9TH GRADE-12TH GRADE

Science and Technology

Content Standard E:

As a result of activities in grades 9-12, all students should develop

- **Abilities of technological design**
- **Understandings about science and technology**

Content Summary

National Science Education Content Standards

K-4

Abilities to distinguish between natural objects and objects made by humans

Abilities of technological design

Understandings about science and technology

5-8

Abilities of technological design

Understandings about science and technology

9-12

Abilities of technological design

Understandings about science and technology

Minnesota Graduation Standards

Primary Level

Intermediate Level

Middle Level

Group Resources:
Manage resources as a team to produce a product or service

Writing:
Write for a variety of academic and technical purposes, situations and audiences

Technical Reading:
Comprehend technical information from documents or electronic media

High School Level

Technical Systems:
Apply knowledge, skills and tools of technological systems to extend human capabilities while preserving ecological functions

Technical Applications:
Apply mathematics to solve technical problems

New Product Development:
Research, develop and test a new product

Technical Reading:
Read and apply technical information from documents or electronic media

Technical Writing:
Write for a variety of technical purposes, situations, and audiences

Focus K-12

Grade	Early	Late
K-4	The focus of instruction early in this grade range is on providing opportunities for all students to investigate designed products and begin to develop the ability to design a solution to a problem.	The focus of instruction later in this grade range is on providing all students opportunities that continue to develop the abilities to design solutions to problems using situations and materials the students encounter in their daily lives.
5-8	The focus of instruction for all students early in this grade range is on establishing an awareness of the distinctions between science and technology and increasing students' abilities in design, using familiar science contexts.	The focus of instruction later in this grade range is on developing all students' understandings about similarities and differences between science and technology and using their abilities of technological design to solve problems in a variety of contexts.
9-12	The focus of instruction for all students at the high school level is on deepening students' understanding of the close relationship between science and technology and providing opportunities for them to apply science content and use their abilities of technological design to solve complex problems.	The focus of instruction for students pursuing further study is on providing opportunities for independent problem solving experiences which involve the full range of abilities and understandings of technological design.

Close-up 9-12

The focus of instruction at the high school level is on deepening students' understanding of the close relationship between science and technology and providing opportunities for them to apply science content and use their abilities of technological design to solve complex problems.

All high school students develop a deeper understanding of the relationship between science and technology and are less teacher-directed as they explore a range of design tasks including the development of products and systems. The teacher continues to set safety parameters for designs and students take responsibility for identifying problems or designs, choosing tools and materials, and implementing proposed solutions within assigned constraints. Design tasks allow students to identify problems, propose and implement a variety of design solutions, evaluate alternatives, and communicate their results and processes. Students use appropriate scientific content knowledge as they explore a variety of technical systems including the familiar, in homes and community, and those from wider regional, national, or global contexts. Throughout the design process, computers and other technological tools are used to access, record, communicate, analyze, and display information. Students spend time distinguishing between science and technology as well as exploring the ways in which science and technology influence each other. Students and teachers observe established science safety procedures.

The focus of instruction for students pursuing further study is on providing opportunities for independent problem solving experiences which involve the full range of abilities and understandings of technological design.

Students pursuing further study develop a more sophisticated understanding of design and the complex interrelationships between science and technology. Students, under the guidance of a teacher or community mentor, take responsibility for developing and carrying out design tasks. Individuals or groups of students may study different aspects of one problem. Students use print and electronic resources to guide them in implementing proposed solutions, evaluating the solutions and potential consequences, and in the analysis of their designs. Students often use mathematical concepts to develop and analyze their designs. Student understanding should allow them to work independently as they investigate these concepts. Students and teachers observe established science safety procedures.

On Location 9-12

This vignette illustrates the use of design within a content area as a parallel process to inquiry. Students look at nature for design elements. They model those observed elements in an effort to understand how various organisms survive in an aquatic environment.

In Mr. P's high school biology class, students learn about the form and function of marine life in terms of lift and drag while participating in a design unit. To begin the unit, Mr. P leads a discussion to help students define the terms "lift" and "drag," and how lift and drag of objects can be tested. When the teacher includes examples from wind tunnel experiments at General Motors to minimize drag on cars, students understand that design is very important (minimizing drag and improving lift). Mr. P defines the goal, "Find out how form and function of a marine organism enhances or inhibits movement by looking at the form in terms of efficiency of lift and minimizing drag."

Teams of students look through journals, view videotapes, and observe organisms that are in the school's marine aquarium in order to choose an organism to study. Once they have selected an organism, they identify all the design features of the organisms which might have a bearing on how the organism moves and deals with lift and drag.

Students then make clay models of their organism. They use oil-based clay so that as they improve their design, changes can be made. Some students make models of the whole organism while others break the models down into various characteristics of the organism.

Next, students test the shapes that they have designed in a ten-gallon aquarium filled with water. They light the background of the tank and darken the room. As one student suspends the clay model in the water, another student uses a 30 cc syringe to shoot warm colored sugar water at the model in the aquarium. Students follow the currents which form around the model in the tank by watching the path of the colored water.

Students carefully map current patterns on graph paper. They then shoot warm water at the model from several different angles, catching the head, body, flukes or tail, etc., and map the currents.

Students animate the current patterns of their model using animation visualization software and use this software to analyze the lift and drag of the model they selected. Students investigate how marine organisms influence lift and drag and determine why organisms have evolved as they have as a result of those functions.

Students then write formal reports on the results of their studies, relating them to concepts learned about the form and function of the organisms. Finally, the students design models that show ideal conditions of drag and lift.

National Science Education Content Standards

9-12 Content Standard E

Abilities of Technological Design

- **Identify a problem or design an opportunity.** Students should be able to identify new problems or needs and to change and improve current technological designs.
- **Propose designs and choose between alternative solutions.** Students should demonstrate thoughtful planning for a piece of technology or technique. Students should be introduced to the roles of models and simulations in these processes.
- **Implement a proposed solution.** A variety of skills can be needed in proposing a solution depending on the type of technology that is involved. The construction of artifacts can require the skills of cutting, shaping, treating, and joining common materials—such as wood, metal, plastics, and textiles. Solutions can also be implemented using computer software.
- **Evaluate the solution and its consequences.** Students should test any solution against the needs and criteria it was designed to meet. At this stage, new criteria not originally considered may be reviewed.
- **Communicate the problem, process, and solution.** Students should present their results to students, teachers, and others in a variety of ways, such as orally, in writing, and in other forms—including models, diagrams, and demonstrations.

Understandings About Science and Technology

- Scientists in different disciplines ask different questions, use different methods of investigation, and accept different types of evidence to support their explanations. Many scientific investigations require the contributions of individuals from different disciplines, including engineering. New disciplines of science, such as geophysics and biochemistry, often emerge at the interface of two older disciplines.
- Science often advances with the introduction of new technologies. Solving technological problems often results in new scientific knowledge. New technologies often extend the current levels of scientific understanding and introduce new areas of research.
- Creativity, imagination, and a good knowledge base are all required in the work of science and engineering.
- Science and technology are pursued for different purposes. Scientific inquiry is driven by the desire to understand the natural world, and technological design is driven by the need to meet human needs and solve human problems. Technology, by its nature, has a more direct effect on society than science because its purpose is to solve human problems, help humans adapt, and fulfill human aspirations. Technological solutions may create new problems. Science, by its nature, answers questions that may or may not directly influence humans. Sometimes scientific advances challenge people's beliefs and practical explanations concerning various aspects of the world.
- Technological knowledge is often not made public because of patents and the financial potential of the idea or invention. Scientific knowledge is made public through presentations at professional meetings and publications in scientific journals.

Minnesota Graduation Standards

High School Level

Technical Systems:

Apply knowledge, skills and tools of technological systems to extend human capabilities while preserving ecological functions.

What students should know:

1. Know the scientific principles and elements (inputs, processes, outputs, feedback) of a specific technological system in relationship to a macrosystem (e.g., a manufacturing system in relationship to a macro-system such as power and energy)
2. Know basic skills and use of tools related to operating a specific system

What students should do:

1. Create, modify, analyze or troubleshoot a technological system
2. Transfer knowledge of a specific system to create or modify a plan for a macro-system
3. Examine short-term impact on the environment and long-term sustainability

In Addition:

1. Suggestions to indicate appropriate level of difficulty and complexity:
   a. create model of a magnetic bus route system
   b. design distribution and communication system for a building
   c. develop a high-mileage vehicle
   d. construct a solar-powered vehicle
   e. develop a technological system for a developing country
   f. develop a magnetic levitation transportation system accommodating the needs of the disabled

Technical Applications:

Apply mathematics to solve technical problems.

What students should know:

1. Know computational technologies
2. Know how to use complex measurement equipment for several systems (e.g., electronic, construction, transportation)
3. Convert between measuring systems (e.g., metric, English, farads, henrys)
4. Measure to scale (e.g., linear and logarithmic electronic meter scales, scale drawings)
5. Calculate quantities using algebraic formulas (e.g., volume, power, impedance)
6. Understand information in complex graphs, tables, and charts
7. Understand scientific/exponential notation for use in complex systems
8. Understand trigonometric applications appropriate to technical situations
9. Understand fundamental geometric constructions or calculations for use in drafting or construction

What students should do:

1. Create a set of plans to design or modify a complex structure, product, or system:
   a. research background information
   b. calculate mathematical specifications
   c. develop a materials list which matches mathematical specifications
2. Construct a complex structure, product or model to mathematical specifications
3. Analyze an existing complex structure, product or system for purposes of maintenance, repair, troubleshooting or optimizing function

In Addition:

1. The complexity of tasks should be equivalent to that required for entry into apprenticeship training.

Options include:

a. analysis, maintenance, and repair of television systems
b. production of a complete set of plans with specifications for a boat or snowmobile trailer
c. the design and construction of a high-mileage, fuel-efficient vehicle
d. the design and/or complete analysis of the energy characteristics of a residential or commercial structure

Minnesota Graduation Standards

High School Level

New Product Development:

Research, develop and test a new product.

What students should know:

1. Understand the characteristics of needs analysis
2. Know characteristics and impact of the use of specific materials or technology
3. Understand material processing and/or design techniques

What students should do:

1. Develop and test a new product:
   a. research the need and the market
   b. design a new or improved product which meets the need
   c. create the new or improved product
   d. test and evaluate the product
   e. assess the impact of production, use and eventual disposal of the product on the environment, society and health, as applicable

Technical Reading:

Read and apply technical information from documents or electronic media.

What students should do:

1. Apply information from a technical reading, viewing or listening selection in two of the following applications:
   a. build or assemble from a plan
   b. operate, maintain or repair from a technical manual
   c. analyze a situation based on technical information
   d. create a design based on technical reading
2. Identify and select relevant information for the given need
3. Interpret specialized vocabulary
4. Interpret information found in charts, graphs, tables and other visual/graphic representations of data
5. Apply step-by-step procedures

In Addition:

1. Instructor will provide technical documents such as:
   a. code books
   b. plat books
   c. manuals
   d. maps
   e. government regulations
   f. nutrition standards
   g. product plans
   h. environmental impact statement

Technical Writing:

Write for a variety of technical purposes, situations and audiences.

What students should do:

1. Describe a complex process, procedure, or device for a particular audience (e.g., computer programs, business):
   a. evaluate the amount of technical knowledge the audience has
   b. determine where and how the information will be used
   c. use style/format and conventions appropriate for the audience (e.g., bulleted steps, chronological sequencing, neutral voice)
   d. use technical vocabulary appropriately for the audience
   e. incorporate detailed examples or illustrations
   f. include warnings or cautions to help audience prevent problems

In Addition:

1. Writing for technical purposes must include at least one complex project and work in all three of the following categories:
   a. directions and procedures (e.g., handbooks, operating procedures, procedures for assembly)
   b. reports and proposals (e.g., laboratory reports, investigative reports, analytical reports)
   c. correspondence (e.g., memos, meeting minutes, news releases)
2. Whenever possible, the writing product should be evaluated by a knowledgeable person from a technical or business setting.