CTE STEM CONCEPTS

Science, Technology, Engineering & Math

Learning that works for Utah

CTE®

Course Description

A hands-on, project-based course that aids students in developing the ability to apply understanding of how the world works within and across the areas of science, technology, engineering, and math (STEM), promoting abilities to better problem-solve, analyze, communicate, and understand technology.

Intended Grade Level	6
Units of Credit	0.5
Core Code	39-01-0000-050
Concurrent Enrollment Core Code	N/A
Prerequisite	N/A
Skill Certification Test Number	N/A
Test Weight	N/A
License Type	
License 1	Elementary Education 1-8
License 2	Secondary Education 6-12
Required Endorsement(s)	N/A

Utah State Board of Education

ADA Compliant: October 2018

Discussion Points

STEM seems to mean something different to everyone you ask. Anyone who thinks they know what STEM means knows what it means within their field, and with everybody else defining it to fit their own needs. Whether it is researchers, science and mathematics teachers, the aerospace industry, or the construction industry, they all have one thing in common: It is about moving forward, solving problems, learning, and pushing innovation to the next level.

As educators, we seem to consider STEM singularly from an educational perspective in which success in science and mathematics is increasingly important and technology and engineering are "integrated" when appropriate. When you start to divide STEM by subject (the silo approach), it gets even murkier.

Consider the following:

- Can science and mathematics alone be STEM?
- Does using an electronic whiteboard during a lesson, for example, make it a STEM lesson?
- When kindergarteners are playing with building blocks, is that a STEM center?
- What is the difference between Education Technology and Technology Education?

STEM DEFINITIONS

STEM includes four specific disciplines—science, technology, engineering, and mathematics—in an interdisciplinary and applied approach. Most people have a clear concept of Math and Science. Many are far less clear about Engineering or Technology, particularly in how they differ.

- **Science** is the study of the natural world, including the laws of nature associated with physics, chemistry, and biology and the treatment or application of facts, principles, concepts, and conventions associated with these disciplines. Science is both a body of knowledge that has been accumulated over time and a process—scientific inquiry—that generates new knowledge. Knowledge from science informs the engineering design process.
- **Technology**, while not a discipline in the strictest sense, comprises the entire system of people and organizations, knowledge, processes, and devices that go into creating and operating technological artifacts, as well as the artifacts themselves. Throughout history, humans have created technology to satisfy their wants and needs. Much of modern technology is a product of science and engineering, and technological tools are used in both fields. "Technology" is not merely computers or using a computer to solve a problem. Technology is far more than that.
- **Engineering** is both a body of knowledge—about the design and creation of human-made products—and a process for solving problems. This process is design under constraint. One constraint in engineering design is the laws of nature, or science. Other constraints include time, money, available materials, ergonomics, environmental

regulations, manufacturability, and reparability. Engineering utilizes concepts from science and mathematics as well as technological tools.

- **Mathematics** is the study of patterns and relationships among quantities, numbers, and space. Unlike in science, where empirical evidence is sought to warrant or overthrow claims, claims in mathematics are warranted through logical arguments based on foundational assumptions. The logical arguments themselves are part of mathematics along with the claims. As in science, knowledge in mathematics continues to grow, but unlike in science, knowledge in mathematics is not overturned, unless the foundational assumptions are transformed. Specific conceptual categories of K-12 mathematics include numbers and arithmetic, algebra, functions, geometry, and statistics and probability. Mathematics is used in science, engineering and technology.

(Adapted from National Academy of Engineering and National Research Council, 2009.)

STEM Education is a course or program of study that prepares students for successful employment, post-secondary education, or both that require different and more technically sophisticated skills including the application of mathematics and science skills and concepts. It also prepares students to be competent, capable citizens in our technology-dependent, democratic society.

STEM Education is far more than a grouping of four subjects and is best viewed in terms of its attributes, which transcend the four disciplines. A commonly referenced definition for STEM education is:

> "…an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy."
>
> (Tsupros, 2009)

STEM Education is the *intentional* integration of concepts that are usually taught as separate subjects in different classes and an emphasis on the application of knowledge to real-life situations. A lesson or unit in a STEM class is typically based around finding a solution to a real-world problem and tends to emphasize project-based learning. Many STEM lessons involve building prototypes and creating simulations. A *good* STEM lesson ensures that students understand the connection to the real world. A *great* STEM lesson engages students developing critical thinking and collaborative skills by engaging and persevering in real-world problem-solving.

STEM LITERACY

Several professional organizations in STEM have developed working definitions of STEM literacy in each of their content areas, while acknowledging the integrated and interrelated nature of STEM education. The National Governors Association, the College Board, Achieve, Inc., and STEM professional organizations have recommended ways to demonstrate the connections between STEM domains:

- **Scientifically literate students** use scientific knowledge not only in physics, chemistry, biological sciences, and earth/space sciences to understand the natural world, but they also understand the scientific need for existing and new technologies, how new advances in scientific understanding can be engineered, and how mathematics is used to articulate and solve problems.
- **Technologically literate students** understand that technology is the innovation with or manipulation of our natural resources to help create and satisfy human needs. They also learn how to obtain, utilize, and manage technological tools to solve science, mathematics, and engineering problems.
- **Students who are literate in engineering** understand how past, present, and future technologies are developed through the engineering design process to solve problems. They also see how science and mathematics are used in the creation of these technologies.
- **Mathematically literate students** not only know how to analyze, reason, and communicate ideas effectively; they can also mathematically pose, model, formulate, solve, and interpret questions and solutions in science, technology, and engineering.

Through problem/project-based learning situations, students weave together and communicate their understanding of STEM concepts. Concepts that were once taught in isolation become tangible and relevant to their daily lives. Integrated approaches to STEM education in the context of real-world issues can enhance motivation for learning and improve student interest, achievement, and persistence. These outcomes also have the potential to increase the number of students who consider pursuing a STEM-related field.

STEM COMPETENCIES

STEM teaches and trains students to engage in critical thinking, inquiry, problem-solving, collaboration, and what is often referred to in engineering as “design thinking”. These stand out as skills that all students and workers will need to be successful in college, career, and life.

While the four STEM disciplines define categories of knowledge, STEM is equally defined by learning strategies and competencies. It is strongly associated with skills, abilities, work interests, and work values (Carnevale, Melton, and Smith, 2011). Skills include foundational content skills, such as mathematics; processing skills, such as critical thinking and self-awareness; and problem-solving skills, such as evaluating options and implementing solutions. Abilities are defined as enduring personal attributes that influence performance at work, such as creativity, innovation, reasoning, and oral and written communication. Work values are individual preferences for work outcomes, such as recognition, responsibility, or advancement. Work interests are defined as individual preferences for work environments such as environments that are artistic, enterprising, or conventional. There is a growing demand for these competencies throughout today’s economy beyond the traditional STEM occupations, highlighting the importance of implementing a broad STEM strategy across K-12 education in America (Carnevale et al., 2011).

Moreover, readiness for a career in STEM is more than skills, abilities, work interests, and work values. It is a convergence of these with self-knowledge, adaptability, and a commitment to lifelong learning that make students ready to achieve a fulfilling, financially-secure and successful career in an ever-changing global economy.

Specific attention and focus is given to developing rudimentary skills in Mathematical and scientific reasoning, Technology design, Systems analysis and evaluation, Deductive and inductive reasoning, Practical application of engineering science. This may include instruction in foundational skills, such as keyboarding, coding, and documenting the design process in an engineering notebook.

THE ENGINEERING DESIGN PROCESS

Activities in STEM should be focused on problem-solving and employ a disciplined approach. There are numberless versions of engineering design cycles. While a specific version is not being imposed, an effective problem-solving process generally includes the following steps:

As a team, students

1. identify the design problem and decide how to address it.
   - Investigate existing design solutions.
   - Identify requirements and constraints and determine how they will affect the design process and record them in an engineering notebook.
   - Clearly and concisely define the problem to be solved and the measurements of successfully addressing the problem in an engineering notebook.
2. brainstorm solutions.
   - Document multiple solutions in an engineering notebook.
   - Evaluate the strengths and weaknesses of each proposed solution.
   - Decide on and record the best solution in an engineering notebook.
3. create a prototype of the proposed design using available facilities and materials.
   - Mathematical models
   - Scale models
4. test the prototype, record the results, and evaluate the performance of the design.
   - Identify and record both failures and successes in an engineering notebook.
   - Evaluate the performance of the prototype against the stated requirements.
5. redesign the prototype by repeating the design process to further optimize the design.
   - Reconsider any discarded ideas.
   - Look for mathematical relationships and use them to identify the factors that affect the design the most.
   - Record the results of the engineering process in an engineering notebook.

Students need to be taught that design problems are seldom presented in a clearly defined form and that the design requirements (e.g., the criteria, constraints, and efficiency) sometimes compete with one other. The process of engineering design considers many factors including safety, reliability, cost, quality control, the environment, manufacturability, maintenance & repair, and human factors. Engineering design is influenced by the designer's personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.

As they seek a solution to the problem, they should focus on developing the best solution rather than determining the "right" answer. The ideas supporting design choices must be refined and improved. Students need to develop the habit of continually checking and critiquing their work. That iterative process is critical to success.

PROFESSIONAL WORKPLACE SKILLS

Although they may not participate in the workplace for many years, STEM activities provide students with an opportunity to begin developing and honing skills that are essential to success in a professional environment. Those skills include:

1. Demonstrating self-representation/professionalism skills.
   - dressing appropriately (i.e., adhering to professional rather than personal standards)
   - maintaining personal hygiene
   - Adhering to respectful, polite, and professional practices (e.g., language and manners suitable for a professional environment).
2. Demonstrating effective speaking and listening skills.
   - exhibiting public and group speaking skills
   - comprehending details and following directions
   - repeating directions or requests to ensure understanding (i.e., practicing active listening).
3. Demonstrating teamwork skills.
   - contributing to the success of the team (e.g., brainstorming solutions, volunteering, performing in accordance with the assigned role)
   - assisting others (e.g., supporting team members and leaders, taking initiative)
   - requesting help when needed (e.g., asking questions after consulting manuals on policies and procedures, knowing when to seek help from coworkers and supervisors).
   - Negotiating diplomatic solutions to interpersonal conflicts in the workplace (e.g., personality issues, cultural difference issues, disagreements over how to handle work projects, performance issues).
4. Demonstrating creativity and resourcefulness.
   - contributing new ideas (e.g., for improving products and procedures)
   - displaying initiative readily, independently, and responsibly
   - dealing skillfully and promptly with new situations and obstacles
   - developing procedures that use resources in a sustainable manner.
5. Demonstrating critical-thinking and problem-solving skills.
   - recognizing, analyzing, and solving problems that arise in completing assigned tasks
   - identifying resources that may help solve a specific problem
   - using a logical approach to make decisions and solve problems.

6. **Demonstrating information technology skills.**
   - working with available equipment and software/applications
   - working with network/cloud and file-management techniques effectively
   - seeking additional technology to improve work processes and products.
   - using the Internet efficiently and ethically
   - identifying the risks of posting personal and work information on the Internet (e.g., on social networking sites, job search sites)
   - taking measures to avoid Internet security risks (e.g., viruses, malware).

7. **Demonstrating time-, task-, and resource-management skills.**
   - organizing and implementing a productive plan of work (e.g., setting and meeting short- and long-term goals)
   - working efficiently to make the best use of time
   - maintaining equipment to ensure longevity and efficiency
   - using natural resources (and products made from them) in a sustainable manner.