportunity to practice the habits of mind as described in the eight Standards for Mathematical Practice.
- P21: Partnership for 21st Century Skills Framework for 21st Century Learning
    - Note: While not all standards are specifically aligned, teachers will find the framework helpful for setting expectations for student behavior in their classroom and practicing specific career readiness skills.

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STEM Explorers

Primary Career Cluster:	Science, Technology, Engineering, and Mathematics (STEM)
Consultant:	Bethany King Wilkes, (615) 532-2844, Bethany.Wilkes@tn.gov
Course Code:	0649~~TBD~~
Prerequisite(s):	None
Credit:	1
Grade Level:	6
Graduation Requirement:	N/A
Coursework and Sequence:	This is the first course in the *Middle School STEM* sequence of coursework.
Necessary Equipment:	Equipment lists can be found at http://www.tn.gov/education/cte/ScienceTechnologyEngineeringMathematics.shtml~~Refer to the equipment list found on the STEM website linked below.~~
Aligned Student Organization(s):	Technology Student Association (TSA): http://www.tntsa.org Amanda Hodges, (615) 532-6270, Amanda.Hodges@tn.gov
Coordinating Work-Based Learning:	N/A
Available Student Industry Certifications:	N/A
Dual Credit or Dual Enrollment Opportunities:	N/A
Teacher Endorsement(s):	001, 013, 014, 015, 016, 017, 018, 047, 070, 078, 081, 101, 210, 211, 212, 213, 214, 230, ~~231,~~ 232, 233, 400, 401, 402,413, 414, 415, 416, 417, 418, 440, 470, 477
Required Teacher Certifications/Training:	Teachers who have never taught this course must attend training provided by the Department of Education.
Teacher Resources:	http://www.tn.gov/education/cte/ScienceTechnologyEngineeringMathematics.shtml~~doc/STEMResourceList.pdf~~

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Course Description

STEM Explorers is a fundamental course for middle school students to search for answers to *"What is STEM?"* A student proficient in this course will understand science, technology, engineering, and mathematics (STEM) as a collection of interrelated disciplines, rather than a series of isolated fields. Students will come away from this course with a thorough understanding of how the STEM disciplines work together to investigate the world, define problems, and create optimal solutions to benefit society. In this course, students will explore the history of engineering and technology; they will be introduced to the practices of science and engineering; and they will explore various STEM fields to empower them to make an informed decision when selecting a career pathway in high school. Standards in this course are aligned with Tennessee Common Core State Standards in English Language Arts & Literacy in Technical Subjects and Tennessee Common Core State Standards in Mathematics.*

Program of Study Application

This is the first course in the *Middle School STEM* sequence of coursework. This program leads to several programs of study in the STEM career cluster in high school. For more information on the benefits and requirements of implementing these programs in full, please visit the CTE website at http://www.tn.gov/education/cte/.

Course Standards

STEM Overview

1) Drawing on multiple sources (such as the Internet, textbooks, videos, and journals), investigate historical figures and milestones in science, technology, engineering, and mathematics. Create a report over a selected STEM figure or milestone. Explain how this figure or milestone had a lasting influence on at least two of the four STEM fields. (TN CCSS Reading 9; TN CCSS Writing 2, 4)

2) Drawing on multiple sources (such as the internet, textbooks, videos, and journals), research technologies that have benefited society. Create a presentation illustrating society's role in the creation of a chosen technology. Discuss the societal needs that led to the creation of this technology, as well as the benefits resulting from it. Provide examples to support the claim that this technology has been beneficial to society. Relate the specific areas of science, technology, engineering, and math that contributed to the development of this technology. (TN CCSS Reading 7; TN CCSS Writing 1, 4)

Science & Engineering Practices

3) Explain how asking scientific questions can help to define an engineering problem to be solved. Choose a specific question(s) and problem that a scientist or engineer would encounter, then develop a model to illustrate the problem. Provide textual evidence from science and engineering books and websites to justify why the model illustrates the problem. (TN CCSS Reading 2; TN CCSS Writing 1, 4, 9)

Safety

4) Accurately read and interpret safety rules, including but not limited to rules published by the National Science Teachers Association (NSTA), rules pertaining to electrical safety, Occupational Safety and Health Administration (OSHA) guidelines, and state and national code requirements. Be able to distinguish between the rules and explain why certain rules apply. (TN CCSS Reading 3, 4)

5) Identify and explain the intended use of safety equipment available in the classroom. For example, demonstrate how to properly inspect, use, and maintain safe operating procedures with tools and equipment. Incorporate safety procedures and complete safety test with 100 percent accuracy. (TN CCSS Reading 3, 4)

STEM Fields Exploration

6) Investigate the following six STEM-intensive career clusters: Manufacturing; STEM; Health Sciences; Information Technology; Architecture and Construction; Agriculture, Food and Natural Resources; and Transportation, Distribution and Logistics. Identify companies and organizations in the state, region, and the school's local community related to each of these clusters. Create an informative poster or presentation that identifies companies in each cluster, the products they produce, and the services they offer. (TN CCSS Reading 7; TN CCSS Writing 2, 4, 7)

7) Research various occupations in each of the six STEM-intensive career clusters: Manufacturing; STEM; Health Sciences; Information Technology; Architecture and Construction; Agriculture, Food and Natural Resources; and Transportation, Distribution and Logistics. Compose an informative table or chart highlighting at least one occupation in each cluster, to include the following: work activities typically performed; tools and technology used; nature of the work environment; and the knowledge and skills needed for success. (TN CCSS Reading 7; TN CCSS Writing 2, 4)

Manufacturing Cluster

8) Investigate the field of manufacturing and manufacturing processes. Drawing on technical texts and exemplar designs retrieved from manufacturing websites, design and create a model of a manufacturing process. Demonstrate how the model would be used by a manufacturer to conduct a specific manufacturing process. Write a persuasive essay that argues for the quality and efficiency of the model and the process it simulates/demonstrates. Then, evaluate the model and discuss how it and/or the process can be improved. (TN CCSS Reading 7, 9; TN CCSS Writing 1, 4, 9)

STEM Cluster

9) Research engineering and scientific texts to understand the engineering design and scientific inquiry processes. Design and create a product that meets specific constraints and criteria using an engineering process that includes the following: identifying the problem; identifying criteria and specifying constraints; brainstorming for possible solutions; researching and generating

ideas; exploring alternative solutions; selecting an approach; writing a design proposal, developing a model or prototype; testing and evaluating; refining and improving; creating or making a product; and communicating results. Evaluate and report whether the solution met the original criteria and constraints, as well as what improvements could be made to the solution, including a summary of data. *For example, students design and build a paper airplane that will stay aloft for the longest time. Students record their plane design before building and testing it. Students build and test their plane three times, recording the time aloft in each test. Students make a modification to their plane design. Students should be encouraged to only modify a single variable. Students build and test their modified plane three times as with their original plane. This process may be repeated multiple times. Students should create and present a report of the design, test results, results and conclusions. Teachers may wish to have students use their phones to take pictures of their plane designs and test results.* (TN CCSS Reading 3; TN CCSS Writing 1, 4)

Health Sciences Cluster

10) Research areas of the health sciences field. Collect, graph, and analyze personal health or forensic-related information. Write a brief explanation that categorizes the data collected and then describes the significance of the data. *For example, students may collect personal health-related information, such as heart rate (resting, vs. standing vs. active), their BMI, flexibility, or their lung capacity, and compare these against government recommendations. Alternatively, students may collect and analyze forensic information, such as hair or fingerprint samples. Students may then analyze and classify the samples. In either of these examples, the class or individuals' data should be graphed using bar or box-and-whisker graphs.* (TN CCSS Reading 3, TN CCSS Writing 2, 4;TN CCSS Math 6.EE, 6.SP)

Information Technology Cluster

11) Research the field of information technology (IT) and define a problem that could be solved by an IT professional. Create a presentation that defines the problem and presents a possible solution including some form of information technology. Create a model (could be 3-D, a diagram, website, etc.) to illustrate the problem, the solution, or both. Include an informative evaluation of the model that explains the features and limitations of the model. *For example, students design a webpage that educates the community about an issue, concept, or program. The webpage may include audio, video, graphics, and text. After completing the webpage, have students check the size of the webpage, calculate download time under various download speeds, and determine changes that could be made to improve download time.* (TN CCSS Reading 3, 7; TN CCSS Writing 2, 4)

Architecture & Construction Cluster

12) Research a well-known building, such as the Empire State Building. Incorporate information obtained from the research to inform an original design for a structure meant to serve a specific purpose. Create a scaled drawing of the design as well as a 3-D model, attending to appropriate dimensions and scale. Provide evidence supporting why the design will work to meet the specific purpose. *For example, students design and build a model of a bridge that spans a specific space. Present the size of the bridge across a life-sized ravine and specify the material from which the*

students may build their model (i.e., balsa wood, bass wood, tooth picks, or soda straws). Test the load capacity of the bridge. (TN CCSS Reading 3, 7; TN CCSS Writing 1, 4; TN CCSS Math 6.RP)

Agriculture, Food & Natural Resources

13) Research a problem related to agriculture, food, and natural resources that could be solved using science, engineering, technology, and/or math. Design and conduct an experiment with a single independent variable that models the selected problem. Collect and analyze the data from the experiment. Create a report on the experiment that includes:
    a. Introduction explaining the principle tested and the methodology used in the test
    b. Data in graphs and/or tables
    c. Explanation of the data analysis
    d. Findings and conclusion from the experiment, as well as a justification to support the conclusion

    For example, students design a water filtration experiment. The students test the ability of various materials, such as activated charcoal, a coffee filter, rocks, dirt, or a combination of materials, to clean water via a filtration process. Students should measure the volume, mass, and density; judge color; measure spectroscopy; and/or test the pH of water samples before and after filtration. (TN CCSS Reading 3, 7; TN CCSS Writing 1, 2, 4; TN CCSS Math 6.SP)

Transportation, Distribution & Logistics

14) Research a problem relating to transportation, distribution, and logistics that could be solved using science, engineering, technology, and/or math. Design a model of a transportation technology based on specific criteria and constraints. Test the model's performance. Modify single aspects of the model's design and retest the model. Graph and analyze data from the test. Write an explanation based on the data analysis describing how the model could be further modified to optimize the design. Include any reasons why the test may have produced data that does not reflect the actual impact of the change in the test variable. *For example, have students design and build a water bottle rocket. Divide the class into groups and have the various groups each test a different variable such as ballast, nose cone design, fin size, fin shape, water-to-air mixture, and bottle size. After each group presents their findings, assign the students to construct a rocket that will reach the maximum altitude.* (TN CCSS Reading 3, 7; TN CCSS Writing 1, 4; TN CCSS Math 6.RP, 6.SP)

Standards Alignment Notes

*References to other standards include:

- TN CCSS Reading: Common Core State Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects; Reading Standards for Literacy in Science and Technical Subjects 6-12; Grades 6-8 Students (page 62).
    - Note: While not directly aligned to one specific standard, students who are engaging in activities outlined above should be able to also demonstrate fluency in Standards 5, 6, 8, and 10 at the conclusion of the course.

- TN CCSS Writing: Common Core State Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects; Writing Standards for Literacy in History/Social Studies, Science, and Technical Subjects 6-12; Grades 6-8 Students (pages 64-66).
    - Note: While not directly aligned to one specific standard, students who are engaging in activities outlined above should be able to also demonstrate fluency in Standards 3, 5, 6, 8, and 10 at the conclusion of the course.
- TN CCSS Math: Common Core State Standards for Mathematics; Math Standards for Middle School.
    - Note: The standards in this course are not meant to teach mathematical concepts. However, the concepts referenced above may provide teachers with opportunities to collaborate with mathematics educators to design project-based activities or collaborate on lesson planning. Students who are engaging in activities listed above should be able to demonstrate mathematical reasoning as applied to specific technical concepts. In addition, students will have the opportunity to practice the habits of mind as described in the eight Standards for Mathematical Practice.
- P21: Partnership for 21st Century Skills Framework for 21st Century Learning
    - Note: While not all standards are specifically aligned, teachers will find the framework helpful for setting expectations for student behavior in their classroom and practicing specific career readiness skills.

TENNESSEE DEPARTMENT OF EDUCATION
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STEM Innovators

Primary Career Cluster:	Science, Technology, Engineering, and Mathematics (STEM)
Consultant:	Bethany King Wilkes, (615) 532-2844, Bethany.Wilkes@tn.gov
Course Code:	0749~~TBD~~
Prerequisite(s):	None
Credit:	1
Grade Level:	7
Graduation Requirement:	None
Coursework and Sequence:	This is the second course in the *Middle School STEM* sequence of coursework.
Necessary Equipment:	~~Refer to the equipment list found on the STEM website linked below.~~Equipment lists can be found at http://www.tn.gov/eduation/cte/ScienceTechnologyEngineeringMathematics.shtml
Aligned Student Organization(s):	Technology Student Association (TSA): http://www.tntsa.org Amanda Hodges, (615) 532-6270, Amanda.Hodges@tn.gov
Coordinating Work-Based Learning:	N/A
Available Student Industry Certifications:	N/A
Dual Credit or Dual Enrollment Opportunities:	N/A
Teacher Endorsement(s):	001, 013, 014, 015, 016, 017, 018, 047, 070, 078, 081, 101, 210, 211, 212, 213, 214, 230, ~~231,~~232, 233, 400, 401, 402,413, 414, 415, 416, 417, 418, 440, 470, 477
Required Teacher Certifications/Training:	Teachers who have never taught this course must attend training provided by the Department of Education.
Teacher Resources:	http://www.tn.gov/education/cte/ScienceTechnologyEngineeringMathematics.shtml ~~doc/STEMResourceList.pdf~~

Course Description

STEM Innovators is a fundamental course for middle school students to understand the relationship between STEM and innovation, as well as explore the possibilities of *"What could be?"* A student proficient in this course will understand why innovation is important and how it benefits society. Students will learn how innovation requires creativity and leads to new discoveries and technologies that make life better for humans. In this course, students will identify past innovations and what inspired their creation. Students will continue learning the practices of science and engineering. This course will reinforce the specific practices of developing and using models; planning and carrying out investigations; and analyzing and interpreting data. Standards in this course are aligned with Tennessee Common Core State Standards in English Language Arts & Literacy in Technical Subjects and Tennessee Common Core State Standards in Mathematics.*

Program of Study Application

This is the second course in the *Middle School STEM* sequence of coursework and prepares students for many programs of study in the STEM career cluster in high school. For more information on the benefits and requirements of implementing these programs in full, please visit the CTE website at http://www.tn.gov/education/cte/.

Course Standards

Safety

1) Accurately read and interpret safety rules, including but not limited to rules published by the National Science Teachers Association (NSTA), rules pertaining to electrical safety, Occupational Safety and Health Administration (OSHA) guidelines, and state and national code requirements. Be able to distinguish between the rules and explain why certain rules apply. (TN CCSS Reading 3, 4)

2) Identify and explain the intended use of safety equipment available in the classroom. For example, demonstrate how to properly inspect, use, and maintain safe operating procedures with tools and equipment. Incorporate safety procedures and complete safety test with 100 percent accuracy. (TN CCSS Reading 3, 4)

Introduction to Innovation

3) Research great innovators. Create a presentation about selected innovators and their occupations. Discuss what inspired them, how their innovations have affected society, their education and background (Were they engineers or scientists?), and how they used science, technology, engineering, and mathematics to innovate. Examples of great innovators include Alexander Graham Bell (the telephone), Thomas Edison (electricity), Albert Einstein (theory of relativity), Henry Ford (assembly line), Grace Hopper (developed the first compiler for a programming language), Martin Cooper (wireless communications), Bill Gates (Microsoft), Steve Jobs (Apple), Mark Zuckerberg (Facebook), Jack Dorsey (Twitter). (TN CCSS Reading 4; TN CCSS Writing 2, 4, 9)

4) Research and identify skill sets that are important to innovators. Given a specific product, criteria and constraints, apply the innovation skills identified in the research to suggest improvements to the product. Working collaboratively with peers, implement the suggested improvements and defend choices in a presentation to the class. In the presentation, highlight the skill sets that were applied in the process and discuss why they were helpful in improving the product. *For example, students build a wind turbine from a kit and measure the amount of electricity it produces from the wind created by a fan. Students then redesign the size, shape, or number of turbine fins to increase the electrical output by at least 20 percent.* (TN CCSS Reading 3; TN CCSS Writing 1, 4)

5) Select one of the STEM-intensive career clusters and create a timeline of technological developments that helped advance industries associated with that cluster. (The STEM-intensive career clusters are considered to be: Manufacturing; STEM; Health Sciences; Information Technology; Architecture and Construction; Agriculture, Food & Natural Resources; and Transportation, Distribution & Logistics.) Present this timeline as a 3-D model, PowerPoint, Prezi, poster, etc. Include in the presentation how society's needs have affected this technological development. (TN CCSS Reading 4; TN CCSS Writing 2, 4, 9)

6) Research how a specific product became trademarked or patented, and write a brief blog post citing historical documents and other narratives to tell the story. Detail the process involved as this innovator or group of innovators secured intellectual property rights for the product, discussing any legal, political, or cultural obstacles faced. For example, research the development of the first smartphone and describe the experience with the trademark and/or patenting process. (TN CCSS Reading 1, 4; TN CCSS Writing 2, 4, 7, 9)

Innovation Process

7) Select and research a personally-used technology that was an improvement over an existing technology. Identify the reasons for the innovation, the approximate date of the innovation, and the process that resulted in the innovation. Compare and contrast the existing technology with the technology it replaced. Present the findings to the class. (TN CCSS Reading 4; TN CCSS Writing 2, 4, 9)

8) Articulate the concepts of divergent and convergent thinking to classmates. Create a table comparing and contrasting divergent (creativity) thinking and convergent (usually used in engineering) thinking. Research and present an example illustrating the convergent and/or divergent thinking processes involved in a specific innovation. (TN CCSS Reading 3; TN CCSS Writing 2, 4)

9) Research an existing technology whose purpose is to solve a societal problem, and follow a general innovation process to determine if the technology can be improved upon. The process should include, but is not limited to:
    a. Researching the advantages and disadvantages, including costs and benefits, of an existing technology whose purpose is to solve a societal problem
    b. Presenting the advantages and disadvantages and proposing alternatives and solutions to the disadvantages
    c. Analyzing and comparing advantages and disadvantages of a proposed solution

Consider any environmental, health, and economic impacts of the proposed solution. Prepare a chart illustrating the trade-offs and impacts of the proposed solution and include it in the presentation. (TN CCSS Reading 3, 4; TN CCSS Writing 2, 4)

10) Illustrate how the practices of science and engineering relate to the innovation process. This illustration could be in the form of a skit, a PowerPoint, a poster, or other graphic illustration. Science and engineering practices include: Asking questions (for science) and defining problems (for engineering); developing and using models; planning and carrying out investigations; analyzing and interpreting data; using mathematics and computational thinking; constructing explanations (for science) and designing solutions (for engineering); engaging in argument from evidence; obtaining, evaluating and communicating information. *For example, students create questions that could have led to the development of the iPad.* (TN CCSS Reading 3; TN CCSS Writing 2, 4)

11) Given a specific product, apply science and engineering practices *(as listed above)* to improve the product in a measurable manner. Design, produce, test, and analyze an improved product that meets specific constraints and criteria. Compose a report that summarizes the test data, evaluates whether the solution meets the original criteria and constraints, discusses and justifies what improvements were made to the original product, and explains what improvements could be made to the solution. *For example, students are shown a model catapult and a demonstration of its launching power. Students then design a new catapult that outperforms the catapults demonstrated in distance or accuracy. Students create a design that specifically shows what feature is modified to improve performance. Students conduct tests of their design, modify their design, and produce a final product.* (TN CCSS Reading 3; TN CCSS Writing 1, 4)

Fundamental Sketching

12) Identify basic design and sketching principles used in the design stage of the innovation process, including orthographic projection, object lines, hidden lines, dimensioning, and scale. Create a scaled and dimensioned, single or multi-view sketch of a product. *(Note: There are multiple versions of the design process. This standard will address one version.)* (TN CCSS Math 7.RP, 7.G)

3-Dimensional Models & Prototypes

13) Research how 3-D printing and rapid prototyping have revolutionized the innovation process, consulting popular news media, engineering journals, and relevant industry magazines. Design a 3-D model of a chosen product using computer-aided drafting or modeling software such as SolidWorks or Google SketchUp, then create a 3-D model of the design. Explain how 3-D printing can simplify the process of making changes to the product. *For example, students make a product with a 3-D printer, if feasible, after designing it. Otherwise, they could use available materials.* (TN CCSS Reading 2, 3, 4; TN CCSS Math 7.G)

Projects

14) Research the Maker Movement and Maker Faire, exploring associated websites and independent commentary (i.e., in news media, in scholarly magazines) to assess the impact they have had on today's culture of innovation. Develop a proposal to host a Maker Faire or similar exhibition/event in the school. Using research, justify the benefits of hosting such an event,

citing the importance of the modern Maker Movement as it relates to fostering innovation. (TN CCSS Reading 4; TN CCSS Writing 1, 4, 9)

15) Research needs in the community or society in general using the internet, news sources, and/or surveys of individuals outside the classroom. Based on information gathered, apply an innovation process to create a product or technology that meets the need. Create a multimedia presentation that defines the problem or need and illustrates an appropriate method to document the innovation process (such as an innovation portfolio). Use this documentation method to record the process of developing the product or technology that meets the need or solves the problem. Demonstrate visually how the process was applied in the multimedia presentation. *(Example activity: Stage a school junior Maker Faire or technology fair. Have students create, display, and present their products at this event. If possible students can use a 3-D printer to create a prototype or scale model of their product.)* (TN CCSS Reading 3, 4; TN CCSS Writing 2, 4)

Standards Alignment Notes

*References to other standards include:

- TN CCSS Reading: Common Core State Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects; Reading Standards for Literacy in Science and Technical Subjects 6-12; Grades 6-8 Students (page 62).
    - Note: While not directly aligned to one specific standard, students who are engaging in activities outlined above should be able to also demonstrate fluency in Standards 5, 6, 7, 8, 9 and 10 at the conclusion of the course.
- TN CCSS Writing: Common Core State Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects; Writing Standards for Literacy in History/Social Studies, Science, and Technical Subjects 6-12; Grades 6-8 Students (pages 64-66).
    - Note: While not directly aligned to one specific standard, students who are engaging in activities outlined above should be able to also demonstrate fluency in Standards 3, 5, 6, and 10 at the conclusion of the course.
- TN CCSS Math: Common Core State Standards for Mathematics; Math Standards for Middle School.
    - Note: The standards in this course are not meant to teach mathematical concepts. However, the concepts referenced above may provide teachers with opportunities to collaborate with mathematics educators to design project-based activities or collaborate on lesson planning. Students who are engaging in activities listed above should be able to demonstrate mathematical reasoning as applied to specific technical concepts. In addition, students will have the opportunity to practice the habits of mind as described in the eight Standards for Mathematical Practice.
- P21: Partnership for 21st Century Skills Framework for 21st Century Learning
    - Note: While not all standards are specifically aligned, teachers will find the framework helpful for setting expectations for student behavior in their classroom and practicing specific career readiness skills.

TENNESSEE DEPARTMENT OF EDUCATION
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STEM I: Foundation

Primary Career Cluster:	Science, Technology, Engineering, and Mathematics (STEM)
Consultant:	Bethany King Wilkes, (615) 532-2844, Bethany.Wilkes@tn.gov
Course Code:	6144
Prerequisite(s):	None
Credit:	1
Grade Level:	9
Graduation Requirement:	This course satisfies one of three credits required for an elective focus when taken in conjunction with other STEM courses.
Programs of Study and Sequence:	This is the first course in the *STEM Education* program of study.
Necessary Equipment:	Equipment lists can be found ~~on the STEM website linked below.~~at http://www.tn.gov/eduation/cte/ScienceTechnologyEngineeringMathematics.shtml
Aligned Student Organization(s):	Skills USA: http://www.tnskillsusa.com Brandon Hudson, (615) 532-2804, Brandon.Hudson@tn.gov Technology Student Association (TSA): http://www.tntsa.org Amanda Hodges, (615) 532-6270, Amanda.Hodges@tn.gov
Coordinating Work-Based Learning:	If a teacher has completed work-based learning training, he or she can offer appropriate ~~student~~ placement ~~can be offered~~. To learn more, please visit http://www.tn.gov/education/cte/wb/.
Available Student Industry Certifications:	None
Dual Credit or Dual Enrollment Opportunities:	There are no known dual credit/dual enrollment opportunities for this course. If interested in developing, reach out to a local postsecondary institution to establish an articulation agreement.
Teacher Endorsement(s):	477, 013, 014, 015, 016, 017, 018, 047, 070, 078, 081, 210, 211, 212, 213, 214, 413, 414, 415, 416, 417, 418, 230, ~~231,~~232, 233, 470, 477, 519, 531, 595, 596
Required Teacher Certifications/Training:	Teachers who have never taught this course must attend training provided by the Department of Education.
Teacher Resources:	http://www.tn.gov/eduation/cte/ScienceTechnologyEngineeringMathematics.shtml~~http://www.tn.gov/education/cte/doc/STEMResourceList.pdf~~

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Course Description

STEM I: Foundation is a foundational course in the STEM cluster for students interested in learning more about careers in science, technology, engineering and mathematics. This course covers basic skills required for STEM fields of study. Upon completion of this course, proficient students are able to identify and explain the steps in both the engineering design and the scientific inquiry processes. They conduct research to develop meaningful questions, define simple problem scenarios and scientific investigations, develop fundamental design solutions, conduct basic mathematical modeling and data analysis, and effectively communicate solutions and scientific explanations to others. Standards in this course are aligned with Tennessee Common Core State Standards in English Language Arts & Literacy in Technical Subjects and Tennessee Common Core State Standards in Mathematics.*

Note: For clarity, some standards include example applications to science, technology, engineering, and mathematics. Teachers are encouraged to align instruction to one or more of these areas, depending on area of expertise and student interest.

Program of Study Application

This is the first course in the *STEM Education* program of study. For more information on the benefits and requirements of implementing this program in full, please visit the STEM website at http://www.tn.gov/education/cte/ScienceTechnologyEngineeringMathematics.shtml.

Course Standards

Safety

1) Accurately read and interpret safety rules, including but not limited to rules published by the National Science Teachers Association (NSTA), rules pertaining to electrical safety, Occupational Safety and Health Administration (OSHA) guidelines, and state and national code requirements. Be able to distinguish between the rules and explain why certain rules apply. (TN CCSS Reading 3, 4, 6)

2) Identify and explain the intended use of safety equipment available in the classroom. For example, demonstrate how to properly inspect, use, and maintain safe operating procedures with tools and equipment. Incorporate safety procedures and complete safety test with 100 percent accuracy. (TN CCSS Reading 3, 4)

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STEM Fields Exploration

~~1)~~3) Research the history of science, math, and engineering related to technology. Examine how these technologies have evolved, and evaluate their influence on present-day society, citing specific textual evidence from news articles and scholarly journals. (TN CCSS Reading 1, 2; TN CCSS Writing 2)

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~~2)~~4) Explore several occupations within the STEM field (such as manufacturing, computer science/programming, aviation, forensics, health science, engineering, transportation/ distribution & logistics, actuarial science) and describe the many sources and types of

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information that these occupations use. Determine how various industries employ different kinds of data to meet their needs. (TN CCSS Reading 4, 6, 9)

~~3)~~5) Investigate an assortment of skills and education required for STEM professionals. Write an informative text that identifies the typical educational and certification requirements, working environments, and career opportunities for these occupations. For example, participate in an information-gathering tour of a local organization that uses computer-aided design, and report on the roles and responsibilities of STEM professionals on staff, including the kinds of software and equipment they use. (TN CCSS Reading 2; TN CCSS Writing 2)

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Problem-Resolution Skills

~~4)~~6) Research the terms engineering design and scientific inquiry. Compare and contrast the steps of the engineering design process to the steps of the scientific inquiry in a graphic illustration or presentation. (TN CCSS Reading 2, 7, 9; TN CCSS Writing 2, 8)

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~~5)~~7) Evaluate a question to determine if it is testable and can produce empirical data. Plan an investigation that outlines the steps of the design process to collect, record, analyze, and evaluate data. For example,

a. Given a set of symptoms, determine whether there is enough data to diagnose a medical condition as would a physician or nurse practitioner. (Science)
b. Determine the information necessary in order to design a vehicle to carry a specified payload a designated distance in the least amount of time like a mechanical engineer. (Technology/Engineering)
c. Determine what information an actuary would need to know in order to answer a research question about which factors (accident, sickness, disability, etc.) are contributing the most to medical insurance claims in a region. (Mathematics)

(TN CCSS Reading 1, 7, 8; TN CCSS Writing 4, 7)

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~~6)~~8) Given a real-world problem, identify several possible solutions using both the engineering design process and the scientific inquiry. For example,

a. Research several treatment plans for a severe allergy sufferer as would a biochemist or biophysicist. (Science)
b. Investigate a variety of materials suitable for building structures to withstand earthquakes as would a civil engineer. (Technology/Engineering)
c. Explore commonly used methods to safeguard computer files against accidental or unauthorized alteration, destruction, or disclosure as would an information security analyst. (Technology/Mathematics)

(TN CCSS Reading 3, 8; TN CCSS Writing 7, 8)

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~~7)~~9) Analyze solutions to a real-world problem collaboratively, to identify critical factors of the steps of the design process. Explain why these factors are critical. For example,

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a. Research types of prosthetics and submit a proposal for which one most effectively uses the design process in terms of feasibility, cost, safety, aesthetics, and durability like a biomedical engineer. (Science)
b. Research ways a chemical engineer performs tests and monitors performance of processes throughout the stages of production for manufacturing chemicals and products such as gasoline, synthetic rubber, plastics, detergents, cement, paper, and pulp. Submit a proposal for which one most effectively uses the design process in terms of factors like mixing, crushing, heat transfer, distillation, and drying. (Technology/Engineering)
c. Investigate the development and use of models such as diagrams, simulations, graphs, and equations to represent findings from either science or engineering research. Critique others' proposals by providing specific arguments for or against their reasoning and methodology as would a statistician. (Technology/Mathematics)

(TN CCSS Reading 1, 2, 8; TN CCSS Writing 1, 2, 8, 9)

Critical Thinking in Context

~~8)~~10) Given a real-world STEM scenario, identify the problem and develop meaningful questions. Differentiate between necessary and non-essential information as well as needs and wants for applying the scientific method of investigation or the engineering design process. For example, evaluate a STEM scenario related to one of the following:

a. Environmental scientists perform tests on the quality of water in oceans, lakes, beaches, ponds, rivers, etc. Compare and contrast the pros and cons of using a satellite to provide real time data of water conditions in order to determine its validity as a resource for environmental engineers. (Science)
b. The organization Engineers Without Borders implements projects worldwide to provide clean drinking water to developing nations. Identify the conditions and information collected in order to provide a sustainable water source to a rural farming community. (Technology/Engineering)
c. Robots need to be programmed to perform specific tasks in harsh working conditions such as welding parts in an automobile assembly line operation. Compare and contrast the pros and cons of using robots versus humans in a manufacturing facility. (Technology/Mathematics)

(TN CCSS Reading 1, 4, 5, 9; TN CCSS Writing 2)

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~~9)~~11) Design and develop several solution prototypes, conduct feasibility testing, and use the data to justify the solution selected. For example,

a. Use a construction set to efficiently build a vehicle at low cost, and to travel a straight path with predictability. (Science)
b. Using readily available, low cost materials, design a water filter in a soda bottle that lets as much water through as possible, but also removes as much particulate matter as possible as would a civil engineer. (Technology/Engineering)
c. Design and construct a robot to maneuver through a given obstacle course. Use circumference of the wheels and distance needed to travel to calculate how many rotations the wheels need to make. Justify the solution selected for the robot to maneuver most efficiently through the course. (Technology/Mathematics)

(TN CCSS Reading 8, 9; TN CCSS Writing 1)

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~~10)~~12) Collaborate to write a fictional, yet plausible, STEM problem-based scenario. Evaluate possible solutions, aligning work with the steps of the scientific method or the engineering design process. Consider possible constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts. Sample scenarios might include the following:

a. A scenario to diagnosis and identify a method of treatment for an illness based on several physical symptoms. (Science)
b. A scenario that requires the design of a self-sustaining city for humans living on another planet. (Technology/Engineering)
c. A scenario that requires calculation of an investment of an inheritance so that its growth is maximized by a certain time. (Mathematics)

(TN CCSS Reading 7, 9; TN CCSS Writing 2, 7)

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~~11)~~13) Conduct research to create a list of problems that are considered major global challenges. Choose one to analyze. Evaluate possible solutions, aligning work with the steps of the scientific method or the engineering design process. Consider possible constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts. Identify trade-offs and defend decisions that were made as a result of those trade-offs. Possible global challenges could include the following:

a. Scientists work to address the threat of a global pandemic or issues related to food security. (Science)
b. Engineers work to address issues related to climate change and global warming, global water shortages, and the need for alternative energy sources. (Technology/Engineering)
c. Statisticians work on projects related to national and international debt, the global population, or workforce imbalances and lack of jobs worldwide. (Mathematics)

(TN CCSS Reading 1, 7, 8, 9; TN CCSS Writing 1, 7, 8, 9)

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STEM Field Readiness

~~12)~~14) Sort and evaluate data for its significance and/or meaning in the process of solving a problem as a STEM professional would. Examine the data in ways that reveal the relationships, patterns, and trends that can be found within it. Differentiate between quantitative and qualitative data. For example,

a. Environmental scientists collect, synthesize, analyze, manage, and report environmental data, such as pollution emission measurements, atmospheric monitoring measurements, meteorological or mineralogical information, and soil or water samples. (Science)
b. Aerospace engineers identify information by categorizing, estimating, recognizing differences or similarities, and detecting changes in circumstances or events. They are also expected to evaluate product data and design from inspections and reports for conformance to engineering principles, customer requirements, and quality standards. (Technology/Engineering)
c. Economists study economic and statistical data in various areas of specialization, such as finance, labor, or agriculture. They also compile, analyze, and report data to explain economic phenomena and forecast market trends, applying mathematical models and statistical techniques. (Mathematics)

(TN CCSS Reading 1, 3, 4, 8, 9; TN CCSS Writing 2, 9)

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~~13)~~15) Identify multiple forms of data and list mechanisms for collection that are essential to solving a problem. Prepare written documentation to justify findings.

a. Statisticians analyze outcomes such as employment and educational attainment by identifying data sources, such as public data sets available from the Census Bureau, or collecting original data from the field, in order to model relationships among variables.
b. Engineers collect data such as ease of use, operation safety, material properties, and material costs in order to determine an optimal design solution from multiple ideas.

(TN CCSS Reading 1, 7, 8, 9; TN CCSS Writing 1, 9)

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~~14)~~16) Use available data to create an original prototype/solution to a scenario.

a. Biomedical scientists and biomedical engineers design and construct prototype implants to fill and stabilize a partial bone defect. (Science)
b. Aerospace engineers test a drag device to slow a spacecraft and protect its cargo, as well as calculate the surface area and measure the mass of the spacecraft. (Science/Mathematics)

(TN CCSS Reading 3, 8, 9; TN CCSS Writing 1, 9)

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Cause and Effect Relationships in STEM

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~~15)~~17) Analyze multiple aspects of a problem scenario to identify cause/effect patterns. Consider the history of a problem to identify factors such as risks and benefits.

a. Aerospace engineers perform engineering duties in designing, constructing, and testing aircraft, missiles, and spacecraft. They conduct basic and applied research to evaluate adaptability of materials and equipment to aircraft design and manufacture, and recommend improvements in testing equipment and techniques. For example, variations in the nose and fins will result in different behaviors, so construction and testing of multiple designs is necessary. (Engineering)
b. Apply standardized mathematical formulas, principles, and methodology to the solution of technological problems involving projectiles as a mathematical technician would. Use computer software to analyze the critical aspects of parabolic motion, for example: height at any given time, maximum height, maximum distance. (Technology/Mathematics)

(TN CCSS Reading 1, 7, 8, 9; TN CCSS Writing 4, 9)

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~~16)~~18) Explore mathematical models and/or computer simulations that are used by scientists and engineers to accurately predict the effect of components of their original prototype design. Examine a range of resources (e.g. texts, experiments, simulations) to consider which models are likely to be most efficient, economic, and beneficial. Write a justification to support the conclusion.

a. Meteorologists interpret data, reports, maps, photographs, or charts to predict long- or short-range weather conditions, using computer models and knowledge of climate theory, physics, and mathematics. Investigate the use of mathematical or computer models for weather forecasting. (Science)
b. Civil engineers and civil drafters use the computer as a problem-solving tool. They identify locations of forces (tension, compression, torsion, shear, and resonance) in their bridge designs. Investigate the use of software to make modifications to multiple properties and gain immediate access to cost analysis and forces data. (Engineering/Technology)

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(TN CCSS Reading 4, 5, 7, 8; TN CCSS Writing 1, 7, 8, 9)

~~17)~~19) Analyze data from scientific investigation or prototype testing and accurately identify the cause of the results. Examine constraints including cost, safety, reliability, and aesthetics. Consider social, cultural, and environmental impacts. Summarize findings using tables, functions, graphical representations, and written explanations.

a. Forensic scientists collect, identify, classify, and analyze physical evidence related to criminal investigations. They perform tests on weapons or substances, such as fiber, hair, and tissue, to determine significance to the investigation. (Science)
b. Police frequently use mathematics in the analysis of crime data. Data can be stored and interpreted using wavelets, probability, and statistics. It can be securely transmitted using prime numbers and cryptography. (Mathematics/Technology)

(TN CCSS Reading 3, 7, 8, 9; TN CCSS Writing 2, 8, 9)

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Standards Alignment Notes

*References to other standards include:

- TN CCSS Reading: Common Core State Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects; Reading Standards for Literacy in Science and Technical Subjects 6-12; Grades 9-10 Students (page 62).
    - Note: While not directly aligned to one specific standard, students who are engaging in activities outlined above should be able to also demonstrate fluency in Standard 10 at the conclusion of the course.
- TN CCSS Writing: Common Core State Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects; Writing Standards for Literacy in History/Social Studies, Science, and Technical Subjects 6-12; Grades 9-10 Students (pages 64-66).
    - Note: While not directly aligned to one specific standard, students who are engaging in activities outlined above should be able to also demonstrate fluency in Standards 3, 5, 6, and 10 at the conclusion of the course.
- TN CCSS Math: Common Core State Standards for Mathematics; Math Standards for High School: Numbers and Quantity, Algebra, Functions, Geometry, Statistics and Probability.
    - Note: The standards in this course are not meant to teach mathematical concepts. However, the concepts referenced above may provide teachers with opportunities to collaborate with mathematics educators to design project-based activities or collaborate on lesson planning. Students who are engaging in activities listed above should be able to demonstrate quantitative, algebraic, functional, geometric, and statistical reasoning as applied to specific technical concepts. In addition, students will have the opportunity to practice the habits of mind as described in the eight Standards for Mathematical Practice.
- P21: Partnership for 21st Century Skills Framework for 21st Century Learning
    - Note: While not all standards are specifically aligned, teachers will find the framework helpful for setting expectations for student behavior in their classroom and practicing specific career readiness skills.

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STEM II: Applications

Primary Career Cluster:	Science, Technology, Engineering, and Mathematics (STEM)
Consultant:	Bethany King Wilkes, (615) 532-2844, Bethany.Wilkes@tn.gov
Course Code:	6145
Prerequisite(s):	*STEM I: Foundation* (6144); *Algebra I* (3102); and *Physical Science* (3202) or *Biology* (3210)
Credit:	1
Grade Level:	10
Graduation Requirement:	This course satisfies one of three credits required for an elective focus when taken in conjunction with other STEM courses.
Programs of Study and Sequence:	This is the second course in the *STEM Education* program of study.
Necessary Equipment:	Equipment list can be found ~~on the STEM website.~~at http://www.tn.gov/education/cte/ScienceTechnologyEngineeringMathematics.shtml
Aligned Student Organization(s):	Skills USA: http://www.tnskillsusa.com Brandon Hudson, (615) 532-2804, Brandon.Hudson@tn.gov Technology Student Association (TSA): http://www.tntsa.org Amanda Hodges, (615) 532-6270, Amanda.Hodges@tn.gov
Coordinating Work-Based Learning:	If a teacher has completed work-based learning training, he or she can offer appropriate ~~student~~ placement ~~can be offered~~. To learn more, please visit http://www.tn.gov/education/cte/wb/.
Available Student Industry Certifications:	None
Dual Credit or Dual Enrollment Opportunities:	There are no known dual credit/dual enrollment opportunities for this course. If interested in developing, reach out to a local postsecondary institution to establish an articulation agreement.
Teacher Endorsement(s):	013, 014, 015, 016, 017, 018, 047, 070, 078, 081, 210, 211, 212, 213, 214, 230, ~~231,~~ 232, 233, 413, 414, 415, 416, 417, 418, 470, 477, 519, 531, 595, 596
Required Teacher Certifications/Training:	Teachers who have never taught this course must attend training provided by the Department of Education.
Teacher Resources:	http://www.tn.gov/education/cte/ScienceTechnologyEngineeringMathematics.shtml~~doc/STEMResourceList.pdf~~

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Course Description

STEM II: Applications is a project-based learning experience for students who wish to further explore the dynamic range of STEM fields introduced in *STEM I: Foundation*. Building on the content and critical thinking frameworks of *STEM I*, this course asks students to apply the scientific inquiry and engineering design processes to a course-long project selected by the instructor with the help of student input. Instructors design a project in one of two broad pathways (traditional sciences or engineering) that reflects the interest of the class as a whole; the students then apply the steps of the scientific inquiry or the engineering design process throughout the course to ask questions, test hypotheses, model solutions, and communicate results. In some cases, instructors may be able to design hybrid projects that employ elements of both the scientific inquiry and the engineering design process. Upon completion of this course, proficient students will have a thorough understanding of how scientists and engineers research problems and methodically apply STEM knowledge and skills; and they will be able to present and defend a scientific explanation and/or an engineering design solution to comprehensive STEM-related scenarios. Standards in this course are aligned with Tennessee Common Core State Standards for English Language Arts & Literacy in Technical Subjects and Tennessee Common Core State Standards in Mathematics.*

Note: Standards in this course are presented sequentially according to the traditional steps followed in the scientific inquiry or engineering design process. While instructors may tailor the order of course standards to their specifications, it is highly recommended that they maintain fidelity to the overall process. In addition, instructors opting for either the Science Path or the Engineering Path do not have to teach to both sets of standards; they are presented in parallel fashion here for ease of comparison, should teachers wish to combine elements of each.

Program of Study Application

This is the second course in the *STEM Education* program of study. For more information on the benefits and requirements of implementing this program in full, please visit the STEM website at http://www.tn.gov/education/cte/ScienceTechnologyEngineeringMathematics.shtml.

Course Standards

The Roles of Scientists and Engineers

Science Path	Engineering Path
1) Determine the scientist's role in explaining why phenomena occur in the natural world, justified by historical and current science knowledge. Research a known scientist and present in an informative paper, oral presentation, or other format his/her contributions to scientific knowledge. Include an outline of how the scientific inquiry process was used in his/her work. (TN CCSS Reading 1, 2, 3, 8, 9; TN CCSS Writing 2)	1) Determine the engineer's role in developing solutions to design problems that are justified by scientific knowledge. Research a known engineer and present in an informative paper, oral presentation, or other format his/her designs and explain how they influenced technology in his/her field. Include an outline of how the design process was used in his/her work. (TN CCSS Reading 1, 2, 3, 8, 9; TN CCSS Writing 2)

Questioning and Defining Problems

Science Path	Engineering Path
2) Engage in scientific inquiry by brainstorming for questions to understand how a certain phenomenon in the natural world works, to understand why a phenomenon occurs, or to determine the validity of a theory. (TN CCSS Reading 4, 5, 9)	2) Ask clear, relevant questions that lead to defining a design problem. For example, questions should be testable and explore the requirements of a problem solution, but not define the methodology to solve the problem. (TN CCSS Reading 4, 5, 9)
3) Research various sources (e.g., articles, end-uses, textbooks) and identify one or more questions that will guide a scientific investigation. For example, questions should be relevant, testable, and based on current scientific knowledge. (TN CCSS Reading 1, 4, 5, 6, 9; TN CCSS Writing 1, 4)	3) Brainstorm for several problem solutions, then conduct research using various sources (e.g., articles, end-uses, textbooks) to generate more solution ideas. Justify ideas using evidence from the sources. (TN CCSS Reading 1, 4, 5, 6, 9; TN CCSS Writing 1, 4)
4) Develop an original proposal as would a natural or social scientist that will guide the scientific inquiry and follow responsible ethical practices. For example, the proposal should outline the reason for the research interest, hypothesis, methodology, data analysis, importance of study, and deliverables. (TN CCSS Reading 3, 4, 7, 9; TN CCSS Writing 1, 7)	4) Develop a design brief that will guide a design process and follow responsible ethical practices. For example, the design brief should outline a problem definition, design statement, criteria, constraints, and deliverables. (TN CCSS Reading 3, 4, 7, 9; TN CCSS Writing 1, 7)

Modeling

Science Path	Engineering Path
5) Create models to illustrate questions and represent processes or systems that are justified by scientific evidence. For example, models can be diagrams, drawings, or scaled down physical representations. (TN CCSS Reading 1, 4, 7; TN CCSS Writing 4, 8, 9)	5) Create models to illustrate design criteria and represent processes, mechanisms, or systems. For example, models can be drawings, mathematical representations, or computer simulations. (TN CCSS Reading 1, 4, 7; TN CCSS Writing 4, 8, 9)
6) Use mathematics and technology to develop multiple models to predict an occurrence in the natural world. Compare and contrast the recorded observations from each model. For example, computer modeling can be used to analyze current	6) Identify and sketch at least three alternative solutions, to a problem, that consider analyses such as mechanical and electrical systems. For example, computer modeling can be used to analyze the effect of stress and strain on a beam. (TN CCSS

atmospheric conditions to predict the weather in days ahead. (TN CCSS Reading 7, 9; TN CCSS Writing 7, 9)	Reading 7, 9; TN CCSS Writing 7, 9)
7) Analyze results from modeling and appropriately determine when it is necessary to revise questions. Justify revisions with evidence. (TN CCSS Reading 7, 9; TN CCSS Writing 9)	7) Conduct iterations of modeling a solution to a design problem, demonstrate that design criteria are met, and select a reliable design approach. (TN CCSS Reading 7, 9; TN CCSS Writing 9)

Planning & Investigating

Science Path	Engineering Path
8) Make a hypothesis that explains a scientific question, plan and conduct a simple investigation, and record observations (e.g., data) in a manner easily retrievable by others. (TN CCSS Reading 3; TN CCSS Writing 4)	8) Develop a design proposal to create prototypes for testing. The proposal should provide details such as drawings with dimensions, materials, and construction process. (TN CCSS Reading 3; TN CCSS Writing 4)
9) Identify the independent variables and dependent variables in an investigation. Demonstrate the effects of a changing independent variable on a dependent variable, and observe and record results. (TN CCSS Reading 3; TN CCSS Writing 7, 9)	9) Outline testing procedures that identify type of data (e.g., number of trials, cost, risk, and time) that is needed to produce reliable measurements and the specifications (e.g., effectiveness, efficiency, and durability) to determine whether a design has exceeded or failed expectations. (TN CCSS Reading 3; TN CCSS Writing 7, 9)

Data Analysis & Interpretation

Science Path	Engineering Path
10) Use mathematics to represent and solve scientific questions. For example, simple limit cases can be used to determine if a model is realistic. (TN CCSS Reading 3, 7)	10) Use mathematics to represent and solve engineering problems. For example, simple limit cases can be used to determine if a model is realistic. (TN CCSS Reading 3, 7)
11) Evaluate data and identify any limitations of data analysis. Using this information, determine whether to make scientific claims from data or revise an investigation and collect more data. (TN CCSS Reading 3, 7; TN CCSS Writing 7)	11) Evaluate data and identify any limitations of data analysis. Using this information, determine whether a design solution is optimal or should be refined and tested again. (TN CCSS Reading 3, 7; TN CCSS Writing 7)

12) Compare and contrast the data results from multiple iterations of a scientific investigation. For example, consider how well each explanation is supported by evidence, prior research, and scientific knowledge. (TN CCSS Reading 3, 7, 9; TN CCSS Writing 1)	12) Compare and contrast the data results from testing multiple design solutions. For example, consider how well each design solution meets the design criteria and constraints. (TN CCSS Reading 3, 7, 9; TN CCSS Writing 1)

Problem Solutions & Scientific Explanations

Science Path	Engineering Path
13) Develop an explanation to a scientific question that is logically consistent, peer reviewed, and justified by data analysis and scientific knowledge. (TN CCSS Reading 4, 7, 9; TN CCSS Writing 1, 5, 7, 8, 9)	13) Develop an optimal design solution that is justified by data analysis and scientific knowledge, and meets ethical and design criteria and constraints. (TN CCSS Reading 4, 7, 9; TN CCSS Writing 1, 7, 8, 9)

Communicating Solutions & Explanations

Science Path	Engineering Path
14) Develop a technical report to communicate and defend a scientific explanation and justify its merit and validity with scientific information. Consider the ethical implications of the findings. The report can include tables, diagrams, graphs, procedures, and methodology. For example, conduct a STEM forum, present scientific research, and provide evidence to support arguments for or against scientific solutions. (TN CCSS Reading 4, 7, 9; TN CCSS Writing 1, 5, 6, 7, 8, 9)	14) Develop a design document to communicate the final design solution and how well it meets the design criteria and constraints. For example, the design document can include charts, graphs, calculations, engineering drawings, as well as information regarding marketing, distribution, and sales. For example, conduct a STEM forum, present engineering design briefs, and provide evidence to support arguments for or against design solutions. (TN CCSS Reading 4, 7, 9; TN CCSS Writing 1, 5, 6, 7, 8, 9)

Safety

15) Accurately read and interpret safety rules, including but not limited to rules published by the National Science Teachers Association (NSTA), rules pertaining to electrical safety, Occupational Safety and Health Administration (OSHA) guidelines, and state and national code requirements. Be able to distinguish between the rules and explain why certain rules apply. (TN CCSS Reading 3, 4, 6)

~~15)~~16) Identify and explain the intended use of safety equipment available in the classroom. For example, demonstrate how to properly inspect, use, and maintain safe operating procedures with tools and equipment. Incorporate safety procedures and complete safety test with 100 percent accuracy. (TN CCSS Reading 3, 4)

Standards Alignment Notes

*References to other standards include:

- TN CCSS Reading: Common Core State Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects; Reading Standards for Literacy in Science and Technical Subjects 6-12; Grades 9-10 Students (page 62).
    - Note: While not directly aligned to one specific standard, students who are engaging in activities outlined above should be able to also demonstrate fluency in Standard 10 at the conclusion of the course.
- TN CCSS Writing: Common Core State Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects; Writing Standards for Literacy in History/Social Studies, Science, and Technical Subjects 6-12; Grades 9-10 Students (pages 64-66).
    - Note: While not directly aligned to one specific standard, students who are engaging in activities outlined above should be able to also demonstrate fluency in Standards 3, 6, and 10 at the conclusion of the course.
- TN CCSS Math: Common Core State Standards for Mathematics; Math Standards for High School: Numbers and Quantity, Algebra, Functions, Geometry, Statistics and Probability.
    - Note: The standards in this course are not meant to teach mathematical concepts. However, the concepts referenced above may provide teachers with opportunities to collaborate with mathematics educators to design project-based activities or collaborate on lesson planning. Students who are engaging in activities listed above should be able to demonstrate quantitative, algebraic, functional, geometric, and statistical reasoning as applied to specific technical concepts. In addition, students will have the opportunity to practice the habits of mind as described in the eight Standards for Mathematical Practice.
- P21: Partnership for 21st Century Skills Framework for 21st Century Learning
    - Note: While not all standards are specifically aligned, teachers will find the framework helpful for setting expectations for student behavior in their classroom and practicing specific career readiness skills.

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STEM III: STEM in Context

Primary Career Cluster:	Science, Technology, Engineering, and Mathematics (STEM)
Consultant:	Bethany King Wilkes, (615) 532-2844, Bethany.Wilkes@tn.gov
Course Code:	6146
Prerequisite(s):	*STEM II: Applications* (6145); *Algebra I* (3102); *Physical Science* (3202); and *Biology* (3210) or *Chemistry* (3221)
Credit:	1
Grade Level:	11
Graduation Requirement:	This course satisfies one of three credits required for an elective focus when taken in conjunction with other STEM courses.
Programs of Study and Sequence:	This is the third course in the *STEM Education* program of study.
Necessary Equipment:	Equipment list can be found ~~on the STEM website linked below.~~at http://www.tn.gov/education/cte/ScienceTechnologyEngineeringMathematics.shtml
Aligned Student Organization(s):	Skills USA: http://www.tnskillsusa.com Brandon Hudson, (615) 532-2804, Brandon.Hudson@tn.gov Technology Student Association (TSA): http://www.tntsa.org Amanda Hodges, (615) 532-6270, Amanda.Hodges@tn.gov
Coordinating Work-Based Learning:	If a teacher has completed work-based learning training, he or she can offer ~~-~~appropriate ~~student~~ placement ~~can be offered~~. To learn more, please visit http://www.tn.gov/education/cte/wb/.
Available Student Industry Certifications:	None
Dual Credit or Dual Enrollment Opportunities:	There are no known dual credit/dual enrollment opportunities for this course. If interested in developing, reach out to a local postsecondary institution to establish an articulation agreement.
Teacher Endorsement(s):	013, 014, 015, 016, 017, 018, 047, 070, 078, 081, 210, 211, 212, 213, 214, 230, ~~231,~~ 232, 233, 413, 414, 415, 416, 417, 418, 470, 477, 519, 531, 595, 596
Required Teacher Certifications/Training:	Teachers who have never taught this course must attend the training provided by the Department of Education.
Teacher Resources:	http://www.tn.gov/education/cte/ScienceTechnologyEngineeringMathematics.shtml ~~doc/STEMResourceList.pdf~~

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Course Description

STEM III: STEM in Context is an applied course in the STEM career cluster which allows students to work in groups to solve a problem or answer a scientific question drawn from real-world scenarios within their schools or communities. This course builds on *STEM I: Foundation* and *STEM II: Applications* by applying scientific and engineering knowledge and skills to a team project. Proficient students will be able to effectively use skills such as project management, team communication, leadership, and decision making. They will also be able to effectively transfer the teamwork skills from the classroom to a work setting. Standards in this course are aligned with Tennessee Common Core State Standards for English Language Arts & Literacy in Technical Subjects and Tennessee Common Core State Standards in Mathematics.*

Note: Mastery of the following standards should be attained while completing a STEM project that follows the scientific inquiry or engineering design process. This course prepares students for the STEM IV: STEM Practicum course.

Program of Study Application

This is the third course in the *STEM Education* program of study. For more information on the benefits and requirements of implementing this program in full, visit the STEM website at http://www.tn.gov/education/cte/ScienceTechnologyEngineeringMathematics.shtml.

Course Standards

Safety

1) Accurately read and interpret safety rules, including but not limited to rules published by the National Science Teachers Association (NSTA), rules pertaining to electrical safety, Occupational Safety and Health Administration (OSHA) guidelines, and state and national code requirements. Be able to distinguish between the rules and explain why certain rules apply. (TN CCSS Reading 3, 4, 6)

2) Identify and explain the intended use of safety equipment available in the classroom. For example, demonstrate how to properly inspect, use, and maintain safe operating procedures with tools and equipment. Incorporate safety procedures and complete safety test with 100 percent accuracy. (TN CCSS Reading 3, 4)

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Essential Components of STEM Research

~~1)~~3) Explore how research teams are formed in order to answer scientific questions or design solutions to engineering problems. Using a scholarly database such as the Education Resources Information Center (ERIC), or searching on the websites of universities and other research institutions, investigate a well-known team of scientists or engineers (for example, the most recent Nobel Prize-winning teams in the sciences) and report to the class on how they collaborated to produce new scientific knowledge or solve an engineering problem. (TN CCSS Reading 2, 4; TN CCSS Writing 2, 4, 7)

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~~2)~~4) Research the ethical requirements for conducting scientific research or testing a prototype that will involve the public. For example, investigate the process for obtaining Institutional Review

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Board (IRB) approval when proposing a biomedical or human behavioral research study. Describe the concept of risk-benefit analysis in the production of new scientific knowledge; detail the rights and responsibilities of researchers—and, if applicable, their subjects—as they relate to conducting research in STEM fields. (TN CCSS Reading 2, 4, 7; TN CCSS Writing 2, 4, 7)

~~3.~~5) Examine how scientists, engineers, and other STEM professionals obtain funding, seek sponsorship, and/or gain approval to conduct their research. Explore websites such as the National Science Foundation or the National Institutes of Health to identify common processes around submitting proposals for research studies and procuring the necessary funds. Explain specific terminology such as request for proposals (RFP), competitive grants versus formula grants, and seed funding. (TN CCSS Reading 2, 4, 6; TN CCSS Writing 2, 4, 7)

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Research & Project Definition

~~4.~~6) Survey and observe people in your school and/or community. Analyze the results to determine potential STEM problems that need investigating or solving. Use these ideas to conduct research to determine and define a team project. Using supporting evidence from the research, write and present a STEM project proposal defining the project's purpose and goals. Include an outline of how the team intends to follow the scientific inquiry or engineering design process. (TN CCSS Reading 3, 4, 7, 9; TN CCSS Writing 1, 7, 8)

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Team Development

~~5.~~7) Define the team norms, or the set of team values, that are understood and approved by all team members. The norms should include the team's mission and guidelines for how team members will treat each other. Create a team handbook and include the documented team norms. (TN CCSS Writing 2, 4, 5, 6)

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~~6.~~8) As a team, determine the professional attributes that must be embodied by team members in order to successfully complete the proposed project. Collaboratively develop a professionalism rubric with performance indicators for each attribute agreed upon. Include the rubric in the team handbook. Attributes may include the following:

a. Effective communication
b. Respect for fellow team members
c. Ethical use of intellectual property and other project resources (including ethical treatment of test subjects, if applicable)
d. Timely achievement of project deadlines and goals
e. Collaborative and equitable distribution of work among all team members

(TN CCSS Writing 4)

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~~7.~~9) Identify the strengths and weaknesses of team members and organize the results into a graphic representation. Use the graphic representation to define the roles of each team member and create an organizational chart for the team handbook. For example, the strengths and weaknesses document will help identify the leader of the project team. (TN CCSS Reading 7; TN CCSS Writing 4, 6)

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~~8)~~10) Research Tuckman's stage model for team development (i.e., forming, storming, norming, performing, and adjourning). Prior to starting the STEM project, understand and explain each stage. After completing the project, write a brief evaluation of the team's growth at each stage. (TN CCSS Reading 2, 6; TN CCSS Writing 4, 9)

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Communication

~~9)~~11) Develop a process for official team communication. Define and document format guidelines for various modes of communication such as written, verbal, and email. For example, distinguish between communication appropriate to use with a team member versus communication appropriate to use with a supervisor (teacher). Document the communication guidelines in the team handbook. (TN CCSS Writing 4, 5, 6)

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~~10)~~12) Practice effective verbal, nonverbal, written, and electronic communication skills for working with team members while demonstrating the ability to: listen attentively, speak courteously and respectfully, discuss each member's ideas, resolve conflict, and reach a consensus for team progress. (TN CCSS Writing 4, 6)

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~~11)~~13) Research various decision-making methods for teams, such as consensus, majority, minority, averaging, and expert. Practice using these various methods when team disagreements arise, determine which are most effective for the project team, and explain the reasoning. (TN CCCSS Reading 2, 3)

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Project Management

14) Perform an Internet search, interview local professionals, or consult industry journals to identify common principles of successful project management. Based on templates retrieved online or approved by the instructor, estimate a detailed project plan for the course-long project. The project plan should include at minimum the following: a schedule or Gantt chart outlining deliverables, complete with job assignments based on team member strengths and weaknesses; a tracker for progress toward goals; a time management component to log hours worked for each team member; and supporting diagrams, datasheets, and flowcharts illustrating essential stages in the process. (TN CCSS Reading 1, 4, 7; TN CCSS Writing 4, 6, 7)

~~13)~~15) Based on the project proposal and project plan, identify projected costs and estimate a hypothetical budget. The projected costs may include but are not limited to materials, labor, equipment, and travel. Create a method to track the actual costs. For example, spreadsheets can be used to analyze and track project expenses. (TN CCSS Reading 7; TN CCSS Writing 4, 9)

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Project Completion and Presentation

~~14)~~16) Apply all steps of the scientific inquiry or the engineering design process (depending on the nature of the project) to successfully generate a hypothesis or prototype, collect the relevant data, perform the necessary tests, interpret the results, make modifications to models or prototypes, and communicate results over the course of the project's duration. Produce a technical report documenting the findings of the project and justifying the team's final conclusions based on evidence obtained. (TN CCSS Reading 3, 4, 5, 7, 9; TN CCSS Writing 1, 7)

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~~15)~~17) As a team, design a presentation to communicate the results of the project to both a technical and a non-technical audience. The presentation should be delivered orally but supported by relevant graphic illustrations, such as diagrams and models of project findings, and/or physical artifacts that represent the outcome of the project (i.e., a robotic prototype or a 3-D model). Prepare the presentation in a format that could be submitted to a competition such as a local Maker Faire or CTSO competitive event. (TN CCSS Reading 7; TN CCSS Writing 2, 4, 6)

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Evaluation of Project Outcome

~~16)~~18) Using tools that were developed during the course (i.e., professionalism rubric, project plan, organizational chart, team development evaluation), write a reflection paper to evaluate the project team's performance. Present the STEM project and team evaluation to the class. The paper should address, but is not limited to the following:

a. Did the team accomplish the project goal?
b. How well did the team (collectively and individually) meet the performance indicators?
c. How did the team develop throughout the duration of the project?
d. How well did the team resolve disagreements?
e. Was the team leadership effective?
f. Was the project completed within budget?

(TN CCSS Reading 7; TN CCSS Writing 2, 4, 6)

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Standards Alignment Notes

*References to other standards include:

- TN CCSS Reading: Common Core State Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects; Reading Standards for Literacy in Science and Technical Subjects 6-12; Grades 11-12 Students (page 62).
    - Note: While not directly aligned to one specific standard, students who are engaging in activities outlined above should be able to also demonstrate fluency in Standards 8 and 10 at the conclusion of the course.
- TN CCSS Writing: Common Core State Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects; Writing Standards for Literacy in History/Social Studies, Science, and Technical Subjects 6-12; Grades 11-12 Students (pages 64-66).
    - Note: While not directly aligned to one specific standard, students who are engaging in activities outlined above should be able to also demonstrate fluency in Standards 3 and 10 at the conclusion of the course.
- TN CCSS Math: Common Core State Standards for Mathematics; Math Standards for High School: Numbers and Quantity, Algebra, Functions, Geometry, Statistics and Probability.

- Note: The standards in this course are not meant to teach mathematical concepts. However, the concepts referenced above may provide teachers with opportunities to collaborate with mathematics educators to design project-based activities or collaborate on lesson planning. Students who are engaging in activities listed above should be able to demonstrate quantitative, algebraic, functional, geometric, and statistical reasoning as applied to specific technical concepts. In addition, students will have the opportunity to practice the habits of mind as described in the eight Standards for Mathematical Practice.

- P21: Partnership for 21st Century Skills Framework for 21st Century Learning
  - Note: While not all standards are specifically aligned, teachers will find the framework helpful for setting expectations for student behavior in their classroom and practicing specific career readiness skills.

TENNESSEE DEPARTMENT OF EDUCATION
FIRST TO THE TOP

STEM IV: STEM Practicum

Primary Career Cluster:	Science, Technology, Engineering, and Mathematics (STEM)
Consultant:	Bethany King Wilkes, (615) 532-2844, Bethany.Wilkes@tn.gov
Course Code:	6147
Prerequisite(s):	*STEM III: STEM in Context* (6146); *Algebra I* (3102); *Physical Science* (3202); and *Biology* (3210) or *Chemistry* (3221)
Credit:	1
Grade Level:	12
Graduation Requirement:	This course satisfies one of three credits required for an elective focus when taken in conjunction with other STEM courses.
Programs of Study and Sequence:	This is the fourth course in the *STEM Education* program of study.
Necessary Equipment:	Equipment lists can be found ~~on the STEM website linked below.~~at
Aligned Student Organization(s):	Skills USA: http://www.tnskillsusa.com Brandon Hudson, (615) 532-2804, Brandon.Hudson@tn.gov Technology Student Association (TSA): http://www.tntsa.org Amanda Hodges, (615) 532-6270, Amanda.Hodges@tn.gov
Coordinating Work-Based Learning:	If a teacher has completed work-based learning training, he or she can offer appropriate placement. To learn more, please visit http://www.tn.gov/education/cte/wb/.
Available Student Industry Certifications:	None
Dual Credit or Dual Enrollment Opportunities:	There are no known dual credit/dual enrollment opportunities for this course. If interested in developing, reach out to a local postsecondary institution to establish an articulation agreement.
Teacher Endorsement(s):	013, 014, 015, 016, 017, 018, 047, 070, 078, 081, 210, 211, 212, 213, 214, 230, 232, 233, 413, 414, 415, 416, 417, 418, 470, 477, 519, 531, 595, 596~~477, 013, 014, 015, 016, 017, 018, 047, 070, 078, 081, 210, 211, 212, 213, 214, 413, 414, 415, 416, 417, 418, 230, 231, 232, 233, 470, 477, 519, 531, 595, 596~~
Required Teacher Certifications/Training:	Teachers who have never taught this course must attend the training provided by the Department of Education.
Teacher Resources:	~~http://www.tn.gov/education/cte/doc/STEMResourceList.pdf~~http://www.tn.gov/education/cte/ScienceTechnologyEngineeringMathematics.shtml

Course Description

STEM IV: STEM Practicum is a capstone course intended to provide students with the opportunity to apply the skills and knowledge learned in previous *STEM Education* courses within a professional, working environment. In addition to developing an understanding of the professional and ethical issues encountered by STEM professionals in the workplace, students learn to refine their skills in problem solving, research, communication, data analysis, teamwork, and project management. The course is highly customizable to meet local system needs: instruction may be delivered through school laboratory training or through work-based learning arrangements such as internships, cooperative education, service learning, mentoring, and job shadowing. Upon completion of the practicum, students will be prepared for postsecondary study in a STEM field. Standards in this course are aligned with Tennessee Common Core State Standards for English Language Arts & Literacy in Technical Subjects and Tennessee Common Core State Standards in Mathematics.*****

Note: Mastery of the following standards should be attained while completing a STEM project in a practicum setting. The project should follow the scientific inquiry or engineering design process learned in previous courses. Moreover, practicum activities may take the form of work-based learning opportunities (such as internships, cooperative education, service learning, and job shadowing) or in-class projects, depending on local availability. Work-based learning opportunities must follow policies outlined in the work-based learning guide found online at http://www.tn.gov/education/cte/wb/doc/WorkBasedLearningPoliciesApril2013.pdf.

Program of Study Application

This is the fourth course in the *STEM Education* program of study. For more information on the benefits and requirements of implementing this program in full, please visit the STEM website at http://www.tn.gov/education/cte/ScienceTechnologyEngineeringMathematics.shtml.

Course Standards

Safety

1) Accurately read and interpret safety rules, including but not limited to rules published by the National Science Teachers Association (NSTA), rules pertaining to electrical safety, Occupational Safety and Health Administration (OSHA) guidelines, and state and national code requirements. Be able to distinguish between the rules and explain why certain rules apply. (TN CCSS Reading 3, 4, 6)

2) Identify and explain the intended use of safety equipment available in the classroom. For example, demonstrate how to properly inspect, use, and maintain safe operating procedures with tools and equipment. Incorporate safety procedures and complete safety test with 100 percent accuracy. (TN CCSS Reading 3, 4)

STEM Employment Research and Preparation

~~1)~~3) Research and select a company or organization for a work-based learning project in a STEM area of choice. Cite specific textual evidence from the organization's literature as well as independent news articles to summarize:
   a. The mission and history of the organization

b. Headquarters and organizational structure
c. Products or services provided
d. Credentials required for employment and how they are obtained and maintained
e. Policies and procedures
f. Reports, newsletters, and other documents published by the organization
g. Website and contact information

(TN CCSS Reading 1, 2; TN CCSS Writing 7)

~~2)~~4) Search for the resumes and curricula vitae (CVs) of scientists, engineers, and researchers retrieved from the websites of institutions, organizations, or professional networks. Discuss what is typically included in the resumes and CVs of STEM professionals, compare and contrast several examples, and create a personal resume or curriculum vitae modeled after elements identified in the search. (TN CCSS Reading 1, 4, 6, 9; TN CCSS Writing 4)

~~3)~~5) Conduct a job search and simulate the experience by researching local employment options. In preparation for a future career in STEM, complete an authentic job application form and compose a cover letter following guidelines specified in the vacancy announcement. (TN CCSS Reading 5, 7; TN CCSS Writing 4)

~~4)~~6) Participate in a mock interview. Prior to the interview, prepare a paper that includes the following: tips on dress and grooming, most commonly asked interview questions, appropriate conduct during an interview, and recommended follow-up procedures. Upon completion of the interview, write a thank you letter to the interviewer in a written or email format. (TN CCSS Reading 2; TN CCSS Writing 2, 4, 7, 9)

Ethics

~~5)~~7) Collect codes of ethics from various professions related to the STEM area of choice, such as the National Society of Professional Engineers (NSPE) Code of Ethics for Engineers and the American Society for Clinical Laboratory Science (ASCL) Code of Ethics. Participate in a class discussion on the significance of following ethical standards in the STEM fields. Synthesize principles from the codes investigated to create a personal code of ethics related to a STEM area of choice. (TN CCSS Reading 1, 2, 6; TN CCSS Writing 4, 9)

Transferring Course Concepts to Practicum

~~6)~~8) Apply skills and knowledge from previous courses in an authentic work-based learning internship, job shadow, or classroom-based project. Where appropriate, develop, practice, and demonstrate skills outlined from previous courses.

~~7)~~9) Create and continually update a personal journal to document the practicum and draw connections between the experience and previous course content by reflecting on:

a. Tasks accomplished and activities implemented
b. Positive and negative aspects of the experience
c. How challenges were addressed
d. Team participation in a learning environment
e. Comparisons and contrasts between classroom and work environments
f. Interactions with colleagues and supervisors

g. Personal career development
h. Personal satisfaction

(TN CCSS Writing 2, 4)

Portfolio

~~8)~~10) Create a portfolio, or similar collection of work, that illustrates mastery of skills and knowledge outlined in the previous courses and applied in the practicum. The portfolio should reflect thoughtful assessment and evaluation of the progression of work involving the application of steps of the scientific inquiry or the engineering design process (depending on the nature of the work-based learning project). The following documents will reside in the career portfolio:

a. Personal code of ethics
b. Career and professional development plan
c. Resume or Curriculum Vitae
d. List of responsibilities undertaken through the course
e. Examples of visual materials developed and used during the course (such as graphics, drawings, models, presentation slides, videos, and demonstrations)
f. Description of technology used, with examples if appropriate
g. Periodic journal entries reflecting on tasks and activities
h. Feedback from instructor and/or supervisor based on observations

(TN CCSS Reading 7; TN CCSS Writing 4)

Communication of Project Results

~~9)~~11) Apply all steps of the scientific inquiry or the engineering design process (depending on the nature of the project) to successfully generate a hypothesis or prototype, collect the relevant data, perform the necessary tests, interpret the results, make modifications to models or prototypes, and communicate results over the course of the project's duration. Produce a technical report documenting the findings of the project and justifying the final conclusions based on evidence obtained. (TN CCSS Reading 1, 2, 3, 4, 5, 7, 8, 9; TN CCSS Writing 1, 5, 6, 7, 8, 9)

~~10)~~12) Upon completion of the practicum, develop a technology-enhanced presentation showcasing highlights, challenges, and lessons learned from the experience. The presentation should be delivered orally, but supported by relevant graphic illustrations, such as diagrams, drawings, and models of project findings, and/or physical artifacts that represent the outcome of the project (i.e., a prototype or 3-D model). Prepare the presentation in a format that could be presented to both a technical and a non-technical audience, as well as for a career and technical student organization (CTSO) competitive event. (TN CCSS Reading 1, 3, 7, 9; TN CCSS Writing 2, 4, 5, 6, 9)

Standards Alignment Notes

*References to other standards include:

- TN CCSS Reading: Common Core State Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects; Reading Standards for Literacy in Science and Technical Subjects 6-12; Grades 11-12 Students (page 62).
    - Note: While not directly aligned to one specific standard, students who are engaging in activities outlined above should be able to also demonstrate fluency in Standard 10 at the conclusion of the course.
- TN CCSS Writing: Common Core State Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects; Writing Standards for Literacy in History/Social Studies, Science, and Technical Subjects 6-12; Grades 11-12 Students (pages 64-66).
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- P21: Partnership for 21st Century Skills Framework for 21st Century Learning
    - Note: While not all standards are specifically aligned, teachers will find the framework helpful for setting expectations for student behavior in their classroom and practicing specific career readiness skills.