Department of Education

College, Career and Technical Education

May 2025

STEM I: Foundations

Primary Career Cluster:	Science, Technology, Engineering, and Mathematics (STEM)
Course Contact:	CTE.Standards@tn.gov
Course Code:	C21H15
Prerequisite:	None
Credit:	1
Grade Level:	9
Elective Focus-Graduation Requirement:	This course satisfies one of three credits required for an elective focus when taken in conjunction with other *STEM* courses. In addition, this course satisfies one lab science credit requirement for graduation.
Program of Study (POS) Concentrator:	This course satisfies one out of two required courses that meet the Perkins V concentrator definition when taken in sequence in the approved program of study.
Programs of Study and Sequence:	This is the first course in the *STEM Education* program of study.
Aligned Student Organization(s):	SkillsUSA: http://www.skillsusatn.org/ Technology Student Association (TSA): http://www.tntsa.org
Coordinating Work-Based Learning:	Teachers are encouraged to use embedded WBL activities such as informational interviewing, job shadowing, and career mentoring. For information, visit https://www.tn.gov/education/educators/career-and-technical-education/work-based-learning.html.
Promoted Student Industry Credentials:	Credentials are aligned with post-secondary and employment opportunities and with the competencies and skills that students acquire through their selected program of study. For a listing of promoted student industry credentials, visit https://www.tn.gov/content/tn/education/educators/career-and-technical-education/student-industry-certification.html.
Teacher Endorsement(s):	013, 014, 015, 016, 017, 018, 047, 070, 078, 081, 125, 126, 127, 128, 129, 157, 173, 210, 211, 212, 213, 214, 230, 232, 233, 413, 414, 415, 416, 417, 418, 449, 470, 477, 519, 531, 595, 596, 700, 740, 742, 760, 982
Required Teacher Certifications:	None
Required Teacher Training:	Teachers who have never taught this course must attend training provided by the Department of Education.
Teacher Resources:	https://www.tn.gov/education/educators/career-and-technical-education/career-clusters/cte-cluster-stem.html Best for All Central: https://bestforall.tnedu.gov/

Course at a Glance

There is no one way to create meaningful learning experiences for students. There are best practices available that data and students say impact long-term student learning. One of those best practices is to put student learning in context with their experiences.

Career and Technical Student Organizations (CTSOs) provide an opportunity for students to display their learning in the classroom and through regional, state, and/or national competitions. Work-based Learning (WBL) consists of sustained and coordinated work-based activities that relate to the course content. These activities should occur at every level through a program of study. Below is a listing of possible CTSO connections and WBL activities for this course. This listing is intended to be an idea starter and not a comprehensive listing.

Using a Career and Technical Student Organization (CTSO) in Your Classroom

Putting classroom learning into real-life experiences is often what creates a meaningful learning experience for students, one that lasts beyond the exam and course. CTSOs are a great resource to create this type of learning for your students. They are also a great resource to showcase your students' learning through regional, state, and national competitions. Possible connections for this course include the following. This is not an exhaustive list.

- Participate in the CTSO Fall Leadership Conference to engage with peers by demonstrating logical thought processes and developing industry-specific skills that involve teamwork and project management.
- Participate in contests that highlight job skill demonstration, interviewing skills, community service activities, extemporaneous speaking, and job interviews.
- Participate in leadership activities such as the National Leadership and Skills Conference, National Week of Service, and 21st Century Skills.

Using Work-Based Learning (WBL) in Your Classroom

Sustained and coordinated activities that relate to the course content are the key to successful work-based learning. Possible activities for this course include the following. This is not an exhaustive list.

- **Standards 1.1-2.3** | Invite an industry representative to discuss occupations and safety protocols within the STEM career field.
- **Standards 3.1-3.4** | Develop a project to be used by a local industry.
- **Standards 4.1-4.4** | Do an integrated project with an industry professional.
- **Standards 5.1-5.3** | Shadow an environmental scientist.
- **Standards 6.1-6.3** | Invite a panel of scientists, engineers, and mathematicians to discuss relationships in STEM.

Course Description

STEM I: Foundations 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.

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 the area of expertise and student interest.

Course Standards

1. Safety

1.1 Safety Rules: 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.

1.2 Safety Equipment: 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 the safety test with 100 percent accuracy.

2. STEM Fields Exploration

2.1 History of STEM: 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.

2.2 STEM Occupations: Explore several **occupations within the STEM field** (such as manufacturing, computer science/programming, aviation, forensics, health science, engineering, transportation/ distribution & logistics, and actuarial science) and describe the many sources and types of information that these occupations use. Determine how various industries employ different kinds of data to meet their needs.

2.3 STEM Skills and Education: Investigate an **assortment of skills and education required for STEM professionals**. Write an informative text that i**dentifies 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.

2.4 Career and Technical Student Organization Introduction: **Introduce** the program's **aligned Career and Technical Student Organization** (CTSO), Technology Student Association (TSA) and Skills USA, **through an interactive activity**, such as classroom competition.

3. Problem-Resolution Skills

3.1 Engineering Design and Scientific Inquiry: 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.

3.2 Usage of Design Process: 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 at 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)

3.3 Identifying Solutions: 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)

3.4 Critical Factors: 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:

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 the 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)

4. Critical Thinking in Context

4.1 Problem Identification in STEM: 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 on 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)

4.2 Solution Prototypes: 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 a 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 the circumference of the wheels and the 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)

4.3 STEM Problem-Based Scenario: 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 diagnose 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 the calculation of an investment of an inheritance so that its growth is maximized by a certain time. (Mathematics)

4.4 Global Challenges: 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, workforce imbalances, and lack of jobs worldwide. (Mathematics)

5. STEM Field Readiness

5.1 Data Manipulation: 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)

5.2 Data Collection and Forms of Data: 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.

5.3 Using Data for Creation: **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)

5.4 Data Analysis in STEM: **Research** the **use of data in STEM cluster career fields**. Include data that is **generated internally** by businesses, **and externally** by local communicates, state, and the nation. Explore examples of how the data is used, including the following:

a. customer/client use of products or services;
b. demographics of end users;
c. community, state, and national statistics; and
d. data that must reported to another entity.

6. Cause and Effect Relationships in STEM

6.1 Cause and Effect Patterns: 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 the 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, and maximum distance. (Technology/Mathematics)

6.2 Mathematical Models and Computer Simulations: 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)

6.3 Analyzing Data: 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 the significance of 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)

7. Ethical Artificial Intelligence

7.1 Ethical Artificial Intelligence (AI): **Explore the ethical implications of AI usage** through interactive discussions and case studies, learning to identify bias, ensure fairness, and protect privacy in AI systems. **Develop** critical thinking **skills to evaluate the societal impact of AI technologies**, while fostering a sense of responsibility and ethical decision-making in the use of AI tools.

Standards Alignment Notes

*References to other standards include:

- 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.

STEM II: Applications

Primary Career Cluster:	Science, Technology, Engineering, and Mathematics (STEM)
Course Contact:	CTE.Standards@tn.gov
Course Code:	C21H16
Prerequisite(s):	*STEM I: Foundations* (C21H15); *Algebra I* (G02X02, G02H00); and *Physical Science* (G03H00); or *Biology* (G03H03)
Credit:	1
Grade Level:	10
Elective Focus-Graduation Requirement:	This course satisfies one of three credits required for an elective focus when taken in conjunction with other *STEM* courses. In addition, this course satisfies one lab science credit requirement for graduation.
Program of Study (POS) Concentrator:	This course satisfies one out of two required courses that meet the Perkins V concentrator definition when taken in sequence in the approved program of study.
Programs of Study and Sequence:	This is the second course in the *STEM Education* program of study.
Aligned Student Organization(s):	SkillsUSA: http://www.skillsusatn.org/ Technology Student Association (TSA): http://www.tntsa.org
Coordinating Work-Based Learning:	Teachers are encouraged to use embedded WBL activities such as informational interviewing, job shadowing, and career mentoring. For information, visit https://www.tn.gov/education/educators/career-and-technical-education/work-based-learning.html.
Promoted Student Industry Credentials:	Credentials are aligned with post-secondary and employment opportunities and with the competencies and skills that students acquire through their selected program of study. For a listing of promoted student industry credentials, visit https://www.tn.gov/content/tn/education/educators/career-and-technical-education/student-industry-certification.html.
Teacher Endorsement(s):	013, 014, 015, 016, 017, 018, 047, 070, 078, 081, 125, 126, 127, 128, 129, 157, 173, 210, 211, 212, 213, 214, 230, 232, 233, 413, 414, 415, 416, 417, 418, 449, 470, 477, 519, 531, 595, 596, 700, 740, 742, 760, 982
Required Teacher Certifications:	None
Required Teacher Training:	Teachers who have never taught this course must attend training provided by the Department of Education.
Teacher Resources:	https://www.tn.gov/education/educators/career-and-technical-education/career-clusters/cte-cluster-stem.html Best for All Central: https://bestforall.tnedu.gov/

Course at a Glance

There is no one way to create meaningful learning experiences for students. There are best practices available that data and students say impact long-term student learning. One of those best practices is to put student learning in context with their experiences.

Career and Technical Student Organizations (CTSOs) provide an opportunity for students to display their learning in the classroom and through regional, state, and/or national competitions. Work-based Learning (WBL) consists of sustained and coordinated work-based activities that relate to the course content. These activities should occur at every level through a program of study. Below is a listing of possible CTSO connections and WBL activities for this course. This listing is intended to be an idea starter and not a comprehensive listing.

Using a Career and Technical Student Organization (CTSO) in Your Classroom

Putting classroom learning into real-life experiences is often what creates a meaningful learning experience for students, one that lasts beyond the exam and course. CTSOs are a great resource to create this type of learning for your students. They are also a great resource to showcase your students learning through regional, state, and national competitions. Possible connections for this course include the following. This is not an exhaustive list.

- Participate in the CTSO Fall Leadership Conference to engage with peers by demonstrating logical thought processes and developing industry-specific skills that involve teamwork and project management.
- Participate in contests that highlight job skill demonstration, interviewing skills, community service activities, extemporaneous speaking, and job interviews.
- Participate in leadership activities such as the National Leadership and Skills Conference, National Week of Service, and 21st Century Skills.

Using Work-Based Learning (WBL) in Your Classroom

Sustained and coordinated activities that relate to the course content are the key to successful work-based learning. Possible activities for this course include the following. This is not an exhaustive list.

- **Standards 1** | Invite an industry representative to discuss occupations within the Science and Engineering career field.
- **Standards 2** | Do a project that is useful to a local employer based on each STEM path.
- **Standards 3** | Visit a work site to introduce students to scientific modeling.
- **Standards 4** | Work with an industry partner on a real project.
- **Standards 5** | Invite a math teacher to discuss how math is essential to Science and Engineering.
- **Standards 6-7** | Invite a scientific writing specialist to give a seminar.
- **Standards 8.1-8.2** | Invite a science and engineering rep to discuss safety protocols related to each profession.

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.

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.

Course Standards

1. 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 scientific 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.	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.

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.	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.
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.	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.
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.	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.

3. 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.	5) Create models to illustrate design criteria and represent processes, mechanisms, or systems. For example, models can be drawings, mathematical representations, or computer simulations.
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 atmospheric conditions to predict the weather in days ahead.	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.

7) Analyze results from modeling and appropriately determine when it is necessary to revise questions. Justify revisions with evidence.	7) Conduct iterations of modeling a solution to a design problem, demonstrate that design criteria are met, and select a reliable design approach.

4. 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.	8) Develop a design proposal to create prototypes for testing. The proposal should provide details, such as drawings with dimensions, materials, and construction process.
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.	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.

5. 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.	10) Use mathematics to represent and solve engineering problems. For example, simple limit cases can be used to determine if a model is realistic.
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.	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.
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.	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.

6. Problem Solutions & Scientific Explanations

Science Path	Engineering Path
13) Develop an explanation for a scientific question that is logically consistent, peer reviewed, and justified by data analysis and scientific knowledge.	13) Develop an optimal design solution that is justified by data analysis and scientific knowledge and meets ethical and design criteria and constraints.

7. 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.	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.

8. Safety

8.1 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.

8.2 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 the safety test with 100 percent accuracy.

Standards Alignment Notes

*References to other standards include:

- 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.

STEM III: STEM in Context

Primary Career Cluster:	Science, Technology, Engineering, and Mathematics (STEM)
Course Contact:	CTE.Standards@tn.gov
Course Code:	C21H17
Prerequisite(s):	*STEM II: Applications* (C21H16), *Biology* (G03H03), or *Chemistry* (G03H12)
Credit:	1
Grade Level:	11
Elective Focus-Graduation Requirement:	This course satisfies one of three credits required for an elective focus when taken in conjunction with other *STEM* courses. In addition, this course satisfies one lab science credit requirement for graduation.
Program of Study (POS) Concentrator:	This course satisfies one out of two required courses that meet the Perkins V concentrator definition when taken in sequence in the approved program of study.
Programs of Study and Sequence:	This is the third course in the *STEM Education* program of study.
Aligned Student Organization(s):	SkillsUSA: http://www.skillsusatn.org/ Technology Student Association (TSA): http://www.tntsa.org
Coordinating Work-Based Learning:	Teachers are encouraged to use embedded WBL activities such as informational interviewing, job shadowing, and career mentoring. For information, visit https://www.tn.gov/education/educators/career-and-technical-education/work-based-learning.html.
Promoted Student Industry Credentials:	Credentials are aligned with post-secondary and employment opportunities and with the competencies and skills that students acquire through their selected program of study. For a listing of promoted student industry credentials, visit https://www.tn.gov/content/tn/education/educators/career-and-technical-education/student-industry-certification.html.
Teacher Endorsement(s):	013, 014, 015, 016, 017, 018, 047, 070, 078, 081, 125, 126, 127, 128, 129, 157, 173, 210, 211, 212, 213, 214, 230, 232, 233, 413, 414, 415, 416, 417, 418, 449, 470, 477, 519, 531, 595, 596, 700, 740, 742, 760, 982
Required Teacher Certifications/Training:	None
Required Teacher Training:	Teachers who have never taught this course must attend the training provided by the Department of Education.
Teacher Resources:	https://www.tn.gov/education/educators/career-and-technical-education/career-clusters/cte-cluster-stem.html Best for All Central: https://bestforall.tnedu.gov/

Course at a Glance

There is no one way to create meaningful learning experiences for students. There are best practices available that data and students say impact long-term student learning. One of those best practices is to put student learning in context with their experiences.

Career and Technical Student Organizations (CTSOs) provide an opportunity for students to display their learning in the classroom and through regional, state, and/or national competitions. Work-based Learning (WBL) consists of sustained and coordinated work-based activities that relate to the course content. These activities should occur at every level through a program of study. Below is a listing of possible CTSO connections and WBL activities for this course. This listing is intended to be an idea starter and not a comprehensive listing.

Using a Career and Technical Student Organization (CTSO) in Your Classroom

Putting classroom learning into real-life experiences is often what creates a meaningful learning experience for students, one that lasts beyond the exam and course. CTSOs are a great resource to create this type of learning for your students. They are also a great resource to showcase your students learning through regional, state, and national competitions. Possible connections for this course include the following. This is not an exhaustive list.

- Participate in the CTSO Fall Leadership Conference to engage with peers by demonstrating logical thought processes and developing industry-specific skills that involve teamwork and project management.
- Participate in contests that highlight job skill demonstration, interviewing skills, community service activities, extemporaneous speaking, and job interviews.
- Participate in leadership activities such as the National Leadership and Skills Conference, National Week of Service, and 21st Century Skills.

Using Work-Based Learning (WBL) in Your Classroom

Sustained and coordinated activities that relate to the course content are the key to successful work-based learning. Possible activities for this course include the following. This is not an exhaustive list.

- **Standards 1.1-1.2** | Invite an industry representative to discuss occupational safety hazards.
- **Standards 2.1-2.3** | Invite a research specialist to discuss essential components of research.
- **Standards 3.1** | Do a project that is useful to a local employer.
- **Standards 4.1-5.3** | Invite an educational psychologist to discuss team development and communication.
- **Standards 6.1-8.1** | Integrated project evaluated by industry professionals.

Course Description

STEM III: STEM in Context is an applied course in the STEM career cluster that 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. Upon completion of this course, 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.

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.

Course Standards

1. Safety

1.1 Safety Rules: 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.

1.2 Safety Equipment: 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 the safety test with 100 percent accuracy.

2. Essential Components of STEM Research

2.1 Formation of Research Teams: 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.

2.2 Ethical Requirements: 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 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.

2.3 Funding Obtainment: 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.

3. Research & Project Definition

3.1 Research and Project Defining: 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.

4. Team Development

4.1 Team Norms: 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.

4.2 Professional Attributes: 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; and
  e. collaborative and equitable distribution of work among all team members.

4.3 Team Strengths and Weakness: 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.

4.4 Tuckman's Stages of Group Development: 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.

5. Communication

5.1 Team Communication: 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.

5.2 Types of Communication: 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.

5.3 Decision-Making Methods: 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.

6. Project Management

6.1 Principles of Project Management: 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.

6.2 Projected Costs and Budget: 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.

7. Project Completion and Presentation

7.1 Using Scientific Inquiry and Engineering Design Process: 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.

7.2 Presentation Design: 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.

8. Evaluation of Project Outcome

8.1 Project Evaluation: 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?

Standards Alignment Notes

*References to other standards include:

- 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.

STEM IV: STEM Practicum

Primary Career Cluster:	Science, Technology, Engineering, and Mathematics (STEM)
Course Contact:	CTE.Standards@tn.gov
Course Code:	C21H18
Prerequisite:	*STEM III: STEM in Context* (C21H17)
Credit:	1
Grade Level:	12
Elective Focus-Graduation Requirement:	This course satisfies one of three credits required for an elective focus when taken in conjunction with other *STEM* courses.
Program of Study (POS) Concentrator:	This course satisfies one out of two required courses that meet the Perkins V concentrator definition when taken in sequence in the approved program of study.
Programs of Study and Sequence:	This is the fourth course in the *STEM Education* program of study.
Aligned Student Organization(s):	SkillsUSA: http://www.skillsusatn.org/ Technology Student Association (TSA): http://www.tntsa.org
Coordinating Work-Based Learning:	Teachers who hold an active WBL certificate may offer placement for credit when the requirements of the state board's WBL Framework and the Department's WBL Policy Guide are met. For information, visit https://www.tn.gov/education/educators/career-and-technical-education/work-based-learning.html.
Promoted Student Industry Credentials:	Credentials are aligned with post-secondary and employment opportunities and with the competencies and skills that students acquire through their selected program of study. For a listing of promoted student industry credentials, visit https://www.tn.gov/content/tn/education/educators/career-and-technical-education/student-industry-certification.html.
Teacher Endorsement(s):	013, 014, 015, 016, 017, 018, 047, 070, 078, 081, 125, 126, 127, 128, 129, 157, 173, 210, 211, 212, 213, 214, 230, 232, 233, 413, 414, 415, 416, 417, 418, 449, 470, 477, 519, 531, 595, 596, 700, 740, 742, 760, 982
Required Teacher Certifications:	None
Required Teacher Training:	Teachers who have never taught this course must attend the training provided by the Department of Education.
Teacher Resources:	https://www.tn.gov/education/educators/career-and-technical-education/career-clusters/cte-cluster-stem.html Best for All Central: https://bestforall.tnedu.gov/

Course at a Glance

There is no one way to create meaningful learning experiences for students. There are best practices available that data and students say impact long-term student learning. One of those best practices is to put student learning in context with their experiences.

Career and Technical Student Organizations (CTSOs) provide an opportunity for students to display their learning in the classroom and through regional, state, and/or national competitions. Work-based Learning (WBL) consists of sustained and coordinated work-based activities that relate to the course content. These activities should occur at every level through a program of study. Below is a listing of possible CTSO connections and WBL activities for this course. This listing is intended to be an idea starter and not a comprehensive listing.

Using a Career and Technical Student Organization (CTSO) in Your Classroom

Putting classroom learning into real-life experiences is often what creates a meaningful learning experience for students, one that lasts beyond the exam and course. CTSOs are a great resource to create this type of learning for your students. They are also a great resource to showcase your students learning through regional, state, and national competitions. Possible connections for this course include the following. This is not an exhaustive list.

- Participate in the CTSO Fall Leadership Conference to engage with peers by demonstrating logical thought processes and developing industry-specific skills that involve teamwork and project management.
- Participate in contests that highlight job skill demonstration, interviewing skills, community service activities, extemporaneous speaking, and job interviews.
- Participate in leadership activities such as the National Leadership and Skills Conference, National Week of Service, and 21st Century Skills.

Using Work-Based Learning (WBL) in Your Classroom

Sustained and coordinated activities that relate to the course content are the key to successful work-based learning. Possible activities for this course include the following. This is not an exhaustive list.

- **Standards 1.1-2.2** | Invite an OSHA rep to discuss occupational hazards.
- **Standards 3.1-3.4** | Provide students with an industry mentor to discuss career preparation and employment.
- **Standards 4.1** | Invite a local scientist to discuss scientific foundations.
- **Standards 5.1-7.2** | Internship with portfolio evaluation by an industry professional.

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 work-based learning arrangements such as internships, cooperative education, service learning, mentoring, and job shadowing. Upon completion of this course, proficient students will be prepared for postsecondary study in a STEM field.

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.

Work-Based Learning Framework

Practicum activities may take the form of work-based learning (WBL) opportunities (such as internships, cooperative education, service learning, and job shadowing) or industry-driven project-based learning. These experiences must comply with the Work-Based Learning Framework guidelines established in SBE High School Policy 2.103. As such, this course must be taught by a teacher with an active WBL Certificate issued by the Tennessee Department of Education and follow policies outlined in the Work-Based Learning Policy Guide available online at https://www.tn.gov/education/educators/career-and-technical-education/work-based-learning.html. The Tennessee Department of Education provides a Personalized Learning Plan template to ensure compliance with the Work-Based Learning Framework, state and federal Child Labor Law, and Tennessee Department of Education policies, which must be used for students participating in WBL opportunities.

Course Requirements

This capstone course aligns with the requirements of the Work-Based Learning Framework (established in Tennessee State Board High School Policy), with the Tennessee Department of Education's Work-Based Learning Policy Guide, and with state and federal Child Labor Law. As such, the following components are course requirements.

Course Standards

1. Personalized Learning Plan

1.1 <u>Personalized Learning Plan</u>: A student will have a **Personalized Learning Plan** that i**dentifies their long-term goals**, **demonstrates** how the **Work-Based Learning** (WBL) **experience** aligns with their elective focus and/or high school plan of study, addresses **how the student** plans to **meet and demonstrate the course standards**, and addresses **employability skill attainment** in the following areas:

   a. application of academic and technical knowledge and skills (embedded in course standards),
   b. career knowledge and navigation skills,
   c. 21st-century learning and innovation skills, and
   d. personal and social skills.

2. Safety

2.1 Safety Rules: 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.

2.2 Safety Equipment: 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 the safety test with 100 percent accuracy.

3. STEM Employment Research and Preparation

3.1 WBL Research: 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 the following:

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; and
g. website and contact information.

3.2 STEM Resumes: 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.

3.3 Job Search: 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.

3.4 Mock Interviews: 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.

4. Ethics

4.1 Code of Ethics: 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.

5. Transferring Course Concepts to Practicum

5.1 Skills Application: **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.

5.2 Reflections: Create and continually update a personal journal to **document the practicum and draw connections between the experience and previous course content by reflecting** on the following:

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, and
h. personal satisfaction.

6. Portfolio

6.1 Portfolio: 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 a 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; and
h. feedback from instructor and/or supervisor based on observations.

7. Communication of Project Results

7.1 Communicating Results: **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** p**rototyp**e, 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.

7.2 Presentation: 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.

Standards Alignment Notes

*References to other standards include:

- 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.

BioSTEM I

Primary Career Cluster:	Science, Technology, Engineering, and Mathematics (STEM)
Course Contact:	CTE.Standards@tn.gov
Course Code:	**C21H07**
Prerequisite:	**None**
Credit:	**1**
Grade Level:	**9**
Elective Focus-Graduation Requirements:	This course satisfies one of three credits required for an elective focus when taken in conjunction with other *BioSTEM* courses. In addition, this course satisfies one lab science credit requirement for graduation.
Program of Study (POS) Concentrator:	This course satisfies one out of two required courses that meet the Perkins V concentrator definition when taken in sequence in the approved program of study.
Programs of Study and Sequence:	**This is the first course in the *BioSTEM* program of study**
Aligned Student Organization(s):	SkillsUSA: http://www.skillsusatn.org/ Technology Student Association (TSA): http://www.tntsa.org
Coordinating Work-Based Learning:	**Teachers are encouraged to use embedded WBL activities such as informational interviewing, job shadowing, and career mentoring. For information, visit https://www.tn.gov/education/educators/career-and-technical-education/work-based-learning.html.**
Promoted Student Industry Credentials:	Credentials are aligned with post-secondary and employment opportunities and with the competencies and skills that students acquire through their selected program of study. For a listing of promoted student industry credentials, visit https://www.tn.gov/content/tn/education/educators/career-and-technical-education/student-industry-certification.html.
Teacher Endorsement(s):	013, 014, 015, 016, 017, 018, 047, 070, 078, 081, 125, 126, 127, 128, 129,157, 173, 210, 211, 212, 213, 214, 230, 232, 233, 413, 414, 415, 416, 417, 418, 449, 470, 477, 519, 531, 595, 596, 700, 740, 742, 760, 982
Required Teacher Certifications:	**None**
Required Teacher Training:	**Teachers who have never taught this course must attend training provided by the Department of Education.**
Teacher Resources:	https://www.tn.gov/education/educators/career-and-technical-education/career-clusters/cte-cluster-stem.html Best for All Central: https://bestforall.tnedu.gov/

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- Participate in the CTSO Fall Leadership Conference to engage with peers by demonstrating logical thought processes and developing industry-specific skills that involve teamwork and project management.
- Participate in contests that highlight job skill demonstration, interviewing skills, community service activities, extemporaneous speaking, and job interviews.
- Participate in leadership activities such as the National Leadership and Skills Conference, National Week of Service, and 21st Century Skills.

Using Work-Based Learning (WBL) in Your Classroom

Sustained and coordinated activities that relate to the course content are the key to successful work-based learning. Possible activities for this course include the following. This is not an exhaustive list.

- **Standards 1.1-1.2** | Invite an industry representative to discuss occupations within the BioSTEM career field.
- **Standards 2.1-2.3** | Complete an integrated project on Biotechnology with an industry professional.
- **Standards 3.1-3.2** | Invite a local scientist to discuss scientific foundations.
- **Standards 4.1-4.4** | Complete a project to be used by a local industry.
- **Standards 5.1-5.3** | Discuss safety protocols with an OSHA representative.
- **Standards 6.1-6.5** | Have students job shadow at a laboratory.

Course Description

BioSTEM I is a foundational course in the STEM cluster for students interested in learning more about careers in science, technology, engineering, and mathematics with an emphasis on biotechnology. This course covers basic skills required for BioSTEM 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 process. Students 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.

Course Standards

1. STEM Fields Exploration

1.1 Biotechnology vs. Biomedicine: Describe **the dynamic interplay** among science, technology, engineering, and math within living, earth-space, and physical systems. Differentiate between the terms **biotechnology and biomedicine** noting the impact that each has had on society. Explore the **history and development** of these scientific fields, as well as the **roles that their associated industries** have played in the areas of agriculture and food, health and medicine, the environment, research, and forensics.

1.2 BioSTEM Occupations: Explore several **occupations within BioSTEM fields**, such as medical laboratory science, research science, food science, forensic science, and environmental science, and determine how various industries **employ different kinds of data** to meet their needs. Create an infographic to describe **the many sources and types of data** that these occupations use.

1.3 Career and Technical Student Organization: **Introduce** the program's **aligned Career and Technical Student Organization** (CTSO), Technology Student Association (TSA) and Skills USA, **through an interactive activity**, such as classroom competition.

2. Perceptions and Future

2.1 Ethical Issues: Summarize research from professional journals or websites, textbooks, and/or newspaper articles surrounding an **ethical issue related to biotechnology** (i.e., the use of animals for lab testing, genetically modified organisms, or stem cell use). Debate the chosen topics presenting both sides of the issue. Discuss the **moral, ethical, and legal responsibilities** of researchers, policymakers, and other actors as they pertain to informing the public and ensuring the safety and well-being of affected populations.

2.2 Product Development: Develop an original idea for **a new biotechnology product** and simulate a situation in which the product must be pitched to a prospective client. Create an **informational packet** to share during the presentation that includes the following items: definition and protection of intellectual property, type of patent, copyright issues and rules, trademarks, and breeders' rights for plants or animals.

2.3 Biotechnology in Society: Develop an argumentative essay surrounding **public perceptions and attitudes toward the use of biotechnology** in society. Develop claims and counterclaims thoroughly based on facts from research, pointing out the strengths and weaknesses of each claim. Document information using appropriate industry terminology, including areas such as federal and international regulation and oversight, safety assessment, labeling of products, and impact on the economy.

3. Scientific Foundations

3.1 Structural Organization: Review the **structural organization of all living things** at the cellular level. Summarize in an oral, written, or digital presentation how **cellular organization influences scientific approaches** in BioSTEM fields with specific attention given to the various levels of eukaryotic organisms, cellular molecules, cell growth and reproduction, proteins, and nucleic acids.

3.2 Macromolecules: Synthesize information from professional journals and/or websites, textbooks, and news articles to compare and contrast **the structure and properties of the four macromolecules**: carbohydrates, lipids, proteins, and nucleic acids. Describe in an informational artifact how the cell membrane structures may be manipulated to allow the passage of these macromolecules in a cell; relate how this knowledge is used by scientists and applied to BioSTEM research.

4. Problem-Resolution Skills

4.1 Engineering Design and Scientific Inquiry: 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.

4.2 Data: 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 what information an actuary would need to know in order to answer a research question about which factors (e.g., diet, air quality, soil contaminates, sedentary lifestyle, etc.) are contributing the most to medical insurance claims in a region. (Mathematics)

4.3 Identifying Solutions: 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. Explore commonly used methods to decrease carbon emissions in the environment. (Technology/Mathematics)

4.4 Critical Factors of the Design Process: 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:

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 the 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)

5. Safety

5.1 Safety Guidelines: **Review guidelines from governmental agencies** such as the Office of Safety and Health Administration (OSHA) guidelines for medical and research laboratories, OSHA guidelines for Standard Precautions and personal protective equipment, Safety Data Sheets (MSDS) and storage of reagents and compounds, and Environmental Protection Agency (EPA) laboratory guidelines. Compare and contrast the **rules and regulations** of each agency to develop **clear expectations** regarding the maintenance of safety in these laboratories.

5.2 Safety Manual: Develop a **safety manual for a BioSTEM laboratory**, specifically for a lab **that is involved with processing or developing biomedical products**. Include the following in the manual: safety guidelines, procedures for accident prevention and response, and steps for reporting and documenting hazards. Explain the **industry standards** to maintain aseptic and sterile procedures and luminary flow, as well as the purpose of biosafety cabinets. Draw on the **standard operating procedures** from agencies, such as OSHA, EPA, and Centers for Disease Control and Prevention (CDC) when developing the manual.

5.3 Safety Equipment: 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. Also demonstrate the use of safety glasses, gloves, fire extinguisher, shower, and eyewash stations.

6. Laboratory Foundations

6.1 BioSTEM Lab: Understand the **principles of** and successfully perform **skills related to the BioSTEM laboratory.** Utilize appropriate tools and technology then document findings using domain-specific terminology. Incorporate rubrics from textbooks, CTSO guidelines, or clinical standards of practice for the following:

a. correct use of a centrifuge,
b. accurate usage of balance or digital scales,
c. safe use of an autoclave,
d. accurate use of pH meter or strips,
e. accurate use of an inoculating loop for agar plate streaking, and
f. accurate use and reading of glass or mercury thermometers.

6.2 Volume Measuring Devices: Review **the use of volume measuring devices** commonly used by biotechnologists, such as pipettes, micropipettes, and glassware. Prepare solutions and appropriate media; then perform serial dilutions incorporating aseptic techniques.

6.3 Laboratory Terminology: Explain in depth the **terms and phrases often heard in a BioSTEM laboratory** and relate how these terms and practices are important in the safe development of BioSTEM products and services.

a. Quality assurance
b. Quality control
c. Method validation
d. Appropriate documentation
e. Good manufacturing practices
f. Good laboratory practices.

6.4 Record Keeping: Demonstrate the **methods used in basic recordkeeping**. Compare and contrast general methods and explain their design and functionalities including the following:

a. laboratory notebooks,
b. equipment logs,
c. disposal records, and
d. quality assurance/control records.

6.5 Qualitative and Quantitative Measures: In teams, **apply qualitative and quantitative measures to analyze data** and draw conclusions that are free of bias. Compare experimental evidence and conclusions with those drawn by others about the same testable question; then communicate and defend scientific findings.

7. Data Analytics

7.1 Data Analysis in STEM: **Research** the **use of data in STEM cluster career fields**. Include data that is **generated internally** by businesses, **and externally** by local communicates, state, and the nation. Explore examples of how the data is used, including the following:

a. customer/client use of products and services;
b. demographics of end users;
c. community, state, and national statistics; and
d. data that must be reported to another entity.

8. Ethical Artificial Intelligence

8.1 Explore the Ethical Implications of AI Usage (AI): Through interactive discussions and case studies, learn to identify bias, ensure fairness, and protect privacy in AI systems. **Develop** critical thinking **skills to evaluate the societal impact of AI technologies**, while fostering a sense of responsibility and ethical decision-making in the use of AI tools.

Standards Alignment Notes

**References to other standards include:
- 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.

BioSTEM II

Primary Career Cluster:	**Science, Technology, Engineering, and Mathematics (STEM)**
Course Contact:	CTE.Standards@tn.gov
Course Code:	**C21H08**
Prerequisite:	***BioSTEM I* (C21H07)**
Credit:	**1**
Grade Level:	**10**
Elective Focus-Graduation Requirement:	This course satisfies one of three credits required for an elective focus when taken in conjunction with other *BioSTEM* courses. In addition, this course satisfies on lab science credit requirement for graduation.
Program of Study (POS) Concentrator:	This course satisfies one out of two required courses that meet the Perkins V concentrator definition when taken in sequence in the approved program of study.
Programs of Study and Sequence:	This is the second course in the *BioSTEM* program of study.
Aligned Student Organization(s):	SkillsUSA: http://www.skillsusatn.org/ Technology Student Association (TSA): http://www.tntsa.org
Coordinating Work-Based Learning:	Teachers are encouraged to use embedded WBL activities such as informational interviewing, job shadowing, and career mentoring. For information, visit https://www.tn.gov/education/educators/career-and-technical-education/work-based-learning.html.
Promoted Student Industry Credentials	Credentials are aligned with post-secondary and employment opportunities and with the competencies and skills that students acquire through their selected program of study. For a listing of promoted student industry credentials, visit https://www.tn.gov/content/tn/education/educators/career-and-technical-education/student-industry-certification.html.
Teacher Endorsement(s):	**013, 014, 015, 016, 017, 018, 047, 070, 078, 081, 125, 126, 127, 128, 129,157, 210, 211, 212, 213, 214, 230, 232, 233, 413, 414, 415, 416, 417, 418, 449, 470, 477, 519, 531, 595, 596, 700, 740, 760, 982**
Required Teacher Certifications:	**None**
Required Teacher Training:	**Teachers who have never taught this course must attend training provided by the Department of Education.**
Teacher Resources:	https://www.tn.gov/education/educators/career-and-technical-education/career-clusters/cte-cluster-stem.html Best for All Central: https://bestforall.tnedu.gov/

Course at a Glance

There is no one way to create meaningful learning experiences for students. There are best practices available that data and students say impact long-term student learning. One of those best practices is to put student learning in context with their experiences.

Career and Technical Student Organizations (CTSOs) provide an opportunity for students to display their learning in the classroom and through regional, state, and/or national competitions. Work-based Learning (WBL) consists of sustained and coordinated work-based activities that relate to the course content. These activities should occur at every level through a program of study. Below is a listing of possible CTSO connections and WBL activities for this course. This listing is intended to be an idea starter and not a comprehensive listing.

Using a Career and Technical Student Organization (CTSO) in Your Classroom

Putting classroom learning into real-life experiences is often what creates a meaningful learning experience for students, one that lasts beyond the exam and course. CTSOs are a great resource to create this type of learning for your students. They are also a great resource to showcase your students learning through regional, state, and national competitions. Possible connections for this course include the following. This is not an exhaustive list.

- Participate in the CTSO Fall Leadership Conference to engage with peers by demonstrating logical thought processes and developing industry-specific skills that involve teamwork and project management.
- Participate in contests that highlight job skill demonstration, interviewing skills, community service activities, extemporaneous speaking, and job interviews.
- Participate in leadership activities such as the National Leadership and Skills Conference, National Week of Service, and 21st Century Skills.

Using Work-Based Learning (WBL) in Your Classroom

Sustained and coordinated activities that relate to the course content are the key to successful work-based learning. Possible activities for this course include the following. This is not an exhaustive list.

- **Standards 1.1-2.1** | Invite an industry representative to discuss occupations and safety protocols for the career field.
- **Standards 3.1-3.5 |** Invite a geneticist to discuss DNA.
- **Standards 4.1-4.3** | Job shadow a geneticist.
- **Standards 5.1-5.2** | Work on-site with a geneticist on a real project.
- **Standards 6.1-6.3** | Invite a data analyst to discuss data interpretation.
- **Standards 7.1-8.1** | Do a project that is evaluated by a local laboratory.

Course Description

BioSTEM II is a project-based learning experience for students who wish to further explore the dynamic range of BioSTEM fields introduced in BioSTEM I. Building on the content and critical thinking frameworks of BioSTEM 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 the BioSTEM fields of medical laboratory science, research science, food science, forensic science, or environmental science that reflects the interest of the class as a whole; the students then apply the steps of the scientific inquiry 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 several of the BioSTEM fields. Upon completion of this course, proficient students will have a thorough understanding of how scientists research problems and methodically apply BioSTEM knowledge and skills, and they will be able to present and defend a scientific explanation of comprehensive BioSTEM scenarios.

Note: Standards in this course are presented sequentially according to the traditional steps followed in the scientific inquiry 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.

Course Standards

1. Safety

1.1 Safety Rules: 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.

1.2 Safety Equipment: 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 the safety test with 100 percent accuracy.

2. The Roles of Scientists

2.1 Scientific Phenomena: Determine the **scientist's role in explaining why phenomena occur in the natural world**, justified by historical and current scientific knowledge. Research a known scientist and present in an informative paper, oral presentation, or other format his/her contribution to scientific knowledge in the fields of food, environmental, biomedical, research, and forensic science. Include an outline of how the scientific inquiry process was used in his/her work.

3. DNA Basics

3.1 DNA Basics: Explain **how DNA serves as a template for self-replication and encoding of biological information** using an original visual DNA model. Define the terms DNA replication, DNA transcription, and translation of mRNA. Recount the processes involved in each and describe the negative outcomes if there is an interference in the process. Using domain-specific terminology, develop a scientific explanation to support the claim that the structures and mechanisms of DNA and RNA are the primary sources of heritable information.

3.2 <u>DNA Transmission</u>: Construct a visual artifact, annotated with written explanations, detailing **how DNA in chromosomes is transmitted** to the next generation **via mitosis or meiosis**. Note qualitative and quantitative traits, mutations, transposable genetic elements, and regulation of gene expressions.

3.3 <u>Mendel's Model</u>: Research and explain **Mendel's model of inheritance**. Using this model, **trace the pattern of appearance within a family for a heritable disease** that is on the recessive allele and one that is on the dominant allele. Develop an argumentative essay regarding how a certain biotechnology could genetically modify a gene to prevent this disorder, citing information from textbooks and/or professional journals and websites.

3.4 <u>DNA Structure and Function</u>: In an argumentative essay, state claims and counterclaims about **how DNA structure and function may be exploited using modern genetic engineering methods** to produce specific genetic constructs, such as selecting, excising, ligating, and cloning of genetic material. Ensure the documentation is written in domain-specific medical terminology.

3.5 <u>Genes</u>: Distinguish between a number of **strategies used to isolate or clone a gene**, such as activation tagging, map-based gene cloning, plasmid cloning vectors, viral vectors, and shuttle vectors. Present an overview of these strategies in a visual format.

4. Questioning and Defining Problems

4.1 <u>Scientific Inquiry</u>: Engage in **scientific inquiry** by brainstorming to create 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.

4.2 <u>Research the functions of DNA</u>: Research various sources (e.g., articles, end-uses, textbooks) and identify one or more questions that will guide a scientific investigation of the **various functions of DNA in food, environmental, biomedical, research, or forensic science**. For example, questions should be relevant, testable, and based on current scientific knowledge.

4.3 <u>Scientific Proposals</u>: Develop an **original proposal** as would a food, environmental, biomedical, research, or forensic 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, the importance of the study, and deliverables.

5. Planning and Investigating

5.1 <u>Investigations</u>: Make a **hypothesis that explains a scientific question about DNA** and its relationship to food, environmental, biomedical, research, or forensic science. Plan and conduct a simple investigation and record observations (e.g., data) in a manner easily retrievable by others.

5.2 <u>Variables</u>: 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.

6. Data Analysis and Interpretation

6.1 Scientific Questions: **Use mathematics to** represent and **solve scientific questions**. For example, simple limit cases can be used to determine if a model is realistic.

6.2 Data Analysis: 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.

6.3 Data Results: 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.

7. Problem Solutions and Scientific Explanations

7.1 Explanations to Scientific Questions: Develop an **explanation for a scientific question** that is **logically consistent, peer-reviewed, and justified** by DNA analysis and scientific knowledge.

8. Communicating Solutions and Explanations

8.1 Technical Report: 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 BioSTEM forum, present scientific research, and provide evidence to support arguments for or against scientific solutions.

9. Team Project

9.1 Team Project with Data Analysis: As a team, **identify a problem** related to the program of study as a whole. **Research and utilize the Engineering Design Process to design a solution.** Document the following steps in an engineering design notebook for inclusion in the program portfolio. When possible, connect the problem to an existing CTSO event.

a. **Problem Identification**: Brainstorm specific problems and challenges within the program of study. Conduct basic research to understand the scope and implications of the identified problem. Identify one problem as a focus area.
b. **Research and Analysis**: Conduct in-depth research on chosen topics related to the problem. Locate and analyze a dataset related to the problem.
c. **Review the Stages of the Engineering Design Process**: Define the problem, research, brainstorm solutions, develop prototypes, test and evaluate, and iterate. Consider constraints such as cost, efficiency, and environmental impact during the design process.
d. **Project Implementation**: Assign specific roles within the design teams (e.g., project manager, researcher, designer, tester). Design a solution tailored to address the identified problem or scenario. Document progress through design journals, sketches, diagrams, and digital presentations. (Note: Prototype is optional in the Level II course.)

e. **Presentation and Reflection**: Showcase the problem and solution to the class. Share the data that was analyzed and how it affected the solution. Discuss the design process and challenges. As a class, critically evaluate the effectiveness and feasibility of the solutions and propose potential improvements.

Standards Alignment Notes

*References to other standards include:

- 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.

BioSTEM III

Primary Career Cluster:	**Science, Technology, Engineering, and Mathematics (STEM)**
Course Contact:	CTE.Standards@tn.gov
Course Code:	**C21H09**
Prerequisite:	***BioSTEM II* (C21H09)**
Credit:	**1**
Grade Level:	**11**
Elective Focus-Graduation Requirement:	This course satisfies one of three credits required for an elective focus when taken in conjunction with other *BioSTEM* courses. In addition, this course satisfies one lab science credit requirement for graduation.
Program of Study (POS) Concentrator:	This course satisfies one out of two required courses that meet the Perkins V concentrator definition when taken in sequence in the approved program of study.
Programs of Study and Sequence:	This is the third course in the *BioSTEM* program of study.
Aligned Student Organization(s):	SkillsUSA: http://www.skillsusatn.org/ Technology Student Association (TSA): http://www.tntsa.org
Coordinating Work-Based Learning:	Teachers are encouraged to use embedded WBL activities such as informational interviewing, job shadowing, and career mentoring. For information, visit https://www.tn.gov/education/educators/career-and-technical-education/work-based-learning.html
Promoted Student Industry Credentials:	Credentials are aligned with post-secondary and employment opportunities and with the competencies and skills that students acquire through their selected program of study. For a listing of promoted student industry credentials, visit https://www.tn.gov/content/tn/education/educators/career-and-technical-education/student-industry-certification.html.
Teacher Endorsement(s):	**013, 014, 015, 016, 017, 018, 047, 070, 078, 081, 125, 126, 127, 128, 129,157, 173, 210, 211, 212, 213, 214, 230, 232, 233, 413, 414, 415, 416, 417, 418, 449, 470, 477, 519, 531, 595, 596, 700, 740, 742, 760, 982**
Required Teacher Certifications:	**None**
Required Teacher Training:	**Teachers who have never taught this course must attend the training provided by the Department of Education.**
Teacher Resources:	https://www.tn.gov/education/educators/career-and-technical-education/career-clusters/cte-cluster-stem.html Best for All Central: https://bestforall.tnedu.gov/

Course at a Glance

There is no one way to create meaningful learning experiences for students. There are best practices available that data and students say impact long-term student learning. One of those best practices is to put student learning in context with their experiences.

Career and Technical Student Organizations (CTSOs) provide an opportunity for students to display their learning in the classroom and through regional, state, and/or national competitions. Work-based Learning (WBL) consists of sustained and coordinated work-based activities that relate to the course content. These activities should occur at every level through a program of study. Below is a listing of possible CTSO connections and WBL activities for this course. This listing is intended to be an idea starter and not a comprehensive listing.

Using a Career and Technical Student Organization (CTSO) in Your Classroom

Putting classroom learning into real-life experiences is often what creates a meaningful learning experience for students, one that lasts beyond the exam and course. CTSOs are a great resource to create this type of learning for your students. They are also a great resource to showcase your students learning through regional, state, and national competitions. Possible connections for this course include the following. This is not an exhaustive list.

- Participate in the CTSO Fall Leadership Conference to engage with peers by demonstrating logical thought processes and developing industry-specific skills that involve teamwork and project management.
- Participate in contests that highlight job skill demonstration, interviewing skills, community service activities, extemporaneous speaking, and job interviews.
- Participate in leadership activities such as the National Leadership and Skills Conference, National Week of Service, and 21st Century Skills.

Using Work-Based Learning (WBL) in Your Classroom

Sustained and coordinated activities that relate to the course content are the key to successful work-based learning. Possible activities for this course include the following. This is not an exhaustive list.

- **Standards 1.1-1.2** | Invite an industry representative to discuss safety protocols for the career field.
- **Standards 2.1-2.3** | Invite a BioSTEM panel to discuss ethical research.
- **Standards 3.1-3.4** | Invite an educational psychologist to discuss team development.
- **Standards 4.1-7.1** | Do a project to be used and evaluated by a local industry.

Course Description

BioSTEM III is an applied course in the STEM career cluster that 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 *BioSTEM I* and *BioSTEM II* by applying scientific knowledge and skills to a team project. Upon completion of this course, 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.

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

Course Standards

1. Safety

1.1 Safety Rules: 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.

1.2 Safety Equipment: 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.

2. Essential Components of BioSTEM Research

2.1 Research Team Formation: Explore **how research teams are formed** in order **to answer scientific questions or design solutions to BioSTEM 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 (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.

2.2 Ethical Requirements: Research the **ethical requirements for conducting DNA or biomedical research** that will involve the public. For example, investigate the process for obtaining Institutional Review 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 BioSTEM fields.

2.3 Proposal Submission and Procurement Obtainment: Examine how BioSTEM 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.

3. Team Development

3.1 Team Development: Establish **research teams** and create a set of team **norms and 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 tram handbook and include the documented team norms.

3.2 Professional Attributes: As a team, determine the **professional attributes that must be embodied by team members i**n 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; and
e. collaborative and equitable distribution of work among all team members.

3.3 Roles and Responsibilities of Team Members: 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.

3.4 Tuckman's Model of Team Development: Research **Tuckman's stage model for team development** (i.e., forming, storming, norming, performing, and adjourning). Prior to starting the BioSTEM project, understand and explain each stage. After completing the project, write a brief evaluation of the team's growth at each stage.

4. Project Communication

4.1 Communication: 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.

4.2 Communication Skills: 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.

4.3 Decision-making methods: 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.

5. Project Management

5.1 Defining Problems in BioSTEM: Survey and observe people in your school and/or community. Analyze the results to **determine potential BioSTEM 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 BioSTEM project proposal defining the project's purpose and goals. Include an outline of how the team intends to follow the scientific inquiry process.

5.2 Project Plans: 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.

5.3 Projected Costs: 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.

6. Project Completion and Presentation

6.1 Project Completion: **Apply all steps of the scientific inquiry process** 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.

6.2 Presentation: 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. Prepare the presentation in a format that could be submitted to a competition such as a local Maker Faire or CTSO competitive event.

7. Project Evaluation

7.1 Project Evaluation: **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 BioSTEM 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?

Standards Alignment Notes

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- P21: Partnership for 21st Century Skills [Framework for 21st Century Learning]
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BioSTEM Practicum

Primary Career Cluster:	**Science, Technology, Engineering, and Mathematics (STEM)**
Course Contact:	CTE.Standards@tn.gov
Course Code\:	**C21H10**
Prerequisite:	***BioSTEM III* (C21H10)**
Credit:	**1**
Grade Level(s):	**11, 12**
Elective Focus-Graduation Requirement:	**This course satisfies one of three credits required for an elective focus when taken in conjunction with other *STEM* courses.**
Program of Study (POS) Concentrator:	This course satisfies one out of two required courses that meet the Perkins V concentrator definition when taken in sequence in the approved program of study.
Programs of Study and Sequence:	This is the fourth course in the *BioSTEM* program of study.
Aligned Student Organization(s):	SkillsUSA: http://www.skillsusatn.org/ Technology Student Association (TSA): http://www.tntsa.org
Coordinating Work-Based Learning:	Teachers are encouraged to use embedded WBL activities such as informational interviewing, job shadowing, and career mentoring. For information, visit https://www.tn.gov/education/educators/career-and-technical-education/work-based-learning.html.
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Teacher Endorsement(s):	**013, 014, 015, 016, 017, 018, 047, 070, 078, 081, 125, 126, 127, 128, 129,157, 173, 210, 211, 212, 213, 214, 230, 232, 233, 413, 414, 415, 416, 417, 418, 449, 470, 477, 519, 531, 595, 596, 700, 740, 742, 760, 982**
Required Teacher Certifications:	**None**
Required Teacher Training:	**Teachers who have never taught this course must attend training provided by the Department of Education.**
Teacher Resources:	https://www.tn.gov/education/educators/career-and-technical-education/career-clusters/cte-cluster-stem.html Best for All Central: https://bestforall.tnedu.gov/

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- Participate in the CTSO Fall Leadership Conference to engage with peers by demonstrating logical thought processes and developing industry-specific skills that involve teamwork and project management.
- Participate in contests that highlight job skill demonstration, interviewing skills, community service activities, extemporaneous speaking, and job interviews.
- Participate in leadership activities such as the National Leadership and Skills Conference, National Week of Service, and 21st Century Skills.

Using Work-Based Learning (WBL) in Your Classroom

Sustained and coordinated activities that relate to the course content are the key to successful work-based learning. Possible activities for this course include the following. This is not an exhaustive list.

- **Standards 1.1-2.5** | Partner students with an industry mentor who can provide career guidance.
- **Standards 3.1-4.2** | Ask an industry rep to discuss professional ethics in BioSTEM.
- **Standards 5.1-5.4** | Internship.
- **Standards 6.1-6.2** | Create a portfolio to be evaluated by industry representatives.

Course Description

BioSTEM Practicum is the fourth course in the STEM cluster for students interested in learning more about careers in science, technology, engineering, and mathematics with emphasis in Biotechnology. This course provides an opportunity for students to use skills and content learned during the first three courses in a real-world university or industry lab setting. Upon completion of this course, proficient students are able to identify, explain, and execute lab-based research utilizing the scientific inquiry processes. They will 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. Students also will gain knowledge of how a biotechnology business works.

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 the area of expertise and student interest.

Course Standards

1. Personalized Learning Plan

1.1 Personalized Learning Plan: A student will have a Personalized **Learning Plan that identifies their long-term goals, demonstrates how the Work-Based Learning (WBL) experience aligns with their elective focus** and/or high school plan of study, addresses how the student plans to meet and demonstrate the course standards, and addresses employability skill attainment in the following areas:

a. application of academic and technical knowledge and skills (embedded in course standards),
b. career knowledge and navigation skills,
c. 21st-century learning and innovation skills, and
d. personal and social skills.

2. BioSTEM Career Planning

2.1 Career Planning: Research a **company or organization that utilizes BioSTEM applications or specializes in BioSTEM solutions**. Companies could range from large biotech developers, to niche organizations that retain specialists on staff to serve their particular clients' needs. For the chosen company, cite specific textual evidence from the company's literature, as well as press coverage (if available) to summarize the following:

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; and
e. website and contact information.

2.2 BioSTEM Job Requirements: Analyze the **requirements and qualifications for various BioSTEM job postings** identified from specific company websites or online metasearch engines. Gather information from multiple sources, such as sample resumes, interviews with professionals, and job boards, to determine effective strategies for realizing career goals. Create a personal resume modeled after elements based on the findings above, then complete an authentic job application as part of a career search or work-based learning experience.

2.3 Resumes: Search for **BioSTEM resumes** retrieved from the websites of institutions, organizations, or professional networks. Discuss **what is typically included** in the resumes of BioSTEM professionals, compare and contrast several examples, and create a personal resume modeled after elements identified in the search.

2.4 Job Search: Conduct a **job search** and simulate the experience by researching local employment options. In preparation for a future career in BioSTEM, complete an authentic j**ob application form** and compose a **cover letter** following guidelines specified in the vacancy announcement.

2.5 Mock Interview: Participate in a **mock interview**. Prior to the interview, prepare an artifact 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.

3. Professional Ethics and Legal Responsibilities

3.1 Ethical and Legal Issues: Investigate current **issues surrounding BioSTEM and its applications**. Explore a range of arguments concerning privacy rights as they relate to the mining of personal data; determine **when it is ethical and legal to collect data** for profit versus for not-for-profit purposes. Advance an original argument that debates the pros and cons and summarizes the potential ramifications for clients, the public, and one's own personal reputation, drawing on evidence gathered from news media, company policies, and state and federal laws.

3.2 Ethical Impact: Research a case study involving an **ethical issue related to intellectual property rights**. Examine a variety of perspectives surrounding the issue, then develop an original analysis explaining the **impact of the issue** on those involved, using persuasive language and citing evidence from the research. Potential issues include copyright infringement, piracy, plagiarism, creative commons, and the state/federal laws that govern them.

4. Safety

4.1 Safety Rules: 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.

4.2 Safety Equipment: 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 the safety test with 100 percent accuracy.

5. Transferring Course Concepts to Practicum

5.1 Skills and Knowledge: **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.

5.2 Course Concepts: Define a **discreet question and execute a research project** to answer that question. Document all lab work in a lab notebook. Communicate the results of the project by a written paper or poster.

5.3 Documenting Skills: Continually **update a lab notebook to document skills learned during the practicum** and draw connections between the experience and previous course content.

5.4 Course Concepts: 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 the following:

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; and
h. personal satisfaction.

6. Capstone Project

6.1 Capstone Project: Using the scientific method, **design a BioSTEM research project or experiment to investigate BioSTEM applications in healthcare, the food industry, the environment, agriculture, forensics, or related fields**. Upon completion of the project, 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.

a. research to determine the task or topic;
b. exploration of the task or topic;
c. literature review;
d. collection and evaluation of sources;
e. thesis/hypothesis proposal and annotated bibliography;
f. revision and final draft of thesis/hypothesis;
g. outline/plan of action for paper or experiment;
h. data collection/development of research ideas and narratives;
i. submission of first draft of paper/lab report;

j. feedback, revision, and submission of final draft; and
k. reflection and evaluation.

6.2 Portfolio: 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 a thoughtful assessment and evaluation of the progression of work involving the application of steps of the scientific method (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; and
  g. feedback from instructor and/or supervisor based on observations.

Standards Alignment Notes

*References to other standards include:
- 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.

Principles of Engineering and Technology

Primary Career Cluster:	Science, Technology, Engineering, and Mathematics (STEM)
Course Contact:	CTE.Standards@tn.gov
Course Code:	C21H04
Prerequisite:	None
Credit:	1
Grade Level:	9
Elective Focus-Graduation Requirement:	This course satisfies one of three credits required for an elective focus when taken in conjunction with other *STEM* courses.
Program of Study (POS) Concentrator:	This course satisfies one out of two required courses that meet the Perkins V concentrator definition when taken in sequence in the approved program of study.
Programs of Study and Sequence:	This is the first course in the *Engineering* and *Technology* programs of study.
Aligned Student Organization(s):	SkillsUSA: http://www.skillsusatn.org/ Technology Student Association (TSA): http://www.tntsa.org
Coordinating Work-Based Learning:	Teachers are encouraged to use embedded WBL activities such as informational interviewing, job shadowing, and career mentoring. For information, visit https://www.tn.gov/education/educators/career-and-technical-education/work-based-learning.html.
Promoted Student Industry Credentials:	Credentials are aligned with post-secondary and employment opportunities and with the competencies and skills that students acquire through their selected program of study. For a listing of promoted student industry credentials, visit https://www.tn.gov/content/tn/education/educators/career-and-technical-education/student-industry-certification.html.
Teacher Endorsement(s):	013, 014, 015, 016, 017, 018, 047, 070, 078, 081, 125, 126, 127, 128, 129, 157, 173, 210, 211, 212, 213, 214, 230, 232, 233, 413, 414, 415, 416, 417, 418, 449, 470, 477, 519, 531, 595, 596, 700, 740, 742, 760, 982
Required Teacher Certifications:	None
Required Teacher Training:	Teachers who have never taught this course must attend training provided by the Department of Education.
Teacher Resources:	https://www.tn.gov/education/educators/career-and-technical-education/career-clusters/cte-cluster-stem.html Best for All Central: https://bestforall.tnedu.gov/

Course at a Glance

There is no one way to create meaningful learning experiences for students. There are best practices available that data and students say impact long-term student learning. One of those best practices is to put student learning in context with their experiences.

Career and Technical Student Organizations (CTSOs) provide an opportunity for students to display their learning in the classroom and through regional, state, and/or national competitions. Work-based Learning (WBL) consists of sustained and coordinated work-based activities that relate to the course content. These activities should occur at every level through a program of study. Below is a listing of possible CTSO connections and WBL activities for this course. This listing is intended to be an idea starter and not a comprehensive listing.

Using a Career and Technical Student Organization (CTSO) in Your Classroom

Putting classroom learning into real-life experiences is often what creates a meaningful learning experience for students, one that lasts beyond the exam and course. CTSOs are a great resource to create this type of learning for your students. They are also a great resource to showcase your students learning through regional, state, and national competitions. Possible connections for this course include the following. This is not an exhaustive list.

- Participate in the CTSO Fall Leadership Conference to engage with peers by demonstrating logical thought processes and developing industry-specific skills that involve teamwork and project management.
- Participate in contests that highlight job skill demonstration, interviewing skills, community service activities, extemporaneous speaking, and job interviews.
- Participate in leadership activities such as the National Leadership and Skills Conference, National Week of Service, and 21st Century Skills.

Using Work-Based Learning (WBL) in Your Classroom

Sustained and coordinated activities that relate to the course content are the key to successful work-based learning. Possible activities for this course include the following. This is not an exhaustive list.

- **Standards 1.1-1.2** | Invite an industry rep to discuss safety protocols.
- **Standards 2.1-2.3** | Invite a Professional Engineer to discuss the importance of engineering.
- **Standards 3.1-3.3** | Complete an integrated project with an industry professional.
- **Standards 4.1-4.3** | Visit a work site that uses the equipment and have students see how it is operated.
- **Standards 5.1** | Invite a math teacher to discuss measurement.
- **Standards 6.1** | Complete a project that can be used by a local industry.

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.

Course Standards

1. Safety

1.1 Safety Rules: 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.

1.2 Safety Equipment: 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 the safety test with 100 percent accuracy.

2. Introduction to Engineering & Technology

2.1 STEM Defined: 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, the 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 from engineering, yet each influences engineering. Incorporate proper citation conventions used in STEM fields (MLA, APA, or other) to cite sources of information retrieved.

2.2 Historical Events: In teams, create an **artifact illustrating important events in history**, in a given time period, that specifically involves engineering. Use a variety of sources to gather data, cite each source, and briefly describe why the chosen source is reliable.

2.3 Contributions of Engineering: 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.

2.4 Career and Technical Student Organization Introduction: **Introduce** the program's **aligned Career and Technical Student Organization** (CTSO), Technology Student Association (TSA) and Skills USA, **through an interactive activity**, such as classroom competition.

3. Engineering Design Process

3.1 Engineering Design Process: 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, and
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.

3.2 Large-Scale Engineering Design: 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.

3.3 Design Activity: 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.

4. Fundamental Sketching and Engineering Drawing

4.1 Sketching vs. Drafting: 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 the top, front, and right sides.

4.2 Isometric Drawings: 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.

4.3 2D and 3D Drawings: 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.

5. Introduction to Measurement

5.1 Measurement Devices: 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.

6. Data Analysis

6.1 Data Analysis in STEM: **Research** the **use of data in STEM cluster career fields**. Include data that is **generated internally** by businesses, **and externally** by local communicates, state, and the nation. Explore examples of how the data is used, including the following:

a. customer/client use of products and services;
b. demographics of end users;
c. community, state, and national statistics; and
d. data that must be reported to another entity.

7. Ethical Artificial Intelligence

7.1 Ethical Artificial Intelligence (AI): **Explore the ethical implications of AI usage** through interactive discussions and case studies, learning to identify bias, ensure fairness, and protect privacy in AI systems. **Develop** critical thinking **skills to evaluate the societal impact of AI technologies**, while fostering a sense of responsibility and ethical decision-making in the use of AI tools.

8. Class Project

8.1 Design Process Challenge: 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 the following:

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), and
g. conclusions and recommendations for future research.

Standards Alignment Notes

*References to other standards include:

- 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.

Engineering Design I

Primary Career Cluster:	Science, Technology, Engineering, and Mathematics (STEM)
Course Contact:	CTE.Standards@tn.gov
Course Code:	C21H05
Prerequisite(s):	*Principles of Engineering & Technology* (C21H04), *Algebra I* (G02X02, G02H00), and *Physical Science* (G03H00), or *Biology* (G03H03)
Corequisite:	*Geometry* (G02X03, G02H11)
Credit:	1
Grade Level:	10
Elective Focus-Graduation Requirement:	This course satisfies one of three credits required for an elective focus when taken in conjunction with other *STEM* courses. In addition, this course satisfies one lab science credit requirement for graduation.
Program of Study (POS) Concentrator:	This course satisfies one out of two required courses that meet the Perkins V concentrator definition when taken in sequence in the approved program of study.
Programs of Study and Sequence:	This is the second course in the *Engineering* program of study.
Aligned Student Organization(s):	SkillsUSA: http://www.skillsusatn.org/ Technology Student Association (TSA): http://www.tntsa.org
Coordinating Work-Based Learning:	Teachers are encouraged to use embedded WBL activities such as informational interviewing, job shadowing, and career mentoring. For information, visit https://www.tn.gov/education/educators/career-and-technical-education/work-based-learning.html.
Promoted Student Industry Credentials:	Credentials are aligned with post-secondary and employment opportunities and with the competencies and skills that students acquire through their selected program of study. For a listing of promoted student industry credentials, visit https://www.tn.gov/content/tn/education/educators/career-and-technical-education/student-industry-certification.html.
Teacher Endorsement(s):	013, 014, 015, 016, 017, 018, 047, 070, 078, 081, 125, 126, 127, 128, 129, 157, 173, 210, 211, 212, 213, 214, 413, 414, 415, 416, 417, 418, 230, 232, 233, 449, 470, 477, 519, 531, 595, 596, 700, 740, 742, 760, 982
Required Teacher Certifications:	None
Required Teacher Training:	Teachers who have never taught this course must attend training provided by the Department of Education.
Teacher Resources:	https://www.tn.gov/education/educators/career-and-technical-education/career-clusters/cte-cluster-stem.html Best for All Central: https://bestforall.tnedu.gov/

Course at a Glance

There is no one way to create meaningful learning experiences for students. There are best practices available that data and students say impact long-term student learning. One of those best practices is to put student learning in context with their experiences.

Career and Technical Student Organizations (CTSOs) provide an opportunity for students to display their learning in the classroom and through regional, state, and/or national competitions. Work-based Learning (WBL) consists of sustained and coordinated work-based activities that relate to the course content. These activities should occur at every level through a program of study. Below is a listing of possible CTSO connections and WBL activities for this course. This listing is intended to be an idea starter and not a comprehensive listing.

Using a Career and Technical Student Organization (CTSO) in Your Classroom

Putting classroom learning into real-life experiences is often what creates a meaningful learning experience for students, one that lasts beyond the exam and course. CTSOs are a great resource to create this type of learning for your students. They are also a great resource to showcase your students learning through regional, state, and national competitions. Possible connections for this course include the following. This is not an exhaustive list.

- Participate in the CTSO Fall Leadership Conference to engage with peers by demonstrating logical thought processes and developing industry-specific skills that involve teamwork and project management.
- Participate in contests that highlight job skill demonstration, interviewing skills, community service activities, extemporaneous speaking, and job interviews.
- Participate in leadership activities such as the National Leadership and Skills Conference, National Week of Service, and 21st Century Skills.

Using Work-Based Learning (WBL) in Your Classroom

Sustained and coordinated activities that relate to the course content are the key to successful work-based learning. Possible activities for this course include the following. This is not an exhaustive list.

- **Standards 1.1-2.2** | Invite an industry representative to discuss career exploration and safety protocols.
- **Standards 3.1-4.1** | Invite an engineer to discuss the Engineering Design Process.
- **Standards 5.1-5.3** | Visit a local company with this equipment and have the students see a demonstration.
- **Standards 6.1-6.4** | Partner with an industry representative to complete a project for a local company.
- **Standards 7.1-7.2** | Invite an engineering professor to provide an interactive demonstration.
- **Standards 8.1-8.4** | Invite a guest speaker to talk about Energy.
- **Standards 9.1-9.4** | Complete an integrated project with an industry partner.
- **Standards 10.1-11.1** | Complete a project for a local employer that will be evaluated by industry professionals.

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.

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

Course Standards

1. Safety

1.1 Safety Rules: 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.

1.2 Safety Equipment: 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 the safety test with 100 percent accuracy.

2. Career Exploration

2.1 Engineering Disciplines: In teams, use an online editing tool to develop an artifact **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.

2.2 Post-Secondary Opportunities: 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.

3. Engineering Design Process

3.1 Engineering Practices and the Engineering Design Process: Compare and contrast the following **engineering design process** with the following **eight common practices of science and engineering** (Achieve, 2013). Based on observations, explain how the engineering design process and the practices overlap. Present findings to the class.

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	

4. Problem-Solving Format

4.1 Problem-Solving Format: 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.

5. Engineering Drawing**

5.1 Types of Engineer Drawings: 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 principal views of a simple object from top, front, and right sides.

5.2 Isometric Drawings: Building on the knowledge of a two-dimensional drawing, create **complex isometric (3-D pictorial) drawings, properly using lines** (e.g., object, hidden, center), **labels, and dimensioning techniques.**

5.3 2D and 3D Drawings: Use CAD software to create simple **two-dimensional and three-dimensional drawing**s, 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.

**Students who successfully complete 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.*

6. Work, Force, Power & Machines

6.1 Simple Machines: 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.

6.2 Project Completion: 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.

6.3 Force, Work, and Power: 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.

6.4 Mechanical Advantage: 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.

7. Mechanisms

7.1 Mechanisms: Explain the **definition of a mechanism**. Interpret technical information in design problems to identify types of mechanisms such as the following:

a. linkages,

b. cam and follower,
c. bearings,
d. gears,
e. sprockets and chain, and
f. drives.

Explain the typical application and operation in systems of the components listed above, citing measurement and/or observed evidence to support explanations.

7.2 Relationships Used to Solve Engineering Problems: 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.

8. Energy

8.1 Energy: 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.

8.2 Concept of Heat: 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.

8.3 Units of Energy: 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.

8.4 Renewable and Nonrenewable Energy Resources: 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.

9. Electrical Systems

9.1 Subatomic Particles: Describe the **subatomic particles** (e.g., nucleus, proton, neutron, and electron) that make up an atom. 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 levels.

9.2 Voltage, Current, and Resistance: Define, compare, and contrast **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.

9.3 Ohm's Law: 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.

9.4 Function of Series and Parallel Circuits: 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.

10. Computer Software for Engineering Problem Solving

10.1 Using Computer Tools to Solve Problems: 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.

11. Team Project

11.1 Team Project: 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 the following:

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), and
g. conclusions and recommendations for future research.

Standards Alignment Notes

*References to other standards include:

- 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.

Engineering Design II

Primary Career Cluster:	Science, Technology, Engineering, and Mathematics (STEM)
Course Contact:	CTE.Standards@tn.gov
Course Code:	C21H06
Prerequisite(s):	*Engineering Design I* (C21H05,) *Biology* (G03H03), or *Chemistry* (G03H12)
Credit:	1
Grade Level:	11
Elective Focus-Graduation Requirement:	This course satisfies one of three credits required for an elective focus when taken in conjunction with other *STEM* courses. In addition, this course satisfies one lab science credit requirement for graduation.
Program of Study (POS) Concentrator:	This course satisfies one out of two required courses that meet the Perkins V concentrator definition when taken in sequence in the approved program of study.
Programs of Study and Sequence:	This is the third course in the *Engineering* program of study.
Aligned Student Organization(s):	SkillsUSA: http://www.skillsusatn.org/ Technology Student Association (TSA): http://www.tntsa.org
Coordinating Work-Based Learning:	Teachers are encouraged to use embedded WBL activities such as informational interviewing, job shadowing, and career mentoring. For information, visit https://www.tn.gov/education/educators/career-and-technical-education/work-based-learning.html.
Promoted Student Industry Credentials:	Credentials are aligned with post-secondary and employment opportunities and with the competencies and skills that students acquire through their selected program of study. For a listing of promoted student industry credentials, visit https://www.tn.gov/content/tn/education/educators/career-and-technical-education/student-industry-certification.html.
Teacher Endorsement(s):	013, 014, 015, 016, 017, 018, 047, 070, 078, 081, 125, 126, 127, 128, 129, 157, 173, 210, 211, 212, 213, 214, 413, 414, 415, 416, 417, 418, 230, 232, 233, 449, 470, 477, 519, 531, 595, 596, 700, 740, 742, 760, 982
Required Teacher Certifications:	None
Required Teacher Training:	Teachers who have never taught this course must attend training provided by the Department of Education.
Teacher Resources:	https://www.tn.gov/education/educators/career-and-technical-education/career-clusters/cte-cluster-stem.html Best for All Central: https://bestforall.tnedu.gov/

Course at a Glance

There is no one way to create meaningful learning experiences for students. There are best practices available that data and students say impact long-term student learning. One of those best practices is to put student learning in context with their experiences.

Career and Technical Student Organizations (CTSOs) provide an opportunity for students to display their learning in the classroom and through regional, state, and/or national competitions. Work-based Learning (WBL) consists of sustained and coordinated work-based activities that relate to the course content. These activities should occur at every level through a program of study. Below is a listing of possible CTSO connections and WBL activities for this course. This listing is intended to be an idea starter and not a comprehensive listing.

Using a Career and Technical Student Organization (CTSO) in Your Classroom

Putting classroom learning into real-life experiences is often what creates a meaningful learning experience for students, one that lasts beyond the exam and course. CTSOs are a great resource to create this type of learning for your students. They are also a great resource to showcase your students learning through regional, state, and national competitions. Possible connections for this course include the following. This is not an exhaustive list.

- Participate in the CTSO Fall Leadership Conference to engage with peers by demonstrating logical thought processes and developing industry-specific skills that involve teamwork and project management.
- Participate in contests that highlight job skill demonstration, interviewing skills, community service activities, extemporaneous speaking, and job interviews.
- Participate in leadership activities such as the National Leadership and Skills Conference, National Week of Service, and 21st Century Skills.

Using Work-Based Learning (WBL) in Your Classroom

Sustained and coordinated activities that relate to the course content are the key to successful work-based learning. Possible activities for this course include the following. This is not an exhaustive list.

- **Standards 1.1-2.2** | Invite an industry representative to discuss safety protocols and career opportunities.
- **Standards 3.1-3.2** | Invite an ethics professor to discuss ethics in engineering.
- **Standards 4.1-4.3** | Invite a local scientist to discuss scientific foundations.
- **Standards 5.1-5.3** | Invite a scientist to provide an interactive example of control systems.
- **Standards 6.1-6.2** | Invite a materials engineer to speak.
- **Standards 7.1-7.2** | Work on trajectory problem with an engineer.
- **Standards 8.1-9.1** | Invite a mathematician to discuss statistics and economics.
- **Standards 10.1-10.2** | Do a project that is used by a local industry and evaluated by industry experts.

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.

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

Course Standards

1. Safety

1.1 Safety Rules: 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.

1.2 Safety Equipment: 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 the safety test with 100 percent accuracy.

2. Career Exploration

2.1 Engineers vs. Scientists: In teams, research various sources to determine the **differences between engineers and scientists**. Create an artifact 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, to present to local middle school students.

2.2 Job Responsibilities: 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.

3. Engineering Ethics

3.1 Ethics in Engineering: 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.

3.2 Ethical Issues in Engineering: 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.

4. Control Systems

4.1 Components of a System: 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.

4.2 Processors and Controllers: 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.

4.3 Open and Closed Systems: 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 to illustrate the difference between open- and closed-loop systems, supplying examples for each.

5. Fluid Power Systems

5.1 Fluid Power: 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.

5.2 Bernoulli's Principle: 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.

5.3 Gas Laws: 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.

6. Materials and Mechanical Properties

6.1 Testing of Materials: 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.

6.2 Raw Materials: 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.

7. Statics, Kinematics, and Trajectory Motion

7.1 Projectiles, Kinematics, and Kinetics: 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 the 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.

7.2 Magnitude and Direction: 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.

8. Introduction to Statistics and Quality

8.1 Mean, Median, and Mode: 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.

8.2 Quality Management: In teams, prepare an informative report on the i**mportance 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.

9. Engineering Economics

9.1 Impact of Cost: 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.

10. Projects

10.1 Formation of Teams: 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.

10.2 Project: 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 the following:

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), and
h. conclusions and recommendations for future research.

Standards Alignment Notes

*References to other standards include:

- 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.
- National Society of Engineers (NSPE) Code of Ethics. (2014). http://www.nspe.org/resources/ethics/code-ethics.

Engineering Practicum

Primary Career Cluster:	Science, Technology, Engineering, and Mathematics (STEM)
Course Contact:	CTE.Standards@tn.gov
Course Code:	C21H14
Prerequisite(s):	*Engineering Design II* (C21H05) or *Robotics & Automated Systems* (C13H15)
Credit:	1
Grade Level:	12
Elective Focus-Graduation Requirement:	This course satisfies one of three credits required for an elective focus when taken in conjunction with other *STEM* courses.
Program of Study (POS) Concentrator:	This course satisfies one out of two required courses that meet the Perkins V concentrator definitionwhen taken in sequence in the approved program of study.
Programs of Study and Sequence:	This is the fourth course in the *Engineering* program of study.
Aligned Student Organization(s):	SkillsUSA: http://www.skillsusatn.org/ Technology Student Association (TSA): http://www.tntsa.org
Coordinating Work-Based Learning:	Teachers who hold an active WBL certificate may offer placement for credit when the requirements of the state board's WBL Framework and the Department's WBL Policy Guide are met. For information, visit https://www.tn.gov/education/educators/career-and-technical-education/work-based-learning.html.
Promoted Student Industry Credentials:	Credentials are aligned with post-secondary and employment opportunities and with the competencies and skills that students acquire through their selected program of study. For a listing of promoted student industry credentials, visit https://www.tn.gov/content/tn/education/educators/career-and-technical-education/student-industry-certification.html.
Teacher Endorsement(s):	013, 014, 015, 016, 017, 018, 047, 070, 078, 081, 125, 126, 127, 128, 129, 157, 173, 210, 211, 212, 213, 214, 230, 413, 414, 415, 416, 417, 418, 232, 233, 449, 470, 477, 519, 531, 551, 552, 553, 554, 555, 556, 584, 585, 595, 596, 700,740, 742, 760, 982
Required Teacher Certifications:	None
Required Teacher Training:	Teachers who have never taught this course must attend training provided by the Department of Education.
Teacher Resources:	https://www.tn.gov/education/educators/career-and-technical-education/career-clusters/cte-cluster-stem.html Best for All Central: https://bestforall.tnedu.gov/

Course at a Glance

There is no one way to create meaningful learning experiences for students. There are best practices available that data and students say impact long-term student learning. One of those best practices is to put student learning in context with their experiences.

Career and Technical Student Organizations (CTSOs) provide an opportunity for students to display their learning in the classroom and through regional, state, and/or national competitions. Work-based Learning (WBL) consists of sustained and coordinated work-based activities that relate to the course content. These activities should occur at every level through a program of study. Below is a listing of possible CTSO connections and WBL activities for this course. This listing is intended to be an idea starter and not a comprehensive listing.

Using a Career and Technical Student Organization (CTSO) in Your Classroom

Putting classroom learning into real-life experiences is often what creates a meaningful learning experience for students, one that lasts beyond the exam and course. CTSOs are a great resource to create this type of learning for your students. They are also a great resource to showcase your students learning through regional, state, and national competitions. Possible connections for this course include the following. This is not an exhaustive list.

- Participate in the CTSO Fall Leadership Conference to engage with peers by demonstrating logical thought processes and developing industry-specific skills that involve teamwork and project management.
- Participate in contests that highlight job skill demonstration, interviewing skills, community service activities, extemporaneous speaking, and job interviews.
- Participate in leadership activities such as the National Leadership and Skills Conference, National Week of Service, and 21st Century Skills.

Using Work-Based Learning (WBL) in Your Classroom

Sustained and coordinated activities that relate to the course content are the key to successful work-based learning. Possible activities for this course include the following. This is not an exhaustive list.

- **Standards 1.1-2.2** | Invite an OSHA representative to discuss safety protocols.
- **Standards 3.1-4.4** | Provide an industry mentor for students to discuss employment preparation.
- **Standards 5.1-7.2** | Participate in an Internship. Have an industry professional evaluate students' portfolios.

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 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.

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.

Work-Based Learning Framework

Practicum activities may take the form of work-based learning (WBL) opportunities (such as internships, cooperative education, service learning, and job shadowing) or industry-driven project-based learning. These experiences must comply with the Work-Based Learning Framework guidelines established in SBE High School Policy 2.103. As such, this course must be taught by a teacher with an active WBL Certificate issued by the Tennessee Department of Education and follow policies outlined in the Work-Based Learning Policy Guide available online at https://www.tn.gov/education/educators/career-and-technical-education/work-based-learning.html. The Tennessee Department of Education provides a Personalized Learning Plan template to ensure compliance with the Work-Based Learning Framework, state and federal Child Labor Law, and Tennessee Department of Education policies, which must be used for students participating in WBL opportunities.

Course Requirements

This capstone course aligns with the requirements of the Work-Based Learning Framework (established in Tennessee State Board High School Policy), with the Tennessee Department of Education's Work-Based Learning Policy Guide, and with state and federal Child Labor Law. As such, the following components are course requirements.

Course Standards

1. Personalized Learning Plan

1.1 Personalized Learning Plan: A student will have a Personalized Learning Plan that **identifies their long-term goals, demonstrates how the Work-Based Learning (WBL) experience aligns with their elective focus** and/or high school plan of study, addresses how the student plans to meet and demonstrate the course standards, and addresses employability skill attainment in the following areas:
   a. application of academic and technical knowledge and skills (embedded in course standards),
   b. career knowledge and navigation skills,

c. 21st-century learning and innovation skills, and
d. personal and social skills.

2. Safety

2.1 Safety Rules: 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.

2.2 Safety Equipment: 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 the safety test with 100 percent accuracy.

3. Career Exploration

3.1 Opportunities for Students: 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.

4. Employment Research and Preparation

4.1 Employment Research: 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 the following:
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; and
g. website and contact information.

4.2 Resumes: 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.

4.3 Job Search: 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.

4.4 Mock Interviews: 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.

5. Transferring Course Concepts to Practicum

5.1 Skills and Knowledge: **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.

5.2 Project Proposal: 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.

5.3 Personal Journal: 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 the following:

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; and
h. personal satisfaction.

6. Portfolio

6.1 Portfolio: 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 a 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; and
g. feedback from instructor and/or supervisor based on observations.

7. Communication of Project Results

7.1 Applying Engineering Design Process: Apply all **steps of the engineering design process** to successfully **generate a prototype**, **collec**t 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.

7.2 Presentation: 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.

Standards Alignment Notes

*References to other standards include:

- 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.

TN Department of Education | College, Career and Technical Education

May 2025

Digital Electronics

Primary Career Clusters:	Advanced Manufacturing and STEM
Course Contact:	CTE.Standards@tn.gov
Course Code:	C13H07
Prerequisite:	*Algebra I* (G02X02, G02H00)
Credit:	1
Grade Level:	10
Elective Focus-Graduation Requirement:	This course satisfies one of three credits required for an elective focus when taken in conjunction with other Advanced Manufacturing or *STEM* courses.
Program of Study (POS) Concentrator:	This course satisfies one out of two required courses that meet the Perkins V concentrator definition when taken in sequence in the approved program of study.
Programs of Study and Sequence:	This is the second course in the *Mechatronics* and *Technology* programs of study.
Aligned Student Organization(s):	SkillsUSA: http://www.skillsusatn.org/ Technology Student Association (TSA): http://www.tntsa.org
Coordinating Work-Based Learning:	Teachers are encouraged to use embedded WBL activities such as informational interviewing, job shadowing, and career mentoring. For information, visit https://www.tn.gov/education/educators/career-and-technical-education/work-based-learning.html.
Promoted Tennessee Student Industry Credentials:	Credentials are aligned with postsecondary and employment opportunities and with the competencies and skills that students acquire through their selected program of study. For a listing of promoted student industry credentials, visit https://www.tn.gov/education/educators/career-and-technical-education/student-industry-certification.html.
Teacher Endorsement(s):	013, 014, 015, 016, 017, 018, 047, 070, 078, 081, 125, 126, 127, 128, 129, 157, 210, 211, 212, 213, 214, 230, 231, 232, 233, (042 and 043), (042 and 044), (042 and 045), (042 and 046), (042 and 047), (042 and 077), (042 and 078), (042 and 079), (043 and 044), (043 and 045), (043 and 046), (043 and 047), (043 and 077), (043 and 078), (043 and 079), (044 and 045), (044 and 046), (044 and 047), (044 and 077), (044 and 078), (044 and 079), (045 and 046), (045 and 047), (045 and 077), (045 and 078), (045 and 079), (046 and 047), (046 and 077), (046 and 078), (046 and 079), (047 and 077), (047 and 078), (047 and 079), (077 and 078), (077 and 079), (078 and 079), 413, 414, 415, 416, 417, 418, 449, 470, 477, 501, 502, 519, 523, 531, 537, 551, 552, 553, 554, 555, 556, 557, 567, 575, 582, 584, 585, 595, 596, 598, 700, 701, 705, 707, 740, 760, 982
Required Teacher Certifications:	Some endorsements require NIMS industry certification to teach this course. Please refer to Occupational Educator Licensure Guidance for a full list.
Required Teacher Training:	None
Teacher Resources:	https://www.tn.gov/education/educators/career-and-technical-education/career-clusters/cte-cluster-advanced-manufacturing.html https://www.tn.gov/education/educators/career-and-technical-education/career-clusters/cte-cluster-stem.html Best for All Central: https://bestforall.tnedu.gov/

Course at a Glance

CTE courses provide students with an opportunity to develop specific academic, technical, and 21st-century skills necessary to be successful in careers and life. In pursuit of ensuring every student in Tennessee achieves this level of success, we begin with rigorous course standards that feed into intentionally designed programs of study.

Students engage in industry-relevant content through general education integration and experiences such as career and technical student organizations (CTSO) and work-based learning (WBL). Through these experiences, students are immersed with industry-standard content and technology, solve industry-based problems, meaningfully interact with industry professionals, and use/produce industry-specific, informational texts.

Using a Career and Technical Student Organization (CTSO) in Your Classroom

CTSOs are a great resource to put classroom learning into real-life experiences for students through classroom, regional, state, and national competitions, and leadership opportunities. Below are CTSO connections for this course. Note this is not an exhaustive list.

- Participate in the CTSO Fall Leadership Conference to engage with peers by demonstrating logical thought processes and developing industry-specific skills that involve teamwork and project management.
- Participate in contests that highlight job skill demonstrations. These include Career Pathways Showcase, Job Interview, Automated Manufacturing Technology, and Electronics Technology.

Using a Work-Based Learning (WBL) in Your Classroom

Sustained and coordinated activities that relate to the course content are the key to successful work-based learning. Possible activities for this course include the following. This is not an exhaustive list.

- **Standards 1.1-1.2** | Include a safety briefing in a visit to an industry partner/job site.
- **Standards 2.1-2.2** | Visit an employer and talk with those employees about career options.
- **Standards 3.3-3.4, 6.2-7.1, 8.2, 10.1** | Complete a project that is used by local industry or evaluated by local industry managers.
- **Standards 5.1-5.2** | Have an industry person visit the class to talk about and demonstrate the importance of logic circuits on the job.
- **Standard 9.1** | Discuss troubleshooting with an employee responsible for troubleshooting.

Course Description

Digital Electronics is intended to provide students with an introduction to the basic components of digital electronic systems and equip them with the ability to use these components to design more complex digital systems. Proficient students will be able to (1) describe basic functions of digital components (including gates, flip flops, counters, and other devices upon which larger systems are designed); (2) use these devices as building blocks to design larger, more complex circuits; (3)

implement these circuits using programmable devices; and (4) effectively communicate designs and systems. Students develop additional skills in technical documentation when operating and troubleshooting circuits. Upon completion of the *Digital Electronics* course, proficient students will be able to design a complex digital system and communicate their designs through a variety of media.

Course Standards

1. Safety

1.1 Safety Rules: Accurately read, interpret, and **demonstrate adherence to safety rules** including (1) rules published by the National Science Teachers Association (NSTA); (2) rules pertaining to electrical safety; (3) Occupational Safety and Health Administration (OSHA) guidelines; and (4) state and national code requirements. Be able to distinguish between the rules and explain why certain rules apply.

1.2 Safety Equipment: 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.

2. Citizenship and Career Exploration

2.1 Citizenship: Explain the **importance of electrical and/or computer engineers' contributions to society.** Select several contributions as justification and provide compelling evidence for how electrical/computer engineers' designs are used in everyday applications. Incorporate a variety of sources to gather data, including print and electronic; cite each source, and briefly describe why the particular source is reliable.

2.2 Postsecondary: Identify the **postsecondary institutions** in Tennessee that offer electrical engineering or electrical and/or computer engineering technology. Individually or in teams, develop and publish information that identifies admissions criteria, the postsecondary programs of study, and the secondary courses that will prepare students for success after high school in electrical or computer engineering fields. Cite each source adhering to standard citation conventions used in engineering disciplines.

3. Gates in Logic Circuits

3.1 Logic Gates: Identify each type of **logic gate** with a drawing, a description of its function in a short sentence or paragraph, a specification of each truth table, and the equation for each gate (buffer, inverter, AND, NAND, OR, NOR, XOR [difference], and XNOR [equivalence]), including the valid number of input(s) and output(s) for each gate.

3.2 Flip Flops: Define **D and JK flip flops** by including a drawing, a description of the function in a short sentence or paragraph, and a specification of each truth table and equation. The description should explain how the "clock" signal is related to the flip flop.

3.3 Combinational Devices: Design three (or more) **combinational (without a clock signal) devices** to a scale that would be typically implemented in a medium-scale integrated circuit (MSI: typically 10-1000 gates). One of the devices should incorporate XOR / XNOR gates. Examples of devices include 4-bit or greater versions of the following: adder/subtractor, comparator, multiplexer, and calculator. Upon completion of the design, provide an overview of the device and its specifications, an accompanying schematic, and a list of the gates used. Present the project to classmates and refine the presentation based on their feedback.

3.4 Combinational Project: Develop and publish information detailing a rich description of one of the **combinational projects**, including a schematic and summary of test results. If a prototyping system is available in the classroom (Xilinx, Altera, or similar), physically test the project and report results. If possible, include a video of the test. Present the project to the class, and revise based on peer feedback.

3.5 Diagram and Schematic: Design a counter with up to 32 states and write an explanatory text describing how the counter operates using technical and domain-specific vocabulary. **Provide a state diagram and draw a schematic** for the circuit using D or JK flip flips.

4. Counters in Logic Circuits

4.1 Counter: Design two (or more) **sequential devices that utilize a counter**. For example, design a traffic light system with two turn arrows. Explain the project with a description of the device, an accompanying schematic, and a list of the gates used.

5. Oscillators in Logic Circuits

5.1 Astable Monovibrator: In teams, design a clock signal using a 555-timer in an **astable monovibrator** configuration. Simulate the design and/or build a prototype and measure the output frequency. If instrumentation to measure the frequency is not available (an oscilloscope for example), a clock frequency timed using a stopwatch can be used as an alternative. Compare and contrast the prediction of the outcome with actual results. Explain the circuit design, the prediction, and the results from the simulation or prototype. *Note: The instructor may wish to constrain the output frequency by supplying a resistor value and/or a capacitor value.*

5.2 Counter: In teams, **design a counter** with between 16 and 32 states. Clock the counter using an oscillator of known frequency and predict the frequency from each output (each bit in the counter). Simulate the counter to verify the prediction. If possible, the counter should be physically prototyped to verify the prediction and simulation. Calculate the error between the prediction and simulation or prototype. Produce a technical report to summarize findings.

6. Multiplexers in Signal Distribution

6.1 Multiplexer: Design a circuit with 4-8 signals and **use a multiplexer** to select one of the signals as the output, then simulate the circuit. Explain the circuit describing the inputs, explaining the circuitry used to select the channel to output, featuring a timing diagram illustrating the successful operation of the circuit.

6.2 Multiplexer with Gates: In teams, design a **4-channel multiplexer using gates**. Simulate or build a prototype of the circuit and demonstrate it to the class. Participate in a class discussion that compares and contrasts the various designs exhibited. As a class, determine the best design and provide supporting evidence from observations and functionality to justify the decision.

7. Functions of Analog and Digital Convertors

7.1 Analog and Digital Counters: Design a **circuit using an A/D converter** to measure the temperature in the room. Specify the assumptions made for minimum and maximum temperatures and calculate the resolution (step) of the system. Upon completion of the circuit, write a technical specification of the design; then present the design and technical specifications to the class, including a graph showing the input and output values. Using the feedback from classmates, write a summary describing how the design could be revised and improved in future projects. *Note: Instructors may substitute a similar project in which a continuous and limited quantity is measured.*

7.2 Uses for Converters: Explain the **uses for A/D and D/A converters** in a current technical device. For example, describe how data acquisition systems in race cars use A/D and D/A converters. Draw on the research findings to develop talking points and participate in a mock public forum on the uses for A/D and D/A converters.

8. Physical Computing and Program Microcontrollers

8.1 Computer System: Sketch and describe a **block diagram of a computer system**, detailing at least the following components:

a. microcontroller/microprocessor,
b. cache,
c. RAM (random access memory),
d. large-scale memory,
e. input devices, and
f. output devices (monitor[s]).

Show the proper connections between each component, such as data bus and address bus connections. Using visual aids, present and explain the block diagram to the class.

8.2 Microcontroller: **Program a microcontroller-based system** to perform a series of tasks. The microcontroller should be part of a larger system. Upon completion of the programming, explain the functions and intended uses of the end product. Include the specifications of the series of tasks performed by the microcontroller and the programming code with comments for each function.

8.3 Physical Computing: Create a system to **demonstrate how hardware is connected to code**. For example, write code, assemble the hardware components, run the code, and assess if the hardware does the intended action.

9. Technical Documentation and Troubleshooting

9.1 Troubleshooting: Consult technical documents (such as data sheets, timing diagrams, operating manuals, and schematics) of digital components (TTL, CMOS, etc.) to **develop a troubleshooting methodology for a digital circuit** that could be used by a new technician. Explain the troubleshooting procedure.

10. Projects

10.1 Project: Identify a problem requiring a digital circuit (including A/D, D/A conversion, and/or a microprocessor). Follow the design process to **solve the problem using digital electronics**. Explain the solution, including a background section describing the problem which cites written or electronic sources and documentation of each stage in the design process. Build a prototype proof-of-concept if feasible. Present the problem, the design process used, and the developed solution to the class and other technical or non-technical audience members (e.g., parents, teachers, school administrators, STEM professionals, etc.). The final report draft should be critiqued by a different student team or outside expert. Thereafter, incorporate feedback to refine the report and submit a final version.

11. Team Project

11.1 Team Project with Data Analysis: As a team, **identify a problem** related to the program of study as a whole. **Research and utilize the Engineering Design Process to design a solution**. Document the following steps in an engineering design notebook for inclusion in the program portfolio. When possible, connect the problem to an existing SkillsUSA event.

a. **Problem Identification**: Brainstorm specific problems and challenges with the program of study. Conduct basic research to understand the scope and implications of the identified problem. Identify one problem as a focus area.
b. **Research and Analysis**: Conduct in-depth research on chosen topics related to the problem. Locate and analyze a dataset related to the problem.
c. **Review the Stages of the Engineering Design Process**: Define the problem, research, brainstorm solutions, develop prototypes, test and evaluate, and iterate. Consider constraints such as cost, efficiency, and environmental impact during the design process.
d. **Project Implementation**: Assign specific roles within the design teams (e.g., project manager, researcher, designer, tester). Design a solution tailored to address the identified problem or scenario. Document progress through design journals, sketches, diagrams, and digital presentations.
e. **Presentation and Reflection**: Showcase the problem and solution to the class. Share the data that was analyzed and how it affected the solution. Discuss the design process and challenges. As a class, critically evaluate the effectiveness and feasibility of the solutions and propose potential improvements.

Standards Alignment Notes

*References to other standards include:

- P21: Partnership for 21st Century Skills Framework for 21fixedst 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.

STEM Explorers

Primary Career Cluster:	Science, Technology, Engineering, and Mathematics (STEM)
Course Contact:	CTE.Standards@tn.gov
Course Code:	C25600
Prerequisite:	None
Credit:	N/A
Grade Level:	6
Graduation Requirement:	N/A
Coursework and Sequence:	This is the first course in the *Middle School STEM* sequence of coursework.
Aligned Student Organization:	Technology Student Association (TSA): http://www.tntsa.org
Coordinating Work-Based Learning:	Teachers are encouraged to use embedded WBL activities such as informational interviewing, job shadowing, and career mentoring. For information, visit https://www.tn.gov/education/educators/career-and-technical-education/work-based-learning.html.
Promoted Student Industry Credentials:	N/A
Teacher Endorsement(s):	001, 013, 014, 015, 016, 017, 018, 047, 070, 078, 081, 101, 121, 122, 123, 124, 125, 126, 127, 128, 129, 157, 210, 211, 212, 213, 214, 230, 232, 233, 400, 401, 402, 413, 414, 415, 416, 417, 418, 440, 449, 470, 477, 499, 982
Required Teacher Certifications/Training:	Teachers who have never taught this course must attend training provided by the Department of Education.
Teacher Resources:	https://www.tn.gov/education/educators/career-and-technical-education/career-clusters/cte-cluster-stem.html Best for All Central: https://bestforall.tnedu.gov/

Course at a Glance

There is no one way to create meaningful learning experiences for students. There are best practices available that data and students say impact long-term student learning. One of those best practices is to put student learning in context with their experiences.

Career and Technical Student Organizations (CTSOs) provide an opportunity for students to display their learning in the classroom and through regional, state, and/or national competitions. Work-based Learning (WBL) consists of sustained and coordinated work-based activities that relate to the course content. These activities should occur at every level through a program of study. Below is a listing of possible CTSO connections and WBL activities for this course. This listing is intended to be an idea starter and not a comprehensive listing.

Using a Career and Technical Student Organization (CTSO) in Your Classroom

Putting classroom learning into real-life experiences is often what creates a meaningful learning experience for students, one that lasts beyond the exam and course. CTSOs are a great resource to create this type of learning for your students. They are also a great resource to showcase your students learning through regional, state, and national competitions. Possible connections for this course include the following. This is not an exhaustive list.

- Participate in the CTSO Fall Leadership Conference to engage with peers by demonstrating logical thought processes and developing industry-specific skills that involve teamwork and project management.
- Participate in contests that highlight job skill demonstration, interviewing skills, community service activities, extemporaneous speaking, and job interviews.
- Participate in leadership activities such as the National Leadership and Skills Conference, National Week of Service, and 21st Century Skills.

Using Work-Based Learning (WBL) in Your Classroom

Sustained and coordinated activities related to the course content are the key to successful work-based learning. Possible activities for this course include the following. This is not an exhaustive list.

- **Standards 1.1-11.1** | Attend a career fair that exposes students to all aspects of STEM and Manufacturing with a multi-industry discussion panel.

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. Instructors are encouraged to utilize local industry and community issues in the related sections to make the engineering design process personal for students.

Course Standards

1. STEM Overview

1.1 STEM Influence: **Investigate historical figures and milestones in science, technology, engineering, and mathematics**. Explain how these figures or milestones had a lasting influence on the way we live in society today.

1.2 Benefits of Technology: **Research technologies that have benefited society**. 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.

2. Engineering Design Process

2.1 Scientific Questions: 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, and 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.

3. Safety

3.1 Safety Rules: Accurately r**ead 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.

3.2 Safety Equipment: 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 the safety test with 100 percent accuracy.

4. STEM Fields Exploration

4.1 STEM Career Clusters: **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.**

4.2 STEM Occupations: **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. 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.

5. Manufacturing Cluster

5.1 Manufacturing: 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. Then, evaluate the model and discuss how it and/or the process can be improved.

6. STEM Cluster

6.1 Engineering Design Process: 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.

7. Health Sciences Cluster

7.1 Health Science Field: **Research areas of the health sciences field**. Collect, graph, and analyze personal health or forensic-related information. Categorize the data collected and then describe 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 individual's data should be graphed using bar or box-and-whisker graphs.*

8. Information Technology Cluster

8.1 Information Technology Field: **Research the field of information technology** (IT) and define a **problem that could be solved by an IT professional**. Define the problem and present a possible solution including some form of information technology. 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.*

9. Architecture and Construction Cluster

9.1 Architecture and Design: 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. Test the load capacity of the bridge.*

10. Agriculture, Food and Natural Resources

10.1 Agriculture Field: 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; and
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.

11. Transportation, Distribution & Logistics

11.1 Transportation, Distribution and Logistics Field: 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. Explain 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.*

Standards Alignment Notes

*References to other standards include:

- 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.

STEM Innovators

Primary Career Cluster:	Science, Technology, Engineering, and Mathematics (STEM)
Course Contact:	CTE.Standards@tn.gov
Course Code:	C25701
Prerequisite:	None
Credit:	N/A
Grade Level:	7
Graduation Requirement:	N/A
Coursework and Sequence:	This is the second course in the *Middle School STEM* sequence of coursework.
Aligned Student Organization:	Technology Student Association (TSA): http://www.tntsa.org/ https://www.skillsusatn.org
Coordinating Work-Based Learning:	Teachers are encouraged to use embedded WBL activities such as informational interviewing, job shadowing, and career mentoring. For information, visit https://www.tn.gov/education/educators/career-and-technical-education/work-based-learning.html.
Promoted Student Industry Credentials:	N/A
Teacher Endorsement(s):	001, 013, 014, 015, 016, 017, 018, 047, 070, 078, 081, 101, 121, 122, 123, 124, 125, 126, 127, 128, 129, 157, 210, 211, 212, 213, 214, 230, 232, 233, 400, 401, 402, 413, 414, 415, 416, 417, 418, 440, 449, 470, 477, 982
Required Teacher Certifications/Training:	Teachers who have never taught this course must attend training provided by the Department of Education.
Teacher Resources:	https://www.tn.gov/education/educators/career-and-technical-education/career-clusters/middle-school-cte-standards.html Best for All Central: Best for All Central (tnedu.gov)

Course at a Glance

The STEM middle school courses are designed to give students a chance to think critically about design, creation, and innovation. STEM Innovators allows students to explore and should be taught in collaboration with local industry and values.

Career and Technical Student Organizations (CTSOs) provide an opportunity for students to display their learning in the classroom and through regional, state, and/or national competitions. Work-based Learning (WBL) consists of sustained and coordinated work-based activities that relate to the course content. These activities should occur at every level through a program of study. Below is a listing of possible CTSO connections and WBL activities for this course. This listing is intended to be an idea starter and not a comprehensive listing.

Using a Career and Technical Student Organization (CTSO) in Your Classroom

Putting classroom learning into real-life experiences is often what creates a meaningful learning experience for students, one that lasts beyond the exam and course. CTSOs are a great resource to create this type of learning for your students. They are also a great resource to showcase your students learning through regional, state, and national competitions. Possible connections for this course include the following. This is not an exhaustive list.

- Participate in the CTSO Fall Leadership Conference to engage with peers by demonstrating logical thought processes and developing industry-specific skills that involve teamwork and project management.
- Participate in contests that highlight job skill demonstration, interviewing skills, community service activities, extemporaneous speaking, and job interviews.
- Participate in leadership activities such as the National Leadership and Skills Conference, National Week of Service, and 21st Century Skills.

Using Work-Based Learning (WBL) in Your Classroom

Sustained and coordinated activities that relate to the course content are the key to successful work-based learning. Possible activities for this course include the following. This is not an exhaustive list.

- **Standards 1.1-1.2** | Invite an OSHA industry representative to discuss occupational hazards.
- **Standards 2.1-2.4** | Invite a Scientist, Engineer, and Mathematician to discuss the evolution of STEM.
- **Standards 3.1-3.5** | Complete a virtual tour of a Tech Lab.
- **Standards 4.1-5.1** | Visit a university and its computer-aided drafting facility to showcase equipment and demonstrate usage.
- **Standards 6.1-6.2** | Partner with an industry representative to do an integrated project.

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?"* Upon completion of this course, proficient students will understand why innovation is important and how it benefits society. Students will learn how innovation requires creativity and leads to 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 engineering design process. This course will reinforce the specific practices of developing and using models; planning and carrying out investigations; and analyzing and interpreting data.

Course Standards

1. Safety

1.1 Safety Rules: 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.

1.2 Safety Equipment: 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 the safety test with 100 percent accuracy.

2. Introduction to Innovation

2.1 Innovators: Research **great innovators**. Discuss **what inspired them, how their innovations have affected society, their education and background**, and how they used the engineering design process to innovate. Examples of great innovators include Alexander Graham Bell (the telephone), Thomas Edison (electricity), Albert Einstein (theory of relativity), George Washington Carver (agricultural products), Henry Ford (assembly line), Grace Hopper (developed the first compiler for a programming language), Garrett Morgan (traffic lights), Luis Walter Alvarez (aircraft radar and landing systems), Martin Cooper (wireless communications), Bill Gates (Microsoft), Steve Jobs (Apple), Mark Zuckerberg (Facebook), and Jack Dorsey (Twitter).

2.2 Innovator Skills: 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. Highlight the skill sets that were applied in the process and discuss why they were helpful in improving the product.

2.3 STEM in Technological Development: Select one of the **STEM-intensive industries** and showcase the **technological developments that helped advance industries associated with that cluster**. (The STEM-intensive industries are considered to be Manufacturing; Health Sciences; Digital Technology; Architecture and Construction; Agriculture and Sustainable Resources; and Transportation, and Energy) Include how society's needs have affected this technological development.

2.4 Patents and Trademarks: Research **how a specific product became trademarked or patented** 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.

3. Innovation Process

3.1 Innovation in Technology: 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.

3.2 Divergent and Convergent Thinking: Articulate the **concepts of divergent and convergent thinking** to classmates. Compare and contrast divergent (creativity) thinking and convergent (usually used in engineering) thinking. Research and illustrate the convergent and/or divergent thinking processes involved in a specific innovation.

3.3 Technology Used to Solve Societal Problem: 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; and
c. analyzing and comparing advantages and disadvantages of a proposed solution.

Consider any environmental, health, and economic impacts of the proposed solution. Illustrate the trade-offs and impacts of the proposed solution.

3.4 Engineering Design in Innovation: Illustrate **how engineering design relates to the innovation process**. Engineering design practices include: Asking questions and defining problems; developing and using models; planning and carrying out investigations; analyzing and interpreting data; using mathematics and computational thinking; constructing explanations and designing solutions; 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.*

3.5 Engineering Design Practices Used for Improvement: Given a specific product, apply engineering design 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. Summarize the tested data, evaluate whether the solution meets the original criteria and constraints, discussand justify the improvements that were made to the original product, and explain 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.*

4. Fundamental Sketching

4.1 Design and Sketch Principles: Identify **basic design and sketching principles used in the design stage of the innovation and engineering design processes**, 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.)*

5. 3-Dimensional Models & Prototypes

5.1 3-D Models and Prototyping: Research **how 3-D printing and rapid prototyping have revolutionized the innovation process** Design a 3-D model of a chosen product using computer-aided drafting or modeling software, and 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.*

6. Projects

6.1 Maker Movement and Maker Faire: **Research the Maker Movement and Maker Faire** and 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.

6.2 Community and Societal Needs: Research **needs in the community or society in general**. Based on information gathered, **apply an innovation process to create a product or technology that meets the need.** Define a problem or need and develop an appropriate method to document the innovation process (such as an innovation design 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. *(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.)*

Standards Alignment Notes

*References to other standards include:
- 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.

STEM Designers

Primary Career Cluster:	Science, Technology, Engineering, and Mathematics (STEM)
Course Contact:	CTE.Standards@tn.gov
Course Code:	C25801
Prerequisite:	None
Credit:	N/A
Grade Level:	8
Graduation Requirement:	N/A
Coursework and Sequence:	This is the third course in the *Middle School STEM* sequence of coursework.
Aligned Student Organization:	Technology Student Association (TSA) http://www.tntsa.org
Coordinating Work-Based Learning:	Teachers are encouraged to use embedded WBL activities such as informational interviewing, job shadowing, and career mentoring. For information, visit https://www.tn.gov/education/educators/career-and-technical-education/work-based-learning.html.
Promoted Student Industry Credentials:	N/A
Teacher Endorsement(s):	001, 013, 014, 015, 016, 017, 018, 047, 070, 078, 081, 101, 121, 122, 123, 124, 125, 126, 127, 128, 129, 157, 210, 211, 212, 213, 214, 230, 232, 233, 400, 401, 402, 413, 414, 415, 416, 417, 418, 440, 449, 470, 477, 982
Required Teacher Certification:	None
Required Teacher Training:	Teachers who have never taught this course must attend training provided by the Department of Education.
Teacher Resources:	https://www.tn.gov/education/educators/career-and-technical-education/career-clusters/cte-cluster-stem.html Best for All Central: https://bestforall.tnedu.gov/

Course at a Glance

There is no one way to create meaningful learning experiences for students. There are best practices available that data and students say impact long-term student learning. One of those best practices is to put student learning in context with their experiences.

Career and Technical Student Organizations (CTSOs) provide an opportunity for students to display their learning in the classroom and through regional, state, and/or national competitions. Work-based Learning (WBL) consists of sustained and coordinated work-based activities that relate to the course content. These activities should occur at every level through a program of study. Below is a listing of possible CTSO connections and WBL activities for this course. This listing is intended to be an idea starter and not a comprehensive listing.

Using a Career and Technical Student Organization (CTSO) in Your Classroom

Putting classroom learning into real-life experiences is often what creates a meaningful learning experience for students, one that lasts beyond the exam and course. CTSOs are a great resource to create this type of learning for your students. They are also a great resource to showcase your students learning through regional, state, and national competitions. Possible connections for this course include the following. This is not an exhaustive list.

- Participate in the CTSO Fall Leadership Conference to engage with peers by demonstrating logical thought processes and developing industry-specific skills that involve teamwork and project management.
- Participate in contests that highlight job skill demonstration, interviewing skills, community service activities, extemporaneous speaking, and job interviews.
- Participate in leadership activities such as the National Leadership and Skills Conference, National Week of Service, and 21st Century Skills.

Using Work-Based Learning (WBL) in Your Classroom

Sustained and coordinated activities that relate to the course content are the key to successful work-based learning. Possible activities for this course include the following. This is not an exhaustive list.

- **Standards 1.1-1.2** | Invite an OSHA representative to discuss safety protocols.
- **Standards 2.1-2.3** | Invite an engineer to discuss engineering foundations.
- **Standards 3.1-3.3** | Visit an engineering firm to showcase the design process.
- **Standards 4.1-4.3** | Partner with an industry partner to provide a hands-on CAD experience for students.
- **Standards 5.1** | Complete a project that is useful to the community.

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 students 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* place 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.

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

Course Standards

1. Safety

1.1 <u>Safety Rules</u>: 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.

1.2 <u>Safety Equipment</u>: 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 the safety test with 100 percent accuracy.

2. Introduction to Engineering

2.1 <u>History of Engineering</u>: Research the **history of engineering**, and explain **how science, technology, and math have influenced its development**.

2.2 <u>Relationship between STEM</u>: Research and illustrate the **relationship between science, technology, engineering, and math**. Provide an **example of a design solution** that incorporated at least three of the disciplines and articulate how they each contributed to the design.

3. <u>Benefits of Engineers</u>: 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**. **Engineering Design Process**

3.1 <u>Engineering Design Process Evaluation</u>: **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 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.

3.2 <u>Alternative Solutions</u>: 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 of the solutions. Write a conclusion 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 to 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

3.3 Engineering Design Process Utilization: **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**. **Document the entire process** in an engineering notebook. For example, design a balsa or basswood bridge that has the best performance ratio, and maximum capacity divided by mass of the bridge. Tests can be done on 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 a minimum, address the following science and engineering practices:
   a. using mathematics and computational thinking;
   b. designing solutions;
   c. engaging in argument from evidence; and
   d. obtaining, evaluating, and communicating information.

4. Fundamental Sketching and Engineering Drawing

4.1 Two Dimensional Design: 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.

4.2 3-D Design: 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.*

4.3 Design Model Concept: **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.

5. Final Project

5.1 Final Project: 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.

Standards Alignment Notes

*References to other standards include:

- 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.