High School Engineering Design and Development Curriculum Essentials Document

Boulder Valley School District
Department of CTEC
May 2012
Introduction – Engineering Design and Development Course

This document is intended to be a complete teaching curriculum, not just a guide or an outline. The curriculum is composed of units, which contain lessons and activities. The teacher guidelines and resource materials are integrated, via links, into the curriculum to make it easier for teachers to have access to the teaching tools needed to implement the course.

Each Unit begins with a Preface, a listing of Concepts, Essential Questions, and Lessons for the Unit with a recommendation for Unit Evaluations. The Concepts are the broad learning objectives for the unit. The intent of the Essential Questions, in combination with the Purpose of each lesson that is an anticipatory set, is to create a framework for teachers and students to focus student learning. Course specific projects can be developed by the students to solve problems posed by the questions. The Concepts and Essential Questions along with the anticipatory set should be communicated to the students at the beginning of every Unit to establish the focus of the unit’s learning objectives.

Each Unit is composed of lessons. Included in the Lessons are the Concepts specific to each Lesson; a listing of technology, science, mathematics, and English language arts national standards; Performance Objectives aligned with the national standards; Assessment suggestions; Essential questions aligned with the Concepts; Key Terms; a Day-by-Day Lesson plan; and a listing of instructional resources to aid instruction. Each of these components is clearly discussed and described in the Lesson Template Instructions and Activities, Projects, Problems Template Instructions found in the Course Implementation Suggestions section. Each Lesson is to begin with the instructor presenting the Lesson’s Purpose and Essential Questions to the students for them to think about and to develop solutions to, by the end of the Lesson. These questions are repeated for students at the end of an activity that is designed to help students focus their thoughts, learn skills, and apply those skills to solve problems, a key tenet of project-based learning.

This curriculum is designed to be taught to high school students within a “typical” high school schedule. This means that a class which meets each day for 45 minutes, 175 days a year should be able to cover the content of this course. Some minor adjustments will need to be made by those schools that teach under a “double block” system. For the most part, this will simply entail combining two “days” worth of activities into one.
### Engineering Design and Development Overview

#### Course Description

Engineering Design and Development (EDD) is the capstone course in the PLTW high school engineering program. It is an engineering research course in which students work in teams to design and develop an original solution to a valid open-ended technical problem by applying the engineering design process. The course applies and concurrently develops secondary level knowledge and skills in mathematics, science, and technology.

Utilizing the activity-project-problem-based (APPB) teaching and learning pedagogy, students will perform research to choose, validate, and justify a technical problem. After carefully defining the problem, teams of students will design, build, and test their solution. Finally, student teams will present and defend their original solution to an outside panel. While progressing through the engineering design process, students will work closely with experts and will continually hone their organizational, communication and interpersonal skills, their creative and problem solving abilities, and their understanding of the design process.

Engineering Design and Development is a high school level course that is appropriate for 12th grade students. Since the projects on which students work can vary with student interest and the curriculum focuses on problem solving, EDD is appropriate for students who are interested in any technical career path. EDD should be taken as the final capstone PLTW course since it requires application of the knowledge and skills from the PLTW foundation courses.

#### Topics at a Glance

- Overview and Expectations
- The Design Process
- Identify a Valid Problem
- Justify the Problem
- Select a Solution Path
- Select a Solution Path
- Plan for the Prototype
- Build the Prototype
- Plan the Test Phase
- Test the Prototype
- Documentation and Presentation

### Assessments

**Perspective**

- Students will consider one or more of the problems and projects they have completed in the past and detail to what extent each of those was accomplished with design by craft, visualization, and the incorporation of math and science.

**Self-knowledge**

- Students will recognize and record their strengths and weaknesses as a team member and consider how they can benefit a team by using certain skills and improving other skills.
Prepared Graduates

The preschool through twelfth-grade concepts and skills that all students who complete the Colorado education system must master to ensure their success in a postsecondary and workforce setting.

1. CTE Essential Skills: Academic Foundations

ESSK.01: Achieve additional academic knowledge and skills required to pursue the full range of career and postsecondary education opportunities within a career cluster.

Prepared Graduate Competencies in the CTE Essential Skills standard:

- Complete required training, education, and certification to prepare for employment in a particular career field
- Demonstrate language arts, mathematics, and scientific knowledge and skills required to pursue the full range of post-secondary and career opportunities

2. CTE Essential Skills: Communications Standards

ESSK.02: Use oral and written communication skills in creating, expressing, and interrupting information and ideas, including technical terminology and information

Prepared Graduate Competencies in the CTE Essential Skills standard:

- Select and employ appropriate reading and communication strategies to learn and use technical concepts and vocabulary in practice
- Demonstrate use of concepts, strategies, and systems for obtaining and conveying ideas and information to enhance communication in the workplace
3. CTE Essential Skills: Problem Solving and Critical Thinking

ESSK.03: Solve problems using critical thinking skills (analyze, synthesize, and evaluate) independently and in teams using creativity and innovation.

Prepared Graduate Competencies in the CTE Essential Skills standard:

- Employ critical thinking skills independently and in teams to solve problems and make decisions
- Employ critical thinking and interpersonal skills to resolve conflicts with staff and/or customers
- Conduct technical research to gather information necessary for decision-making

4. CTE Essential Skills: Safety, Health, and Environmental

ESSK.06: Understand the importance of health, safety, and environmental management systems in organizations and their importance to organizational performance and regulatory compliance

Prepared Graduate Competencies in the CTE Essential Skills standard:

- Implement personal and jobsite safety rules and regulations to maintain safe and helpful working conditions and environment
- Complete work tasks in accordance with employee rights and responsibilities and employers obligations to maintain workplace safety and health
5. CTE Essential Skills: Leadership and Teamwork

ESSK.07: Use leadership and teamwork skills in collaborating with others to accomplish organizational goals and objectives

Prepared Graduate Competencies in the CTE Essential Skills standard:

- Employ leadership skills to accomplish organizational skills and objectives

6. CTE Essential Skills: Employability and Career Development

ESSK.09: Know and understand the importance of employability skills; explore, plan, and effectively manage careers; know and understand the importance of entrepreneurship skills

Prepared Graduate Competencies in the CTE Essential Skills standard:

- Identify and demonstrate positive work behaviors and personal qualities needed to be employable
- Develop skills related to seeking and applying for employment to find and obtain a desired job
COLORADO COMMUNITY COLLEGE SYSTEM CAREER & TECHNICAL EDUCATION TECHNICAL STANDARDS REVISION & ACADEMIC ALIGNMENT PROCESS

Colorado’s 21st Century Career & Technical Education Programs have evolved beyond the historic perception of vocational education. They are Colorado’s best kept secret for:

• Relevant & rigorous learning

• Raising achievement among all students

• Strengthening Colorado’s workforce & economy

Colorado Career & Technical Education serves more than 116,000 Colorado secondary students annually through 1,200 programs in 160 school districts, 270 High Schools, 8 Technical Centers, 16 Community Colleges & 3 Technical Colleges. One of every three Colorado high school students gains valuable experiences by their enrollment in these programs.

ALIGNMENT REQUIRED BY SB 08-212

22-7-1005. Preschool through elementary and secondary education - aligned standards - adoption - revisions.

2(b): In developing the preschool through elementary and secondary education standards, the State Board shall also take into account any Career & Technical Education standards adopted by the State Board for Community Colleges and Occupational Education, created in Section 23-60-104, C.R.S., and, to the extent practicable, shall align the appropriate portions of the preschool through elementary and secondary education standards with the Career and Technical standards.

STANDARDS REVIEW AND ALIGNMENT PROCESS

Beginning in the fall of 2008, the Colorado Community College System conducted an intensive standards review and alignment process that involved:

NATIONAL BENCHMARK REVIEW

Colorado Career & Technical Education recently adopted the Career Cluster and Pathway Model endorsed by the United State Department of Education, Division of Adult and Technical Education. This model provided access to a national set of business and industry validated knowledge and skill statements for 16 of the 17 cluster areas. California and Ohio provided the comparative standards for the Energy cluster

• Based on this review Colorado CTE has moved from program-specific to Cluster & Pathway based standards and outcomes

• In addition, we arrived at fewer, higher, clearer and more transferrable standards, expectations and outcomes.

COLORADO CONTENT TEAMS REVIEW
The review, benchmarking and adjusting of the Colorado Cluster and Pathway standards, expectations and outcomes was through the dedicated work of Content Teams comprised of secondary and postsecondary faculty from across the state. Participation by instructors from each level ensured competency alignment between secondary and postsecondary programs. These individuals also proposed the draft academic alignments for math, science reading, writing and communication, social studies (including Personal Financial Literacy) and post secondary and workforce readiness (PWR.)

ACADEMIC ALIGNMENT REVIEW

In order to validate the alignment of the academic standards to the Career & Technical Education standards, subject matter experts in math, science, reading, writing and communication, and social studies were partnered with career & technical educators to determine if and when a true alignment existed.

CURRENT STATUS

• One set of aligned Essential skills to drive Postsecondary and Workforce Readiness inclusion in all Career & Technical Education programs.
• 52 pathways with validated academic alignments
• 12 pathways with revised standards ready for alignment (currently there are no approved programs in these pathways)
• 21 pathways where no secondary programming currently exists. Standards and alignments will be developed as programs emerge.
• Available for review at: www.coloradostateplan.com/content_standards.htm
Lesson 1.1 Overview and Expectations

Preface

Engineering Design and Development (EDD) gives students an opportunity to exercise the skills they have developed not only in their PLTW classes, but in other classes and in their personal experiences in general. Students will work in teams to solve a problem of their choosing. EDD is not focused on producing a marketable process or product, though this can and does happen using the design process. EDD is not intended to be an “invention class” or a “patent generating class” but rather a class that centers on using, documenting, and working through the engineering design process to address a problem. The end result should always be driven by the process rather than an individual or team’s skill sets, opinions, or personal preferences. As an example, students with an interest in electronics and aeronautics who apply the design process to address pilot errors may find that their results point to an ergonomic solution centered on organizing and displaying information in the cockpit rather than developing a new piece of instrumentation or a new control device. Others interested in chemistry and medicine may find that redesigning the way people enter and are processed through an emergency room may be a more effective way to address the rate of disease transmission in a hospital than designing a new chemical disinfectant. Because the focus is on the problem and using the design process, the topic choices for students are infinite.

EDD is about the journey of seeking a well-justified original solution to a real-world problem. Some solutions will prove to have merit as a potential solution, but when tested, will prove to have little value in solving the problem. Some solution attempts will prove to cause as many new problems as they solve, and some will prove to have great merit toward solving the problem in the end. No one will know the solution outcome at the beginning of the journey, but all groups will move through the problem solving process and gain skills they will be able to implement in any profession for the rest of their lives.

This first lesson is a chance for you to get the students excited about this journey and prepare them for the experience of EDD. Because EDD is less structured than most other courses, students must take more responsibility in their learning than they are accustomed to or are comfortable with taking. However, more responsibility should translate to more ownership and more reward.

This class will also be much different for you as the instructor, or more accurately, as the facilitator. It is important that, as you introduce the course, you make the students aware of the fundamental differences in the student and teacher roles between EDD and most other courses.

Concepts

1. The engineering design process is both a guide and a series of waypoints for effective problem solving and self-evaluation as an engineer moves through the process.
2. Individuals and other entities put extraordinary effort into protecting their intellectual property so they can control who has access to and use of their work and to maintain rights to profit from their ideas.

3. Procuring a patent from a government provides intellectual property protection and indicates that the idea is considered useful, novel, and nonobvious.

4. Assessing a product’s lifecycle creates an opportunity for identifying potential improvements in the process and provides a method for evaluating the product’s degree of success.

5. The Engineering Design Process Portfolio Rubric (EDPPSR) is a tool that can be used to assess and/or improve the design process and outcome of a design project.

Standards and Benchmarks Addressed

Standards for Technological Literacy

Standard 1: Students will develop an understanding of the characteristics and scope of technology.

BM K: The rate of technological development and diffusion is increasing rapidly.

BM L: Inventions and innovations are the results of specific, goal-directed research.

Standard 2: Students will develop an understanding of the core concepts of technology.

BM Z: Selecting resources involves trade-offs between competing values, such as availability, cost, desirability, and waste.

Standard 3: Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.

BM G: Technology transfer occurs when a new user applies an existing innovation developed for one purpose in a different function.

BM H: Technological innovation often results when ideas, knowledge, or skills are shared within a technology, among technologies, or across other fields.
**BM I:** Technological ideas are sometimes protected through the process of patenting. The protection of a creative idea is central to the sharing of technological knowledge.

**Standard 4:** **Students will develop an understanding of the cultural, social, economic, and political effects of technology.**

**BM I:** Making decisions about the use of technology involves weighing the trade-offs between the positive and negative effects.

**BM J:** Ethical considerations are important in the development, selection, and use of technologies.

**Standard 5:** **Students will develop an understanding of the effects of technology on the environment.**

**BM G:** Humans can devise technologies to conserve water, soil, and energy through such techniques as reusing, reducing and recycling.

**BM H:** When new technologies are developed to reduce the use of resources, considerations of trade-offs are important.

**BM L:** Decisions regarding the implementation of technologies involve the weighing of tradeoffs between predicted positive and negative effects on the environment.

**Standard 9:** **Students will develop an understanding of engineering design.**

**BM L:** The process of engineering design takes into account a number of factors.

**Standard 12:** **Students will develop the abilities to use and maintain technological products and systems.**

**BM L:** Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

**BM P:** Use computers and calculators to access, retrieve, organize and process, maintain, interpret, and evaluate data and information in order to communicate.

**Standard 13:** **Students will develop the abilities to assess the impacts of products and systems.**

**BM J:** Collect information and evaluate its quality.

**BM K:** Synthesize data, analyze trends, and draw conclusions regarding the effect of technology on the individual, society, and environment.
National Science Education Standards

Unifying Concepts and Processes: As a result of activities in grades K-12, all students should develop understanding and abilities aligned with the following concepts and processes.

- Systems, order, and organization
- Evidence, models, and explanation
- Change, constancy, and measurement

Science As Inquiry Standard A: As a result of activities in grades 9-12, all students should develop

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Science and Technology Standard E: As a result of activities in grades 9-12, all students should develop

- Abilities of technological design
- Understandings about science and technology

Science in Personal and Social Perspectives Standard F: As a result of activities in grades 9-12, all students should develop understanding of

- Natural Resources
- Environmental quality
- Natural and human-induced hazards
- Science and technology in local, national, and global challenges

Standards for English Language Arts

Standard 8 Students use a variety of technological and informational resources (e.g. libraries, databases, computer networks, video) to gather and synthesize information and to create and communicate knowledge.
Performance Objectives

*It is expected that students will*

- Justify why some discoveries are inventions and others are innovations.
- Conduct patent searches and judge which patents are most relevant to a given topic.
- Assess a product using a Product Lifecycle Assessment.
- Detail ecological and sustainable design attributes of a specific product.
- Summarize research findings in visual and verbal form.

Assessment

*Perspective*

- Students will consider a product that was primarily used more than a hundred years ago and describe how it has influenced modern products.

*Empathy*

- Students will imagine they are an independent inventor with an idea that they are convinced has enormous profit potential. Students will consider the steps needed to ensure that they will be able to protect their intellectual property.

Essential Questions

1. Why do companies advertise the positive ecological and sustainable design attributes of products?
2. How do you decide what key points are most important when given limited time to present findings?

Key Terms

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Closed-Loop Recycling</td>
<td>Recycling a material back to the same type.</td>
</tr>
<tr>
<td>Copyright</td>
<td>Exclusive legal rights to reproduce, publish, sell, or distribute the matter and form of something (as a literary, musical, or artistic work).</td>
</tr>
<tr>
<td>Downcycling</td>
<td>Recycling of a material to a lower grade of physical or commercial value.</td>
</tr>
<tr>
<td>Ecological Design</td>
<td>A method of design that is environmentally benign and economically viable.</td>
</tr>
<tr>
<td>Term</td>
<td>Description</td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Engineering Design Process</td>
<td>A decision making process (often iterative) in which the basic sciences, mathematics, and engineering sciences are applied to convert resources optimally to meet a stated objective.</td>
</tr>
<tr>
<td>Engineering Design Process Portfolio</td>
<td>A detailed rubric developed by a group of post-secondary educators and led by the University of Maryland aimed at organizing and assessing the engineering design process. The rubric was started in March of 2010 and is in a process of research and validation that will take place over three years.</td>
</tr>
<tr>
<td>Entrepreneur</td>
<td>A person who organizes and manages a business undertaking, assuming the risk for the sake of the profit.</td>
</tr>
<tr>
<td>Innovation</td>
<td>An improvement of an existing technological product, system, or method of doing something.</td>
</tr>
<tr>
<td>Innovation Portal</td>
<td>An online center on which students can build secure digital portfolios of their original design work and connect that work to a variety of opportunities. The template for portfolio building is organized around the Engineering Design Process Portfolio Scoring Rubric (EDPPSR).</td>
</tr>
<tr>
<td>Intellectual Property</td>
<td>Any product of someone's intellect that has commercial value, especially copyrighted material, patents, and trademarks.</td>
</tr>
<tr>
<td>Intrapreneur</td>
<td>A person in a corporation who is given the freedom and resources to initiate products, business ventures, etc.</td>
</tr>
<tr>
<td>Invention</td>
<td>A new product, system, or process that has never existed before, created by study and experimentation.</td>
</tr>
<tr>
<td>Licensing</td>
<td>The granting of permission to use intellectual property rights, such as trademarks, patents, or technology, under defined conditions.</td>
</tr>
<tr>
<td>Patent</td>
<td>A grant made by a government that gives an individual or a body the sole right to make, use, and sell an invention for a set period of time.</td>
</tr>
<tr>
<td>Provisional Patent</td>
<td>A less expensive and detailed application that allows one year's protection to provide time to further investigate or pursue licensing before filing a regular patent application.</td>
</tr>
<tr>
<td>Royalties</td>
<td>A share of the proceeds or product paid to the owner of a right, as a patent, for permission to use it or operate under it.</td>
</tr>
<tr>
<td>Sustainable Design</td>
<td>Design that is environmentally benign, economically viable, and socially equitable.</td>
</tr>
</tbody>
</table>
### Trade Secret
Any device, method, formula, etc. known to the manufacturer who uses it but not to competitors.

### Trademark
A symbol, design, word, letter, etc. used by a manufacturer or dealer to distinguish a product or products from those of competitors.

---

#### Day-by-Day Plans

**Time:** 7 days

**NOTE:** In preparation for teaching this lesson, it is strongly recommended that the teacher read the **Lesson 1.1 Teacher Notes.**

**Days 1-2:**
- The teacher will present **Concepts, Key Terms, and Essential Questions** in order to provide a lesson overview.
- The teacher will distribute The EDPPSR (Engineering Design Project Portfolio Scoring Rubric), **The Ten Mighty Questions and Project Flow Chart** and **Product Development Process.** The teacher will present **Why EDD.ppt** and lead a discussion.
- NOTE: It is recommended that you show only a couple of the videos that are available and use others throughout the course as deemed appropriate and timely.
- The students will take notes during the presentation.
- The teacher will distribute or give access to the EDD example stories (**Student Resources**) in order to help frame the course and generate discussions on possible topics for projects.
- The teacher will introduce the opportunities available to students doing original technical work located on the Innovation Portal and in the **Going Beyond** section of the Curriculum.
- **Optional:** The teacher may wish to assign use of the Innovation Portal as the means for creating project portfolios for the EDD course.
- **Optional:** The teacher may wish to assign **Lesson 1.1 Key Terms Crossword Puzzle** after all key terms have been introduced.

**Days 3-7:**
- The Teacher will present the **Innovation Portal Introduction.ppt.**
- Students will take notes during the presentation.
- The teacher will present the **Intellectual Property.ppt.**
- Students will take notes during the presentation.
- **Optional:** The teacher will distribute, explain, and assign **Activity 1.1.1 Invention and Innovation Patents (Optional)** and **Invention and Innovation Patents template.**
- **Optional:** Students will individually complete Activity 1.1.1 Invention and Innovation Patents and the conclusion questions.

- **Optional:** The teacher will collect Activity 1.1.1 Invention and Innovation Patents for assessment, check conclusion questions for completion, and lead a class discussion using those questions to assess students.

- The teacher will distribute **Product Lifecycle** handout and present **Product Life Cycle Assessment.ppt**.

- Students will take notes during the presentation.

- The teacher will distribute, explain, and assign **Project 1.1.2 Product Assessment** and **Project 1.1.2 Product Assessment Rubric**.

- Students will individually Complete Project 1.1.2 Product Assessment and the conclusion questions and then present their findings.

- The teacher will check Project 1.1.2 Product Assessment conclusion questions for completion and lead a class discussion using those questions to assess students.

### Instructional Resources

**Presentations**

- Why EDD?
- Innovation Portal Introduction
- Intellectual Property
- Product Life Cycle Assessment
- Interview about EDD with Karen High from “Why EDD” (Video)
- Interview about EDD with Bill Leonard from “Why EDD” (Video)

**Word Documents**

- Activity 1.1.1 Invention and Innovation Patents (Optional)
- Project 1.1.2 Product Assessment
- Invention and Innovation Patents template
- The Ten Mighty Questions and Project Flow Chart
- Product Life Cycle
- Product Development Process
- Lesson 1.1 Key Terms Crossword Puzzle

**Answer Keys and Rubrics**

- Project 1.1.2 Product Assessment Rubric
- Lesson 1.1 Key Terms Crossword Answer Key

**Teacher Guidelines**

- Teacher Notes
Reference Sources


National Council of Teachers of English (NCTE) and International Reading Association (IRA) (1996). *Standards for the English language arts*. Newark, DE: IRA; Urbana, IL: NCTE.


Lesson 1.2 the Design Process

Preface

This lesson is intended to reinforce the design process that students have been using throughout PLTW courses. It provides students with the opportunity to reflect upon prior experiences and to consider how best to succeed with the design problem selected during the next unit. This is also a time to set student expectations for quality of work, including teamwork and quality engineering notebook entries. This experience will probably be unlike prior learning experiences and thus should come with increased expectations.

This lesson’s centerpiece is a project that allows students to practice some of the skills necessary for successful completion of the course-long design problem.

Concepts

1. Many design processes guide professionals in developing solutions to problems.
2. Successful problem solving often incorporates known scientific and mathematical principles at the design and testing phases.
3. In order to solve difficult design problems, a team works together, utilizing each individual’s strengths to improve the design process and the final solution.
4. Project planning and management ensure that any project is completed in a way that meets all constraints and is satisfactory to all stakeholders.
5. A designer uses an engineering notebook to chronologically document all aspects of a design project as they move through the design process.
6. A designer/problem solver builds a portfolio to document their work to provide a means through which others may review and assess the outcome.

Standards and Benchmarks Addressed

Standards for Technological Literacy

Standard 1: Students will develop an understanding of the characteristics and scope of technology.

- **BM J:** The nature and development of technological knowledge and processes are functions of the setting.
- **BM K:** The rate of technological development and diffusion is increasing rapidly.
- **BM L:** Inventions and innovations are the results of specific, goal-directed research.

Standard 2: Students will develop an understanding of the core concepts of technology.

- **BM W:** Systems’ thinking applies logic and creativity with appropriate compromises in complex real-life problems.
BM AA: Requirements involve the identification of the criteria and constraints of a product or system and the determination of how they affect the final design and development.

BM EE: Management is the process of planning, organizing, and controlling work.

Standard 3: Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.
BM J: Technological progress promotes the advancement of science and mathematics. Likewise, progress in science and mathematics leads to advances in technology.

Standard 4: Students will develop an understanding of the cultural, social, economic, and political effects of technology.
BM J: Ethical considerations are important in the development, selection, and use of technologies.

Standard 7: Students will develop an understanding of the influence of technology on history.
BM G: Most technological development has been evolutionary, the result of a series of refinements to a basic invention.

Standard 8: Students will develop an understanding of the attributes of design.
BM H: The design process includes defining a problem, brainstorming, researching and generating ideas, identifying criteria and specifying constraints, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype, testing and evaluating the design using specifications, refining the design, creating or making it, and communicating processes and results.

BM K: Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other.

Standard 9: Students will develop an understanding of engineering design.
BM I: Established design principles are used to evaluate existing designs, to collect data, and to guide the design process.

BM K: A prototype is a working model used to test a design concept by making actual observations and necessary adjustments.

Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.
Technological problems must be researched before they can be solved.

Many technological problems require a multidisciplinary approach.

**Standard 11: Students will develop abilities to apply the design process.**

- **BM N:** Identify criteria and constraints and determine how these will affect the design process.
- **BM O:** Refine a design by using prototypes and modeling to ensure quality, efficiency, and productivity of the final product.
- **BM P:** Evaluate the design solution using conceptual, physical, and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed.
- **BM Q:** Develop and produce a product or system using a design process.
- **BM R:** Evaluate final solutions and communicate observation, processes, and results of the entire design process, using verbal, graphic, quantitative, virtual, and written means, in addition to three-dimensional models.

**Standard 13: Students will develop the abilities to assess the impacts of products and systems.**

- **BM J:** Collect information and evaluate its quality.
- **BM K:** Synthesize data, analyze trends, and draw conclusions regarding the effect of technology on the individual, society, and environment.
- **BM L:** Use assessment techniques, such as trend analysis and experimentation to make decisions about the future development of technology.

**Standard 17: Students will develop an understanding of and be able to select and use information and communication technologies.**

- **BM P:** There are many ways to communicate information, such as graphic and electronic means.

---

**National Science Education Standards**

- **Unifying Concepts and Processes:** As a result of activities in grades K-12, all students should develop understanding and abilities aligned with the following concepts and processes.
  - Systems, order, and organization
  - Evidence, models, and explanation
Change, constancy, and measurement

Science As Inquiry Standard A: As a result of activities in grades 9-12, all students should develop
- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Science and Technology Standard E: As a result of activities in grades 9-12, all students should develop
- Abilities of technological design
- Understandings about science and technology

Science in Personal and Social Perspectives Standard F: As a result of activities in grades 9-12, all students should develop understanding of
- Science and technology in local, national, and global challenges

Principles and Standards for School Mathematics

Measurement
Instructional programs from pre-kindergarten through grade 12 should enable all students to understand measurable attributes of objects and the units, systems, and processes of measurement; apply appropriate techniques, tools, and formulas to determine measurements.

Data Analysis and Probability
Instructional programs from pre-kindergarten through grade 12 should enable all students to formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them; select and use appropriate statistical methods to analyze data; develop and evaluate inferences and predictions that are based on data; understand and apply basic concepts of probability.

Standards for English Language Arts

Standard 8
Students use a variety of technological and informational resources (e.g. libraries, databases, computer networks, video) to gather and synthesize information and to create and communicate knowledge.

Performance Objectives

It is expected that students will:
- Create a solution to a problem using a design process.
- Create a Gantt Chart for project planning purposes.
Construct a working prototype.
Design and implement a prototype testing procedure.
Interpret test results.
Create documentation to support a design process and results.
Identify personal strengths that can benefit a problem solving team.

Assessment

Perspective

- Students will consider one or more of the problems and projects they have completed in the past and detail to what extent each of those was accomplished with design by craft, visualization, and the incorporation of math and science.

Self-knowledge

- Students will recognize and record their strengths and weaknesses as a team member and consider how they can benefit a team by using certain skills and improving other skills.

Essential Questions

1. Why is it crucial to use a design process when trying to solve complex problems?
2. What are advantages of successful project planning and management?
3. Why is it important for engineers and designers to utilize known scientific and mathematical principles?
4. What negative issues does successful project planning and management potentially prevent?
5. Why is teaming often more effective than individuals working alone when solving a complex problem?

Key Terms

<table>
<thead>
<tr>
<th>Key Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assumptions</td>
<td>Beliefs about what is true, usually describing the context of a project.</td>
</tr>
<tr>
<td>Constraint</td>
<td>1. A limit to a design process. Constraints may be such things as appearance, funding, space, materials, and human capabilities. 2. A limitation or restriction.</td>
</tr>
<tr>
<td>Deliverables</td>
<td>The end product; that which will be delivered; often used in the plural.</td>
</tr>
<tr>
<td>Design</td>
<td>1. An iterative decision-making process that produces plans by which resources are converted into products or systems that meet human needs and wants or solve problems. 2. A plan or drawing produced to show the look and function or working drawings of something before it is built or made.</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Gantt Chart</td>
<td>A time and activity bar chart representing a time schedule that is used for planning, managing, and controlling major programs that have a distinct beginning and end.</td>
</tr>
<tr>
<td>Milestones</td>
<td>Key dates, usually when a particularly important deliverable must be delivered.</td>
</tr>
<tr>
<td>Outcome Documentation</td>
<td>A presentation of the important findings, data, and work on which the final form of a product or system is based.</td>
</tr>
<tr>
<td>Planning</td>
<td>The project phase concerned with breaking the project into manageable chunks and planning how best to proceed.</td>
</tr>
<tr>
<td>Process Documentation</td>
<td>A step-by-step record of the process used throughout a project or task.</td>
</tr>
<tr>
<td>Project Life Cycle</td>
<td>The phases that any project progresses through (initiating, planning, executing, controlling, and closing).</td>
</tr>
<tr>
<td>Project Management</td>
<td>Planning, organizing, and managing resources to successfully complete a project.</td>
</tr>
<tr>
<td>Project Organization Chart</td>
<td>A diagram showing everyone involved in the project team, project board, key stakeholders, and resources.</td>
</tr>
<tr>
<td>Scope</td>
<td>The work involved in the definition, design, and production of a product, service, or result with the specified features and functions.</td>
</tr>
<tr>
<td>Scope Creep</td>
<td>The expansion of the scope of a project beyond the initial planning of the project.</td>
</tr>
<tr>
<td>Stakeholders</td>
<td>All those who are involved, interested in, or affected by the project.</td>
</tr>
<tr>
<td>Tasks</td>
<td>The activities undertaken to achieve deliverables.</td>
</tr>
<tr>
<td>Value Creation</td>
<td>The expression of the business benefits of the project, either in terms of cost savings, efficiency gains, increased sales, or reduced risk.</td>
</tr>
</tbody>
</table>
Day-by-Day Plans

Time: 14 days

NOTE: In preparation for teaching this lesson, it is strongly recommended that the teacher read the Lesson 1.2 Teacher Notes.

Day 1:

☐ The teacher will present Concepts, Key Terms, and Essential Questions in order to provide a lesson overview.

☐ The teacher will distribute and explain Project 1.2.1 Design Project and Project 1.2.1 Design Project Rubric and then explain that the activities completed in this lesson contribute to the completion of this project.

☐ The teacher will present The Design Process.ppt.

☐ Students will take notes during the presentation.

☐ The teacher will distribute, explain, and assign Activity 1.2.2 The Design Process.

☐ Students will complete number 1 in the procedure portion of Activity 1.2.2 The Design Process before the next class.

☐ Optional: The teacher may wish to assign Lesson 1.2 Key Terms Crossword Puzzle after all key terms have been introduced.

Day 2:

☐ The teacher will present Design by Craft, Visualization, and Math/Science.ppt and lead a discussion about the important aspects of each type of design.

☐ Students will take notes and record reflections during the presentation.

☐ Teacher will assign groups for Project 1.2.1 Design Project.

☐ Students will meet in project groups and complete Activity 1.2.2 The Design Process.

Day 3:

☐ The teacher will check Activity 1.2.2 The Design Process for completion.

☐ The teacher will present Documenting the Process.ppt.

☐ The teacher will distribute Engineering Notebook Guide and Amplifying Guides for Engineering Notebook and will present Engineering Notebook.ppt.

☐ Students will take notes during the presentations.

☐ Students will set up individual practice engineering notebooks for Project 1.2.1 Design Project.

Days 4-5:

☐ The teacher will present Project Management.ppt.

☐ Students will take notes during the presentation.
The teacher will distribute, explain, and assign Activity 1.2.3 Project Management, The Rule of Thirds, Team Responsibilities and the Creating Gantt Charts Tutorial.

The teacher will lead a discussion on how the Rule of Thirds relates to the design process and project management.

Students will individually complete Activity 1.2.3 Project Management conclusion questions.

Day 6:

The teacher will check team Gantt Charts and Activity 1.2.3 Project Management conclusion questions for completion and lead a class discussion using those questions to assess students.

The teacher will present Teamwork.ppt.

Students will take notes during the presentation.

Students will meet in teams in order to create team norms.

Days 7-13:

The teacher will check team norms for each group and offer suggestions and assistance where needed to support better functioning of teams.

The teacher will distribute Recording Turbidity with Logger Pro and demonstrate the use of the LabQuest Mini and Turbidity Sensor as needed.

Teams will complete Project 1.2.1 Design Project and the corresponding project portfolio.

Day 14:

The teacher will distribute, explain, and assign Activity 1.2.4 Teamwork and the Team Role Descriptions document.

Students will individually complete Activity 1.2.4 Teamwork conclusion questions.

The following day the teacher will check Activity 1.2.4 Teamwork conclusion questions for completion and lead a class discussion using those questions to assess students.

The teacher will assess Project 1.2.1 Design Project using the provided rubric.

The teacher will discuss with students how well they met expectations while completing the project. The discussion will address areas requiring improvement in order to encourage student success during the course-long design problem.

Instructional Resources

Presentations

The Design Process
Design by Craft, Visualization, and Math/Science
Documenting the Process
Engineering Notebook
Project Management
Teamwork

Word Documents

**Project 1.2.1 Design Project**

**Activity 1.2.2 The Design Process**

**Activity 1.2.3 Project Management**

**Activity 1.2.4 Teamwork**

Engineering Notebook Guide

Amplifying Guidelines for Engineering Notebook

Engineering Notebook Rubric

Recording Turbidity with Logger Pro

**Rule of Thirds**

Team Role Descriptions

**Team Responsibilities**

Lesson 1.2 Key Terms Crossword Puzzle

Answer Keys and Rubrics

**Project 1.2.1 Design Project Rubric**

Lesson 1.2 Key Terms Crossword Answer Key

Tutorials

**Creating Gantt Charts**

Student Support

Logger Pro Resource Sheet

Teacher Support

**Teacher Notes**

Reference Sources


Lesson 2.1 Identify a Valid Problem

Preface

The first step in every technical problem-solving endeavor is to concisely define the problem. This is crucially important. The problem statement is the foundation upon which all problem-solving effort is based. A well-written problem statement, simply stated, clearly identifies a problem. The problem statement allows the students to focus effort. It also serves as a means to measure the success of the design effort. When the result of the design and development process successfully solves the problem as stated in the problem statement, the student can say that he or she has a workable design. For this reason, it is important to carefully craft a concise and specific problem statement.

An acceptable problem is one for which there is no known solution, or one for which there is a solution that can be significantly improved upon. It must be valid (i.e., not a problem because the student says so, but because other credible sources agree that it is a problem) and justifiable (i.e., the effort to solve the problem is warranted based on need and cost). This lesson will guide students in the selection of a valid problem on which to base their work for the remainder of the course and in the writing of a concise problem statement. Students will use the researching skills they have accumulated throughout their school years to discover as much as they can on the topic of their proposed project in order to validate their problem. Research should not be restricted to “traditional” sources, such as books and professional journals, but should also include research techniques such as personal interviews, patent searches, and investigating web bulletin boards. During the problem selection process, students will also be encouraged to consider their own abilities, the available resources and school facilities, and time constraints.

Concepts

1. An accurately written problem statement identifies a need and guides the design process that will be used in engineering design problems.

2. An accurately written problem statement aids in determining whether the result of the engineering design and development process has solved the identified problem.

3. Experts are professionals that have specific knowledge in an area of interest and can guide the research needed for accurate justification and solutions to design problems.

Standards and Benchmarks Addressed

Standards for Technological Literacy

Standard 1: Students will develop an understanding of the characteristics and scope of technology.

BM K: The rate of technological development and diffusion is increasing rapidly.
BM L: Inventions and innovations are the results of specific, goal-directed research.

BM M: Most development of technologies these days is driven by the profit motive and the market.

**Standard 3:** Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.

BM G: Technology transfer occurs when a new user applies an existing innovation developed for one purpose in a different function.

BM H: Technological innovation often results when ideas, knowledge, or skills are shared within a technology, among technologies, or across other fields.

BM I: Technological ideas are sometimes protected through the process of patenting. The protection of a creative idea is central to the sharing of technological knowledge.

**Standard 6:** Students will develop an understanding of the role of society in the development and use of technology.

BM H: Different cultures develop their own technologies to satisfy their individual and shared needs, wants, and values.

**Standard 7:** Students will develop an understanding of the influence of technology on history.

BM G: Most technological development has been evolutionary, the result of a series of refinements to a basic invention.

**Standard 8:** Students will develop an understanding of the attributes of design.

BM H: The design process includes defining a problem, brainstorming, researching and generating ideas, identifying criteria and specifying constraints, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype, testing and evaluating the design using specifications, refining the design, creating or making it, and communicating processes and results.

BM I: Design problems are seldom presented in a clearly defined form.

**Standard 10:** Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

BM J: Technological problems must be researched before they can be solved.

**Standard 11:** Students will develop abilities to apply the design process.
BM M: Identify the design problem to solve and decide whether or not to address it.

National Science Education Standards

Science and Technology Standard E: As a result of activities in grades 9-12, all students should develop
- Abilities of technological design
- Understandings about science and technology

Principles and Standards for School Mathematics

Number and Operations
Instructional programs from pre-kindergarten through grade 12 should enable all students to understand numbers, ways of representing numbers, relationships among numbers, and number systems; understand meanings of operations and how they relate to one another; compute fluently and make reasonable estimates.

Standards for English Language Arts

Standard 8 Students use a variety of technological and informational resources (e.g. libraries, databases, computer networks, video) to gather and synthesize information and to create and communicate knowledge.

Performance Objectives

It is expected that students will:
- Appraise current and past products to inform the creation of a problem statement.
- Brainstorm problem statements for unique innovations or inventions.
- Write clear, complete, and concise problem statements.
- Document research that validates and justifies problem statements.
- Summarize and critique the most relevant content of research and patents.
- Distinguish between credible and non-credible sources while conducting research.
- Develop and use a decision matrix to choose a problem statement.
- Evaluate classmates’ problem statements.
Communicate professionally with experts and mentors on a specific topic.
Record and organize correspondence with experts and mentors.

Assessment

Perspective
Students will ask for input regarding the problems that they have identified in order to learn how they might improve their problem statements.

Self-knowledge
Students will access their life experiences and interests to develop a personally motivating and engaging problem statement.

Essential Questions
1. How can one establish the validity of a problem?
2. Why is it important to begin a design project with a valid problem statement?
3. How are experts and mentors valuable to the design process?
4. How can valuable and credible research be identified for use?

Key Terms

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Artifact</td>
<td>Handmade object or other result of human activity such as a design or document.</td>
</tr>
<tr>
<td>Brainstorming</td>
<td>A group technique for solving problems, generating ideas, and stimulating creative thinking through unrestrained spontaneous participation in discussion.</td>
</tr>
<tr>
<td>Decision Matrix</td>
<td>A graphical tool consisting of columns and rows that is used to compare alternatives while considering a list of specifications and constraints.</td>
</tr>
<tr>
<td>Expert</td>
<td>Someone recognized as a reliable source of knowledge, technique, or skill whose judgment is accorded authority and status by the public or their peers.</td>
</tr>
<tr>
<td>Justifiable</td>
<td>Capable of being shown as reasonable or merited according to accepted standards.</td>
</tr>
<tr>
<td>Mentor</td>
<td>An experienced person in an organization or institution who trains and counsels new employees or students.</td>
</tr>
</tbody>
</table>
Patent | A grant made by a government that gives an individual or body the sole right to make, use, and sell an invention for a set period of time.
---|---
Professional Organization | An organization of and for professional people.
Professionalism | The competence or skill expected of a professional.
Valid | Well-founded on evidence and corresponds accurately to the real world.

**Day-by-Day Plans**

*Time: 10 days*

**NOTE:** In preparation for teaching this lesson, it is strongly recommended that the teacher read the **Lesson 2.1 Teacher Notes**.

**NOTE:** You will need to provide examples of products for students to complete Activity 2.1.3 What Is the Problem? Further details can be found in the activity and Teacher Notes.

**Day 1:**

- The teacher will present **Concepts, Key Terms**, and **Essential Questions** in order to provide a lesson overview.
- The teacher will distribute and preview **Activity 2.1.1 Choosing a Topic**.
- The teacher will present **Choosing a Topic.ppt**.
- Students will take notes during the presentation.
- Students will begin considering possible topics in preparation for the next class session.
- **Optional:** The teacher may wish to assign **Key Terms 2.1 Crossword Puzzle** after all key terms have been introduced.

**Day 2:**

- The teacher will assign Activity 2.1.1 Choosing a Topic and distribute and explain **Brainstorming Help, Effective Research, EDD Resources**, and **Citations APA Style** to aid students in choosing topics.
- Students will complete Activity 2.1.1 Choosing a Topic before the next class.

**Days 3-4:**

- The teacher will check Activity 2.1.1 Choosing a Topic conclusion questions for completion and lead a class discussion using those questions to assess student understanding.
- The teacher will distribute, explain, and assign **Activity 2.1.2 Forming Teams**.
Students will complete Activity 2.1.2 Forming Teams.

Day 5:
- The teacher will check Activity 2.1.2 Forming Teams conclusion questions for completion and lead a class discussion using those questions to assess student understanding.
- The teacher will present Writing a Problem Statement.ppt.
- Students will take notes during the presentation.
- The teacher will distribute, explain, and assign Activity 2.1.3 What Is the Problem?, Problem Statement Evaluation, and Problem Statement Rubric.
- Students will complete Activity 2.1.3 What Is the Problem? before the next class session.

Days 6-10:
- The teacher will check Activity 2.1.3 What Is the Problem? conclusion questions for completion and lead a class discussion using the questions to assess student understanding.
- The teacher will distribute, explain, and assign Project 2.1.4 Choosing a Problem, Problem Statement Evaluation, Problem Statement Rubric, Working with Mentors and Experts, and the electronic versions of Research Summary Sheet, Patent Summary Sheet, Problem Statement Matrix, and Correspondence Log.

Instructional Resources

Presentations
- Choosing a Topic
- Writing a Problem Statement

Word Documents
- Activity 2.1.1 Choosing a Topic
- Activity 2.1.2 Forming Teams
- Activity 2.1.3 What Is the Problem?
- Project 2.1.4 Choosing a Problem
- Brainstorming Help
- Effective Research
- EDD Resources
- Citations APA Style
- Problem Statement Evaluation
- Research Summary Sheet
- Patent Summary Sheet
- Problem Statement Matrix
- Working with Experts and Mentors
- Correspondence Log
Lesson 2.1 Key Terms Crossword Puzzle
Answer Keys and Rubrics

Problem Statement Rubric
Lesson 1.2 Key Terms Crossword Answer Key
Teacher Guidelines

Teacher Notes

Reference Sources

Lesson 2.2 Justify the Problem

Preface

In the previous lesson, each student group should have selected a valid problem on which to base their project work in EDD. Once sufficient validation of the problem is obtained, the students should move on to the next step, justification. This lesson will guide student groups through a process of justifying their problems wherein students will gather evidence to support pursuit of a solution to their problem.

In EDD, evidence that a problem is justified will be gathered via market research and analysis. By the end of the lesson, teams should be able to produce a project proposal that addresses a valid problem that is not overly constrained by a lack of necessary resources and that is justified by market research and analysis. The proposal will include a project schedule (Gantt chart) that clearly identifies the scope of the work to be completed.

The essential point in justifying the problem statement is to reinforce the academic validity of the entire project. It is not acceptable to work on a whimsical problem. The students must use external validation to prove that the problem they choose to work on is significant. Perspective is important. While this is an important component of justification, it should not consume the majority of the time available. In reality, searching the literature for validation should take only two or three days. A survey should take no longer than 10 days, most of which is time waiting for replies from survey recipients.

If insufficient justification is found, the students should seek a new problem.

Concepts

1. Market research aids business and industry in making better decisions about the development and marketing of new products.
2. Effective market research focuses on potential users and buyers to gauge whether a problem is worth the investment required for it to be solved.
3. Most innovations and inventions require time and capital that are not available to individuals, so it is necessary to communicate the need and available market to an entity that can provide the necessary resources.
4. Engineers utilize math and science principles, concepts, and laws to solve problems.
Standards and Benchmarks Addressed

Standards for Technological Literacy

Standard 1:  Students will develop an understanding of the characteristics and scope of technology.
BM L: Inventions and innovations are the results of specific, goal-directed research.

BM M: Most development of technologies these days is driven by the profit motive and the market.

Standard 3:  Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.
BM I: Technological ideas are sometimes protected through the process of patenting. The protection of a creative idea is central to the sharing of technological knowledge.

BM J: Technological progress promotes the advancement of science and mathematics. Likewise, progress in science and mathematics leads to advances in technology.

Standard 6:  Students will develop an understanding of the role of society in the development and use of technology.
BM I: The decision whether to develop a technology is influenced by societal opinions and demands, in addition to corporate cultures.

BM J: A number of different factors, such as advertising, the strength of the economy, the goals of a company and the latest fads contribute to shaping the design of and demand for various technologies.

Standard 8:  Students will develop an understanding of the attributes of design.
BM H: The design process includes defining a problem, brainstorming, researching and generating ideas, identifying criteria and specifying constraints, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype, testing and evaluating the design using specifications, refining the design, creating or making it, and communicating processes and results.

Standard 9:  Students will develop an understanding of engineering design.
BM I: Established design principles are used to evaluate existing designs, to collect data, and to guide the design process.

Standard 10:  Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.
BM I: Research and development is a specific problem-solving approach that is used intensively in business and industry to prepare devices and systems for the marketplace.

BM J: Technological problems must be researched before they can be solved.

Standard 11: Students will develop abilities to apply the design process.
BM M: Identify the design problem to solve and decide whether or not to address it.

Standard 12: Students will develop the abilities to use and maintain technological products and systems.
BM L: Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

BM P: Use computers and calculators to access, retrieve, organize and process, maintain, interpret, and evaluate data and information in order to communicate.

Standard 17: Students will develop an understanding of and be able to select and use information and communication technologies.
BM P: There are many ways to communicate information, such as graphic and electronic means.

National Science Education Standards

Science As Inquiry Standard A: As a result of activities in grades 9-12, all students should develop

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Science and Technology Standard E: As a result of activities in grades 9-12, all students should develop

- Abilities of technological design
- Understandings about science and technology

Principles and Standards for School Mathematics

Data Analysis and Probability
Instructional programs from pre-kindergarten through grade 12 should enable all students to formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them; select and use appropriate statistical methods to analyze data; develop and evaluate inferences and predictions that are based on
Problem Solving  
Instructional programs from pre-kindergarten through grade 12 should enable all students to build new mathematical knowledge through problem solving; solve problems that arise in mathematics and in other contexts; apply and adapt a variety of appropriate strategies to solve problems; monitor and reflect on the process of mathematical problem solving.

Connections  
Instructional programs from pre-kindergarten through grade 12 should enable all students to recognize and use connections among mathematical ideas; understand how mathematical ideas interconnect and build on one another to produce a coherent whole; recognize and apply mathematics in contexts outside of mathematics.

Standards for English Language Arts

Standard 5  
Students employ a wide range of strategies as they write and use different writing process elements appropriately to communicate with different audiences and for a variety of purposes.

Standard 7  
Students conduct research on issues and interests by generating ideas and questions, and by posing problems. They gather, evaluate, and synthesize data from a variety of sources (e.g. print and non-print texts, artifacts, and people) to communicate their discoveries in ways that suit their purpose and audience.

Standard 8  
Students use a variety of technological and informational resources (e.g. libraries, databases, computer networks, video) to gather and synthesize information and to create and communicate knowledge.

Performance Objectives

It is expected that students will:

- Create a Statement of Purpose using the details from their problem statement.
- Evaluate the market to determine whether solving the problem is compelling to other entities.
- Identify the target market for a potential solution to an identified problem.
Identify math and science concepts that will be or could be utilized in the process of solving an identified problem.

Create and execute a market research plan to gather data related to an identified problem.

Evaluate and communicate data collected during market research.

Create a document to summarize important information and research in order to justify moving forward with a chosen problem.

Assessment

Perspective

Students will participate in a market research opportunity to better understand a participant’s point of view before designing their own market research tool.

Essential Questions

1. Why should an individual or company be concerned with justification of the problem?
2. How is market research used to aid research and development?

Key Terms

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Available Market</td>
<td>Prospects who are willing and capable (have sufficient resources) buyers and have access to a particular market or service.</td>
</tr>
<tr>
<td>Benchmark</td>
<td>A standard or set of standards used as a point of reference for evaluating performance or level of quality.</td>
</tr>
<tr>
<td>Competition</td>
<td>Open market rivalry in which every seller tries to get what other sellers are seeking at the same time – sales, profit, and market share – by offering the best practicable combination of price, quality, and service.</td>
</tr>
<tr>
<td>Executive Summary</td>
<td>A persuasive summary that provides an overview of the purpose and contents of a report, identifies the issue or need that led to the report, and includes condensed conclusions and recommendations.</td>
</tr>
</tbody>
</table>
### Focus Group
Small number of people (typically 8) brought together with a moderator to focus on a specific product or topic. Aimed at a discussion instead of individual responses to formal questions, the process produces qualitative data (preferences and beliefs) that may or may not be representative of the general population.

### Market Research
The activity of gathering information whereby a specific market is identified and its size and other characteristics are measured.

### Market Share
Percentage of total sales volume in a market captured by a brand, product, or firm.

### Product
A good, idea, method, information, object, service, etc., that is the end result of a process and satisfies a need or want. It is usually a bundle of tangible and intangible attributes (benefits, features, functions, uses).

### Survey
Marketing: Detailed study of a market or geographical area to gather data on attitudes, impressions, opinions, satisfaction level, etc., by polling a section of the population.

### Target Market
A specific group of consumers at which a company aims its products and services.

### Day-by-Day Plans

**Time:** 12 days

**NOTE:** In preparation for teaching this lesson, it is strongly recommended that the teacher read the **Lesson 2.2 Teacher Notes.**

**Day 1:**

- The teacher will present **Concepts, Key Terms, and Essential Questions** in order to provide a lesson overview.
- The teacher will distribute and introduce **Project 2.2.4 Project Proposal** and **Project 2.2.4 Problem Proposal Rubric** to students to preview what they are working toward in this lesson.
- The teacher will present **Problem Statement to Statement of Purpose.ppt**.
- Students will take notes during the presentation.
- The teacher will distribute, explain, and assign **Activity 2.2.1 Problem Statement to Statement of Purpose** and **Activity 2.2.1 Problem Statement to Statement of Purpose Rubric**.
- Student teams will complete Activity 2.2.1 Problem Statement to Statement of Purpose before the next class.
- **Optional:** The teacher may wish to assign **Lesson 2.2 Key Terms Crossword** after all key terms have been introduced.
Days 3-4:

- The teacher will check Activity 2.2.1 Problem Statement to Statement of Purpose conclusion questions for completion and lead a class discussion using those questions to assess student understanding.
- The teacher will evaluate each team’s Statement of the Problem to provide feedback for improvement.
- Teams will, if needed, revise their Statement of the Problem.
- The teacher will present Knowledge of the Marketplace.ppt.
- Students will take notes during the presentation.
- The teacher will distribute, explain, and assign Project 2.2.2 Knowledge of the Marketplace and Project 2.2.2 Knowledge of the Marketplace Rubric.
- Student teams will complete Project 2.2.2 Knowledge of the Marketplace before day 5.

Days 5-8:

- The teacher will check Project 2.2.2 Knowledge of the Marketplace conclusion questions for completion and lead a class discussion using those questions to assess student understanding.
- The teacher will present Conducting Market Research.ppt.
- Students will take notes during the presentation.
- The teacher will distribute, explain, and assign Project 2.2.3 Conducting Market Research and Project 2.2.3 Conducting Market Research Rubric.
- The teacher will distribute and explain Using Charts and Graphs to Explain Data to students to help best summarize and explain their market data.
- Teams will determine which forms of market research work best for the information they need. Students will create the items they need and then develop a plan to use or implement their market research tools by day 7. Their plan and materials should be approved by the instructor before implementation.
- NOTE: Teams may not be able to implement their market research strategies for Project 2.2.3 Conducting Market Research immediately since they are dependent upon others. It is important, though, that they have completed their market research before submitting their project proposals.

Days 9-12:

- The teacher will check Project 2.2.3 Conducting Market Research conclusion questions for completion and assess each team’s market research plan using Project 2.2.3 Conducting Market Research Rubric. The teacher will lead a class discussion using the conclusion questions to assess student understanding.
- Teams will complete Project 2.2.4 Problem Proposal by the end of day 9.
- The teacher will check Project 2.2.4 Problem Proposal conclusion questions for completion and lead a class discussion using those questions to assess student understanding.
Instructional Resources

Presentations

Problem Statement to Statement of Purpose
Knowledge of the Marketplace
Conducting Market Research

Word Documents

Activity 2.2.1 Problem Statement to Statement of Purpose
Project 2.2.2 Knowledge of the Marketplace
Project 2.2.3 Conducting Market Research
Project 2.2.4 Project Proposal

Using Charts and Graphs to Explain Data

Lesson 2.2 Key Terms Crossword Puzzle

Answer Keys and Rubrics

Activity 2.2.1 Problem Statement to Statement of Purpose Rubric
Project 2.2.2 Knowledge of the Marketplace Rubric
Project 2.2.3 Conducting Market Research Rubric
Project 2.2.4 Project Proposal Rubric
Lesson 2.2 Key Terms Crossword Answer Key

Teacher Guidelines

Teacher Notes

Reference Sources


Lesson 3.1 Select a Solution Path

Preface

The importance of detailed specifications cannot be overemphasized. Well-written specifications ensure that the product or service developed is the one that was anticipated. Accurate specifications are necessary to maintain the desired consistency, quantity, quality, performance, and appearance of products that are to be delivered.

Designers are not always able to include everything they want in their design solutions. Multiple factors must be considered and trade-offs accepted during the design process.

Students will begin this lesson by creating a design specification that describes their design solution criteria and the constraints that will be imposed on the design solution. Students will devise at least five possible solutions to compare and evaluate using the design specification that they create in order to reduce the number of potential solutions considered. Next, teams will obtain feedback from potential consumers, stakeholders, and experts regarding the design options. Finally, based on the results of the evaluation, students will narrow their design solution options to a single best option that will be developed in subsequent lessons. They will also provide justification for their selection.

Concepts

1. Specifications for a design solution provide clear parameters for a successful design solution.
2. Engineers use a decision matrix to compare preliminary design solutions by assessing each alternate design based on the design requirements specified.
3. A design should be continually checked and critiqued by experts and stakeholders in order to guide the design process and ensure a successful solution.
4. The use of optimization improves the final design solution by aligning the solution with the specifications imposed.

Standards and Benchmarks Addressed

Standards for Technological Literacy

**Standard 1:** Students will develop an understanding of the characteristics and scope of technology.

**BM J:** The nature and development of technological knowledge and processes are functions of the setting.

**BM L:** Inventions and innovations are the results of specific, goal-directed research.

**BM M:** Most development of technologies these days is driven by the profit
motive and the market.

**Standard 2:** **Students will develop an understanding of the core concepts of technology.**

**BM W:** Systems’ thinking applies logic and creativity with appropriate compromises in complex real-life problems.

**BM Z:** Selecting resources involves trade-offs between competing values, such as availability, cost, desirability, and waste.

**BM AA:** Requirements involve the identification of the criteria and constraints of a product or system and the determination of how they affect the final design and development.

**BM BB:** Optimization is an ongoing process or methodology of designing or making a product and is dependent on criteria and constraints.

**BM DD:** Quality control is a planned process to ensure that a product, service, or system meets established criteria.

**Standard 4:** **Students will develop an understanding of the cultural, social, economic, and political effects of technology.**

**BM I:** Making decisions about the use of technology involves weighing the trade-offs between the positive and negative effects.

**BM J:** Ethical considerations are important in the development, selection, and use of technologies.

**Standard 5:** **Students will develop an understanding of the effects of technology on the environment.**

**BM H:** When new technologies are developed to reduce the use of resources, considerations of trade-offs are important.

**BM J:** The alignment of technological processes with natural processes maximizes performance and reduces negative impacts on the environment.

**BM L:** Decisions regarding the implementation of technologies involve the weighing of tradeoffs between predicted positive and negative effects on the environment.

**Standard 6:** **Students will develop an understanding of the role of society in the development and use of technology.**

**BM J:** A number of different factors, such as advertising, the strength of the economy, the goals of a company and the latest fads contribute to shaping the design of and demand for various technologies.

**Standard 8:** **Students will develop an understanding of the attributes of design.**

**BM H:** The design process includes defining a problem, brainstorming, researching and generating ideas, identifying criteria and specifying
constraints, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype, testing and evaluating the design using specifications, refining the design, creating or making it, and communicating processes and results.

**BM J:** The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.

**BM K:** Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other.

**Standard 9:** **Students will develop an understanding of engineering design.**

**BM I:** Established design principles are used to evaluate existing designs, to collect data, and to guide the design process.

**BM J:** Engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.

**BM L:** The process of engineering design takes into account a number of factors.

**Standard 10:** **Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.**

**BM I:** Research and development is a specific problem-solving approach that is used intensively in business and industry to prepare devices and systems for the marketplace.

**BM J:** Technological problems must be researched before they can be solved.

**BM K:** Not all problems are technological, and not every problem can be solved using technology.

**BM L:** Many technological problems require a multidisciplinary approach.

**Standard 11:** **Students will develop abilities to apply the design process.**

**BM N:** Identify criteria and constraints and determine how these will affect the design process.

**BM O:** Refine a design by using prototypes and modeling to ensure quality, efficiency, and productivity of the final product.

**BM P:** Evaluate the design solution using conceptual, physical, and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed.
**BM Q:** Develop and produce a product or system using a design process.

**BM R:** Evaluate final solutions and communicate observation, processes, and results of the entire design process, using verbal, graphic, quantitative, virtual, and written means, in addition to three-dimensional models.

**Standard 12:** Students will develop the abilities to use and maintain technological products and systems.

- **BM L:** Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.
- **BM N:** Troubleshoot, analyze, and maintain systems to ensure safe and proper function and precision.
- **BM P:** Use computers and calculators to access, retrieve, organize and process, maintain, interpret, and evaluate data and information in order to communicate.

**Standard 13:** Students will develop the abilities to assess the impacts of products and systems.

- **BM J:** Collect information and evaluate its quality.

**Standard 17:** Students will develop an understanding of and be able to select and use information and communication technologies.

- **BM P:** There are many ways to communicate information, such as graphic and electronic means.
- **BM Q:** Technological knowledge and processes are communicated using symbols, measurement, conventions, icons, graphic images, and languages that incorporate a variety of visual, auditory, and tactile stimuli.

**Standard 19:** Students will develop an understanding of and be able to select and use manufacturing technologies.

- **BM L:** Servicing keeps products in good operating condition.
- **BM M:** Materials have different qualities and may be classified as natural, synthetic, or mixed.
- **BM N:** Durable goods are designed to operate for a long period of time, while non-durable goods are designed to operate for a short period of time.
- **BM O:** Manufacturing systems may be classified into types, such as customized production, batch production, and continuous production.
National Science Education Standards

Unifying Concepts and Processes: As a result of activities in grades K-12, all students should develop understanding and abilities aligned with the following concepts and processes.

- Systems, order, and organization
- Evidence, models, and explanation
- Change, constancy, and measurement

Science As Inquiry Standard A: As a result of activities in grades 9-12, all students should develop

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Science and Technology Standard E: As a result of activities in grades 9-12, all students should develop

- Abilities of technological design
- Understandings about science and technology

Science in Personal and Social Perspectives Standard F: As a result of activities in grades 9-12, all students should develop understanding of

- Environmental quality
- Natural and human-induced hazards

History and Nature of Science Standard G: As a result of activities in grades 9-12, all students should develop understanding of

- Science as a human endeavor

Principles and Standards for School Mathematics

Communication Instructional programs from pre-kindergarten through grade 12 should enable all students to organize and consolidate their mathematical thinking through communication; communicate their mathematical thinking coherently and clearly to peers, teachers, and others; analyze and evaluate the mathematical thinking and strategies of others; use the language of mathematics to express mathematical ideas precisely.
Standards for English Language Arts

Standard 4  Students adjust their use of spoken, written, and visual language (e.g. conventions, style, vocabulary) to communicate effectively with a variety of audiences and for different purposes.

Standard 5  Students employ a wide range of strategies as they write and use different writing process elements appropriately to communicate with different audiences and for a variety of purposes.

Standard 7  Students conduct research on issues and interests by generating ideas and questions, and by posing problems. They gather, evaluate, and synthesize data from a variety of sources (e.g. print and non-print texts, artifacts, and people) to communicate their discoveries in ways that suit their purpose and audience.

Standard 8  Students use a variety of technological and informational resources (e.g. libraries, databases, computer networks, video) to gather and synthesize information and to create and communicate knowledge.

Performance Objectives

It is expected that students will:

- Identify and describe specific criteria for and constraints to the design of a product.
- Write a clear, complete, and concise design specification.
- Generate and document multiple potential solutions to a problem.
- Develop a decision matrix to compare and rank potential solutions.
- Distinguish between practical and potentially successful design solutions and solutions that are not practical or potentially successful.
- Combine, refine, and optimize conceptual ideas to effectively solve a problem.
- Communicate design concepts using visual and written documentation.
- Evaluate other teams’ conceptual solutions and make recommendations.
- Evaluate feedback from reviewers and modify design concepts as appropriate.
- Collaborate with teammates to select a solution path to pursue.
Assessment

Explanation

☐ The students will document the project’s progress in their engineering notebooks.
☐ The students will create a product specification that clearly defines their problem statement.
☐ The students will record their best design solution and justify the reasons for its selection.

Application

☐ The students will objectively evaluate proposed design solutions using specific criteria and constraints.
☐ The students will use a decision matrix to select the best available design solution.

Perspective

☐ The students will consider the needs of the consumer in the design of a product.

Essential Questions

1. Why would an engineer need to identify the criteria and constraints required for a design solution?
2. How is a decision making matrix used to select the best solution path?
3. How would you explain the following statement? Finding a good solution is an iterative process.
4. Why is it important to take the time to thoroughly explore many potential solutions before selecting a solution path?
5. What benefit does optimization provide at this point in the design process?

Key Terms

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concept</td>
<td>A general idea, thought, or understanding.</td>
</tr>
<tr>
<td>Conceptual</td>
<td>Of, or relating to, concepts or mental conception.</td>
</tr>
<tr>
<td>Constraint</td>
<td>A limitation or restriction.</td>
</tr>
<tr>
<td>Consumer</td>
<td>One who uses commodities.</td>
</tr>
<tr>
<td>Criteria</td>
<td>A means of judging. A standard, rule, or test by which something can be judged.</td>
</tr>
<tr>
<td><strong>Decision Matrix</strong></td>
<td>A table used to compare design options by rating the options based on design criteria or specifications.</td>
</tr>
<tr>
<td>---------------------</td>
<td>--------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Ergonomics</strong></td>
<td>The study of the problems of people in adjusting to their environment; esp., the science that seeks to adapt work or working conditions to the worker.</td>
</tr>
<tr>
<td><strong>Feasible</strong></td>
<td>Capable of being done, performed, executed, or affected; practicable.</td>
</tr>
<tr>
<td><strong>Iterative Process</strong></td>
<td>A process for arriving at a decision or a desired result by repeating rounds of analysis or a cycle of operations.</td>
</tr>
<tr>
<td><strong>Optimization</strong></td>
<td>The process of fine-tuning data, software, processes, or designs to increase efficiency, improve performance, and produce the best possible results.</td>
</tr>
<tr>
<td><strong>Parameter</strong></td>
<td>A fact or circumstance that restricts how something is done or what can be done.</td>
</tr>
<tr>
<td><strong>Preliminary</strong></td>
<td>Coming before or leading up to the main matter, action, or business; preparatory.</td>
</tr>
<tr>
<td><strong>Product Life</strong></td>
<td>Period over which a product progresses from its introduction to its withdrawal from the market.</td>
</tr>
<tr>
<td><strong>Service Life</strong></td>
<td>Period over which an asset (machine, property, computer system, etc.) is expected to be usable, with normal repairs and maintenance, for the purpose for which it was acquired.</td>
</tr>
<tr>
<td><strong>Specification</strong></td>
<td>A detailed, exact statement of particulars, especially a statement prescribing materials, dimensions, and quality of work for something to be built, installed, or manufactured.</td>
</tr>
</tbody>
</table>

**Day-by-Day Plans**

*Time: 16 days*

**NOTE:** In preparation for teaching this lesson, it is strongly recommended that the teacher read the **Lesson 3.1 Teacher Notes**.

**Day 1-2:**

- The teacher will present **Concepts, Key Terms**, and **Essential Questions** in order to provide a lesson overview.
- The teacher will present **Design Specifications.ppt**.
- Students will take notes in their journals during the presentation.
- The teacher will distribute and introduce **Project 3.1.1 Design Specification** and **Project 3.1.1 Design Specification Rubric**.
Students will complete Project 3.1.1 Design Specification before the next class session.

Optional: The teacher may wish to assign Lesson 3.1 Key Terms Crossword after all key terms have been introduced.

Day 3:

The teacher will assess Project 3.1.1 Design Specifications using Activity 3.1.1 Design Specification Rubric.

The teacher will present Brainstorming Solutions.ppt.

Students will take notes in their journals during the presentation.

The teacher will lead a short discussion to facilitate student reflection upon the various methods of brainstorming. Students should reveal how the ideas in the presentation might impact their thinking and strategies as they begin to generate solutions to their EDD problem.

Students will meet in teams to brainstorm and generate many possible solution concepts.

Day 4-7:

The teacher will meet with each group to review each team’s brainstorming documentation. The teacher will check for quantity of ideas and satisfactory documentation of the process. The teacher may guide students in additional brainstorming, if necessary.

The teacher will present Concept Development.ppt.

Students will take notes in their journals during the presentation.

The teacher will distribute and introduce Activity 3.1.2 Concept Development, Product Concept Template, and Activity 3.1.2 Concept Development Rubric.

Teams will complete Activity 3.1.2 Concept Development.

The teacher will check Activity 3.1.2 Concept Development using Activity 3.1.2 Concept Development Rubric and check conclusion questions for completion.

Day 8-9:

The teacher will lead the students in a discussion of alternate methods to select a solution (perhaps including personal preference, external decision, intuition, surveys, design team voting, listing pros and cons, and a decision matrix).

The teacher will present Selecting a Solution Path.ppt.

Students will take notes in their journals during the presentation.

The teacher will distribute and introduce Project 3.1.3 Best Solution, Project 3.1.3 Best Solution Rubric, and Decision Matrix Template.

Students will work on Project 3.1.3 Best Solution to narrow the number of possible solutions.

Day 10-12:

The teacher will lead the students in a discussion of the importance of soliciting input from potential consumers and other stakeholders during the design process.
The teacher will distribute and introduce Project 3.1.4 Concept Testing, Project 3.1.4 Concept Testing Rubric, and Example Concept Test Survey.

Students will complete Project 3.1.4 Concept Testing.

The students will participate in a poster session during which they will present their problem and design concepts for peer review and/or to an engineering panel.

The teacher will assess students using Project 3.1.4 Concept Testing Rubric.

**Day 13-16:**

Students will complete Project 3.1.3 Best Solution.

The teacher will check Project 3.1.3 Best Solution conclusion questions for completion and lead a class discussion using those questions to assess student understanding.

The teacher will assess students using Project 3.1.3 Best Solution Rubric.

**Instructional Resources**

**Presentations**
- Design Specifications
- Brainstorming Solutions
- Concept Development
- Selecting a Solution Path

**Word Documents**
- Project 3.1.1 Design Specifications
- Activity 3.1.2 Concept Development
- Project 3.1.3 Best Solution
- Project 3.1.4 Concept Testing
- Product Concept Template
- Example Concept Test Survey
- Lesson 3.1 Key Terms Crossword

**Spreadsheets**
- Decision Matrix Template

**Answer Keys and Rubrics**
- Project 3.1.1 Design Specification Rubric
- Activity 3.1.2 Concept Development Rubric
- Project 3.1.3 Best Solution Rubric
- Project 3.1.4 Concept Testing Rubric
- Lesson 3.1 Key Terms Crossword Answer Key

**Teacher Guidelines**
- Teacher Notes
Reference Sources


National Council of Teachers of English (NCTE) and International Reading Association (IRA) (1996). *Standards for the English language arts*. Newark, DE: IRA; Urbana, IL: NCTE.


Lesson 3.2 Develop a Design Proposal

Preface

Once student teams have identified their solution path, the process of developing the selected concept into a workable solution begins. The final goal of this lesson is to develop and document the product design in detail so that, in following lessons, a prototype can be built and tested. In many cases designers are expected or required to present their design to other interested parties (e.g., potential investors or research and development teams within companies that will decide whether development of a product will continue, etc.).

In this lesson student teams will consider many factors that affect the success of a product (such as function, aesthetics, ergonomics, etc.) in order to refine and improve their product design. They will also consider the ethical implications of product design and the consequence, good and bad, that their product or the potential failure of their product may have on people, the environment, and society. Based on this ethical analysis, students must decide whether the benefits of their product outweigh the risks and if further development of the product is the right course of action.

If further development of the product is justified, students will begin to develop a business plan in order to document information about the industry in which their product will compete and detail strategies to make their product successful in that industry. Most successful companies and entrepreneurs develop a business plan in order to set goals, to guide operations toward reaching those goals, and to assess the level of achievement of those goals. In many cases potential investors also require a business plan as a means to determine the potential success of an endeavor.

At this point in the design process, students will create a design proposal that will provide detailed documentation of their proposed product design and information gathered for their business plan to provide justification for further development of their product. In some cases the research may show that the product cannot successfully compete in the market, forcing students to return to previous steps in the design process to modify the problem, their concept selection, or details of their design. Based on the design proposal, the teacher (and review panels, if applicable) will decide whether students have performed adequate research, provided sufficient documentation, and adequately justified further development of their product.

Concepts

1. Multiple factors affect the commercial success of a consumer product.
2. Drawings and sketches are used to organize, record, and communicate ideas.
3. Engineers use working drawings to show all of the information needed to make a part, subassembly, or a complete design solution.
4. Engineers use a peer review process to review and evaluate design solutions to provide feedback and implement necessary revisions.
5. Engineers and designers have ethical responsibilities to clients, peers, their profession, and the general public.

6. Product development will result in consequences, both good and bad, that must be considered when deciding whether or not to develop a product.

7. A business plan formalizes the goals of a company and provides a plan for reaching those goals that can be used to both guide the company’s policies and strategies and to solicit outside support and financing.

Standards and Benchmarks Addressed

Standards for Technological Literacy

Standard 1: Students will develop an understanding of the characteristics and scope of technology.
BM L: Inventions and innovations are the results of specific, goal-directed research.

BM M: Most development of technologies these days is driven by the profit motive and the market.

Standard 2: Students will develop an understanding of the core concepts of technology.
BM Z: Selecting resources involves trade-offs between competing values, such as availability, cost, desirability, and waste.

BM AA: Requirements involve the identification of the criteria and constraints of a product or system and the determination of how they affect the final design and development.

BM BB: Optimization is an ongoing process or methodology of designing or making a product and is dependent on criteria and constraints.

BM DD: Quality control is a planned process to ensure that a product, service, or system meets established criteria.

Standard 4: Students will develop an understanding of the cultural, social, economic, and political effects of technology.
BM I: Making decisions about the use of technology involves weighing the trade-offs between the positive and negative effects.

BM J: Ethical considerations are important in the development, selection, and use of technologies.

BM K: The transfer of a technology from one society to another can cause cultural, social, economic, and political changes affecting both societies to varying degrees.

Standard 5: Students will develop an understanding of the effects of technology on the environment.
BM H: When new technologies are developed to reduce the use of resources, considerations of trade-offs are important.
BM J: The alignment of technological processes with natural processes maximizes performance and reduces negative impacts on the environment.

BM L: Decisions regarding the implementation of technologies involve the weighing of tradeoffs between predicted positive and negative effects on the environment.

Standard 6: Students will develop an understanding of the role of society in the development and use of technology.
BM I: The decision whether to develop a technology is influenced by societal opinions and demands, in addition to corporate cultures.

BM J: A number of different factors, such as advertising, the strength of the economy, the goals of a company and the latest fads contribute to shaping the design of and demand for various technologies.

Standard 8: Students will develop an understanding of the attributes of design.
BM H: The design process includes defining a problem, brainstorming, researching and generating ideas, identifying criteria and specifying constraints, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype, testing and evaluating the design using specifications, refining the design, creating or making it, and communicating processes and results.

BM J: The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.

BM K: Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other.

Standard 9: Students will develop an understanding of engineering design.
BM I: Established design principles are used to evaluate existing designs, to collect data, and to guide the design process.

BM L: The process of engineering design takes into account a number of factors.

Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.
BM I: Research and development is a specific problem-solving approach that is used intensively in business and industry to prepare devices and systems for the marketplace.

BM J: Technological problems must be researched before they can be solved.
Standard 11: Students will develop abilities to apply the design process.
BM N: Identify criteria and constraints and determine how these will affect
the design process.
BM P: Evaluate the design solution using conceptual, physical, and
mathematical models at various intervals of the design process in
order to check for proper design and to note areas where
improvements are needed.
BM Q: Develop and produce a product or system using a design process.

Standard 12: Students will develop the abilities to use and maintain
technological products and systems.
BM L: Document processes and procedures and communicate them to
different audiences using appropriate oral and written techniques.
BM P: Use computers and calculators to access, retrieve, organize and
process, maintain, interpret, and evaluate data and information in
order to communicate.

Standard 13: Students will develop the abilities to assess the impacts of
products and systems.
BM J: Collect information and evaluate its quality.
BM K: Synthesize data, analyze trends, and draw conclusions regarding the
effect of technology on the individual, society, and environment.

Standard 17: Students will develop an understanding of and be able to
select and use information and communication technologies.
BM P: There are many ways to communicate information, such as graphic
and electronic means.

National Science Education Standards

Unifying Concepts and Processes: As a result of activities in grades K-12, all
students should develop understanding and abilities aligned with the following
concepts and processes.
☐ Systems, order, and organization
☐ Evidence, models, and explanation
☐ Change, constancy, and measurement

Science and Technology Standard E: As a result of activities in grades 9-12, all
students should develop
☐ Abilities of technological design
☐ Understandings about science and technology
Science in Personal and Social Perspectives Standard F: As a result of activities in grades 9-12, all students should develop understanding of

- Environmental quality
- Natural and human-induced hazards

Principles and Standards for School Mathematics

Connections
Instructional programs from pre-kindergarten through grade 12 should enable all students to recognize and use connections among mathematical ideas; understand how mathematical ideas interconnect and build on one another to produce a coherent whole; recognize and apply mathematics in contexts outside of mathematics.

Standards for English Language Arts

Standard 4
Students adjust their use of spoken, written, and visual language (e.g. conventions, style, vocabulary) to communicate effectively with a variety of audiences and for different purposes.

Standard 5
Students employ a wide range of strategies as they write and use different writing process elements appropriately to communicate with different audiences and for a variety of purposes.

Standard 7
Students conduct research on issues and interests by generating ideas and questions, and by posing problems. They gather, evaluate, and synthesize data from a variety of sources (e.g. print and non-print texts, artifacts, and people) to communicate their discoveries in ways that suit their purpose and audience.

Standard 8
Students use a variety of technological and informational resources (e.g. libraries, databases, computer networks, video) to gather and synthesize information and to create and communicate knowledge.

Performance Objectives

It is expected that students will:

- Assess their product design based on a variety of design factors and implement design changes to improve their product.
- Create a set of working drawings to document their proposed product design.
Perform a peer design review to evaluate their product design in an effort to identify and correct potential mistakes and flaws in their design.

Perform a cost estimate to build a prototype of their proposed product.

Compare the positive and negative consequences of their product design to determine the ethical implications of product development.

Perform competitive product analyses of products that will compete with their proposed product.

Communicate professionally with experts and mentors to obtain feedback on the technical feasibility of their product design, document the interactions, and implement recommended changes to their product design.

Create a document to present their proposed design and provide justification for further development of a product.

**Assessment**

**Explanation**

The student will justify recommended changes made to a product design.

**Application**

Students will gather information regarding the pros and cons of a product’s development in order to determine whether or not to pursue further development of a product.

**Perspective**

Students will analyze a product to improve its ease of use for the consumer.

**Empathy**

Students will consider the consequences of the development of a product throughout its lifecycle to the designers, to the employees of the manufacturer, distributor, seller, to the consumer, and to the general public.

**Essential Questions**

1. What factors can affect the success of a commercial product?
2. What advantage does the use of technical drawings have over verbal communication when explaining a design solution?
3. What is a designer’s ethical responsibility to the client, peers, the profession, and to the general public?
4. Why is it important to consult technical experts when designing a consumer product?
5. How is competitive product analysis used to aid in the research and development of a new product?
6. What is the purpose of a business plan?

**Key Terms**

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analysis</td>
<td>A systematic examination of a problem or complex entity in order to provide new information from what is already known.</td>
</tr>
</tbody>
</table>
### Business Plan
A formal statement that summarizes the goals, strategies, and actions that a company anticipates taking to ensure survival and growth of the business.

### Ethics
The system or code of morals of a particular person, religion, group, profession, etc.

### Moral
Good or right in conduct or character.

### Peer Review
Evaluation of scientific, academic, or professional work by others working in the same field.

### Quality Control
An aggregate of activities (as design analysis and inspection for defects) designed to ensure adequate quality, especially in manufactured products.

### Sustainable
Characterized by a practice that sustains a given condition without destroying or depleting natural resources, polluting the environment, etc.

### Working Drawings
Drawings that convey all of the information needed to manufacture and assemble a product.

### Day-by-Day Plans

**Time: 22 days**

**NOTE:** In preparation for teaching this lesson, it is strongly recommended that the teacher read the Lesson 3.2 Teacher Notes.

#### Days 1-7:

- The teacher will present Concepts, Key Terms, and Essential Questions in order to provide a lesson overview.
- The teacher will distribute and introduce Project 3.2.4 Design Proposal and Project 3.2.4 Design Proposal Rubric to students to preview what they are working toward in this lesson.
- The teacher will lead a discussion on the iterative nature of product design and development and how a design is continually improved throughout the design process.
- The teacher will distribute and discuss Activity 3.2.1 Product Improvement and Documentation and assist students with copying documents as necessary.
- Students will complete Activity 3.2.1 Product Improvement and Documentation.
- **Optional:** The teacher may wish to assign Lesson 3.2 Key Term Crossword after all key terms have been introduced.
Days 8-10:
- The teacher will check Activity 3.2.1 Product Improvement and Documentation for completion.
- The teacher will present Design Ethics.ppt.
- Students will take notes in their journals during the presentation.
- The teacher will lead a discussion on the importance of ethics in product design.
- The teacher will distribute and discuss Activity 3.2.2 Consequences of the Solution.
- Students will complete Activity 3.2.2 Consequences of the Solution before the next class session.

Days 11-16:
- The teacher will check Activity 3.2.2 Consequences of the Solution for completion.
- The teacher will present The Business Plan.ppt.
- The teacher will lead a discussion on the importance of business planning to the success of a business and how it applies to their product development.
- Students will take notes in their journals during the presentation.
- The teacher will distribute and introduce Activity 3.2.3 Beginning the Business Plan.
- Students will complete Activity 3.2.3 Beginning the Business Plan prior to the next class session.

Days 17-21:
- The teacher will check Activity 3.2.3 Beginning the Business Plan for completion.
- If not already done, the teacher will distribute and introduce Project 3.2.4 Design Proposal and Project 3.2.4 Design Proposal Rubric.
- Students will work on Project 3.2.4 Design Proposal.

Day 22:
- Student teams will present their elevator pitch from Project 3.2.4 Design Proposal.
- The teacher will assess Project 3.2.4 Design Proposal using Project 3.2.4 Design Proposal Rubric.

Instructional Resources
- Presentations
  - Design Ethics
  - The Business Plan
- Word Documents
  - Activity 3.2.1 Product Improvement and Design Documentation
  - Activity 3.2.2 Consequences of the Solution
  - Activity 3.2.3 Beginning the Business Plan
Project 3.2.4 Design Proposal
Lesson 3.2 Key Terms Crossword

Answer Keys and Rubrics
Project 3.2.4 Design Proposal Rubric
Lesson 3.2 Key Terms Crossword Answer Key
Teacher Guidelines
Teacher Notes

Reference Sources


Lesson 4.1 Plan for the Prototype

Preface

A well-designed and well-built prototype will make testing and evaluation of the test data more realistic and valuable. Students typically view building the prototype as the most exciting step in the process and sometimes neglect or rush through the planning stage. However, a good plan will result in a better finished prototype. Because individual team members may have different ideas about how to build the prototype, teams should come to consensus on a step-by-step explanation of the assembly directions. Continued emphasis using brainstorming techniques will result in a better assembly procedure for their prototype. Well-written directions will provide better guidance for others who choose to continue research on the product and will result in more comparable prototypes if multiple models are built.

At the conclusion of this lesson, students will have a written prototype building procedure and will be ready to begin constructing their prototype.

Concepts

1. Material and equipment requirements are defined by creating a materials and cost analysis during the prototyping phase of a project.
2. Virtual solutions for designs allow engineers to plan, test, and prepare for building a prototype.
3. Designers must consider characteristics such as strength and weight of materials and fastening procedures to be sure that the final design meets design specifications.
4. Prototypes can generally be broken down into subsystems in order to isolate problems and conduct incremental testing.
5. Engineers write step-by-step instructions for the prototype assembly to guide the fabrication of the design solution.

Standards and Benchmarks Addressed

Standards for Technological Literacy

Standard 2: Students will develop an understanding of the core concepts of technology.

BM X: Systems, which are the building blocks of technology, are embedded within larger technological, social, and environmental system.
**BM Y:** The stability of a technological system is influenced by all of the components in the system, especially those in the feedback loop.

**BM Z:** Selecting resources involves trade-offs between competing values, such as availability, cost, desirability, and waste.

**BM AA:** Requirements involve the identification of the criteria and constraints of a product or system and the determination of how they affect the final design and development.

**BM DD:** Quality control is a planned process to ensure that a product, service, or system meets established criteria.

**Standard 8:** Students will develop an understanding of the attributes of design.

**BM J:** The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.

**BM K:** Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other.

**Standard 9:** Students will develop an understanding of engineering design.

**BM K:** A prototype is a working model used to test a design concept by making actual observations and necessary adjustments.

**Standard 11:** Students will develop abilities to apply the design process.

**BM O:** Refine a design by using prototypes and modeling to ensure quality, efficiency, and productivity of the final product.

**BM Q:** Develop and produce a product or system using a design process.

**Standard 12:** Students will develop the abilities to use and maintain technological products and systems.

**BM L:** Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.
**National Science Education Standards**

**Unifying Concepts and Processes:** As a result of activities in grades K-12, all students should develop understanding and abilities aligned with the following concepts and processes.
- Evidence, models, and explanation
- Form and function

**Science and Technology Standard E:** As a result of activities in grades 9-12, all students should develop
- Abilities of technological design
- Understandings about science and technology

**Principles and Standards for School Mathematics**

**Geometry**
Instructional programs from pre-kindergarten through grade 12 should enable all students to analyze characteristics and properties of two- and three-dimensional geometric shapes and develop mathematical arguments about geometric relationships; specify locations and describe spatial relationships using coordinate geometry and other representational systems; apply transformations and use symmetry to analyze mathematical situations; use visualization, spatial reasoning, and geometric modeling to solve problems.

**Measurement**
Instructional programs from pre-kindergarten through grade 12 should enable all students to understand measurable attributes of objects and the units, systems, and processes of measurement; apply appropriate techniques, tools, and formulas to determine measurements.

**Problem Solving**
Instructional programs from pre-kindergarten through grade 12 should enable all students to build new mathematical knowledge through problem solving; solve problems that arise in mathematics and in other contexts; apply and adapt a variety of appropriate strategies to solve problems; monitor and reflect on the process of mathematical problem solving.
Connections

Instructional programs from pre-kindergarten through grade 12 should enable all students to recognize and use connections among mathematical ideas; understand how mathematical ideas interconnect and build on one another to produce a coherent whole; recognize and apply mathematics in contexts outside of mathematics.

Standards for English Language Arts

Standard 4
Students adjust their use of spoken, written, and visual language (e.g. conventions, style, vocabulary) to communicate effectively with a variety of audiences and for different purposes.

Standard 8
Students use a variety of technological and informational resources (e.g. libraries, databases, computer networks, video) to gather and synthesize information and to create and communicate knowledge.

Standard 12
Students use spoken, written and visual language to accomplish their own purposes (e.g. for learning, enjoyment, persuasion, and the exchange of information).

Performance Objectives

*It is expected that students will:*

- Sketch and annotate ideas and details while designing a prototype.
- Use scientific, mathematical, and engineering concepts to design a prototype.
- Evaluate choices of materials and fastening procedures for a prototype design.
- Create virtual designs of a prototype.
- Determine and document resource needs, including a bill of materials, tools, equipment, and knowledge required to build a prototype.
- Identify subsystems of a prototype design.
- Identify opportunities to incrementally test a prototype.
- Create a step-by-step plan for building a prototype.
Assessment

Application

☐ Students conduct research outside of their instructor’s knowledge to determine the most appropriate methods for constructing their prototypes.

Perspective

☐ Students will consider the resources in their community that may be helpful to them when they create their prototype.

Essential Questions

1. What are the subsystems of products or systems that you are familiar with? Which subsystems are essential to system function and which are enhancements?
2. What are advantages of using virtual solutions before and sometimes in place of physical prototypes?

Key Terms

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fit</td>
<td>The ability of an item to physically interface or interconnect with or become an integral part of another system.</td>
</tr>
<tr>
<td>Form</td>
<td>The shape, size, mass, weight, and other visual parameters which uniquely characterize an item.</td>
</tr>
<tr>
<td>Form, Fit, and Function</td>
<td>Physical, functional, and performance characteristics or specifications that uniquely identify a component or device and determine its interchangeability in a system.</td>
</tr>
<tr>
<td>Function</td>
<td>The action or actions that an item is designed to perform.</td>
</tr>
<tr>
<td>Functioning Prototype</td>
<td>A model intended to finalize the operational elements of your invention before it goes into production.</td>
</tr>
<tr>
<td>Incremental Testing</td>
<td>Testing components or subsystems in isolation that will be integrated into a larger system.</td>
</tr>
<tr>
<td>Presentation Prototype</td>
<td>A three-dimensional representation of your invention that offers greater visual impact than a drawing.</td>
</tr>
<tr>
<td>Prototype</td>
<td>A full-scale working model used to test a design concept by making actual observations and necessary adjustments.</td>
</tr>
<tr>
<td>Subsystem</td>
<td>A division of a system that, in itself, has the characteristics of a system.</td>
</tr>
</tbody>
</table>
Test

Examination, evaluation, observation, or trial used (under actual or simulated environmental or operating conditions) to determine and document capabilities, characteristics, effectiveness, reliability, and/or suitability of a material, product, or system.

Day-by-Day Plans

Time: 15 days

NOTE: In preparation for teaching this lesson, it is strongly recommended that the teacher read the Lesson 4.1 Teacher Notes.

Day 1:
- The teacher will present Concepts, Key Terms, and Essential Questions in order to provide a lesson overview.
- The teacher will present Prototypes.ppt.
- Students will take notes in their journals during the presentation.
- Optional: The teacher may wish to assign Lesson 4.1 Key Terms Crossword after all key terms have been introduced.

Days 2-4:
- The teacher will distribute, explain, and assign Activity 4.1.1 Choosing Materials and Fastening Procedures.
- Student teams will complete Activity 4.1.1 Choosing Materials and Fastening Procedures and conclusion questions individually.

Days 5-9:
- The teacher will check Activity 4.1.1 conclusion questions and check engineering notebooks using Activity 4.1.1 Choosing Materials and Fastening Procedures Checklist then lead a class discussion to assess student understanding.
- The teacher will distribute, explain, and assign Project 4.1.2 Virtual Solutions and Project 4.1.2 Virtual Solutions Rubric.
- Student teams will complete Project 4.1.2 Virtual Solutions and conclusion questions individually.

Days 10-12:
- The teacher will check Project 4.1.2 Virtual Solutions conclusion questions for completion and assess engineering notebooks using Project 4.1.2 Virtual Solutions Rubric and then lead a class discussion to assess student understanding.
- The teacher will distribute, explain, and assign Activity 4.1.3 Resource Planning and Activity 4.1.4 Professional Correspondence.
- Student teams will complete Activity 4.1.3 Resource Planning and conclusion questions individually.
Days 13-15:

- The teacher will check Activity 4.1.3 Resource Planning conclusion questions and engineering notebooks for completion and then lead a class discussion to assess student understanding.
- (Optional) The teacher will distribute, explain, and assign Activity 4.1.5 Mock-Up (Optional).
- (Optional) Student teams will complete Activity 4.1.5 Mock-Up and conclusion questions individually.
- (Optional) The teacher will check Activity 4.1.5 Mock-Up conclusion questions and engineering notebooks for completion and then lead a class discussion to assess student understanding.
- The teacher will present Subsystems and Incremental Testing.ppt.
- Students will take notes in their journals during the presentation.
- The teacher will lead a discussion and class activity in which subsystems of a consumer product(s) are identified using examples in the presentation or actual products that can be disassembled in the classroom.
- (Optional) The teacher will distribute, explain, and assign Activity 4.1.6 Identifying Subsystems and Incremental Testing Opportunities (Optional).
- (Optional) Student teams will complete Activity 4.1.6 Identifying Subsystems and Incremental Testing Opportunities and conclusion questions individually.
- (Optional) The teacher will check Activity 4.1.6 Identifying Subsystems and Incremental Testing Opportunities conclusion questions and engineering notebooks for completion and then lead a class discussion to assess student understanding.
- The teacher will distribute, explain, and assign Activity 4.1.7 Build Procedure and the Prototype Build Procedure Template
- Student teams will complete Activity 4.1.7 Build Procedure and conclusion questions individually.
- Student teams will update their Gantt charts.

Instructional Resources

Presentations
- Subsystems and Incremental Testing
- Prototype Build Procedure Template

Word Documents
- Activity 4.1.1 Choosing Materials and Fastening Procedures
- Project 4.1.2 Virtual Solutions
- Activity 4.1.3 Resource Planning
- Activity 4.1.4 Professional Correspondence
- Project 4.1.5 Mock-Up (Optional)
Activity 4.1.6 Identifying Subsystems and Incremental Testing Opportunities (Optional)

Project 4.1.7 Build Procedure

Example Material Request Letter

Unit 4 Key Terms Crossword Puzzle

Answer Keys and Rubrics

Activity 4.1.1 Choosing Materials and Fastening Procedures Checklist

Project 4.1.2 Virtual Solutions Rubric

Unit 4 Key Terms Crossword Puzzle Answer Key

Teacher Guidelines

Teacher Notes

Reference Sources


Lesson 4.2 Build the Prototype

Preface

A well-designed and well-built prototype will make testing and the evaluation of the test data more realistic and valuable. Students typically view this lesson as the most exciting because they are actively engaged in building their prototypes. Using the agreed upon step-by-step explanation of the assembly directions will be important since all members of the team will have their own way of approaching the building of the prototype. Continued emphasis on the brainstorming technique will result in a better assembly procedure for their prototype. The modifications reinforce the importance of continued improvement across a project’s lifespan. Engineers seldom have a design solution that satisfies all criteria on the first try. Engineering change orders (ECOs) are a fact of life for design teams. Keep in mind that the materials used for the prototypes may have to be adjusted based on availability and access to the equipment necessary for the fabrication process.

At the end of this lesson, students should have a prototype that is ready for testing. Encourage the students to take the time to produce high-quality work so that they will have credible data to evaluate.

Concepts

1. Prototyping provides the engineer with a scaled working model of the design solution.
2. The construction of a physical model can enhance the quality, efficiency, and productivity of the final product.

Standards and Benchmarks Addressed

Standards for Technological Literacy

Standard 2: Students will develop an understanding of the core concepts of technology.
BM AA: Requirements involve the identification of the criteria and constraints of a product or system and the determination of how they affect the final design and development.

BM BB: Optimization is an ongoing process or methodology of designing or making a product and is dependent on criteria and constraints.

BM FF: Complex systems have many layers of controls and feedback loops to provide information.

Standard 8: Students will develop an understanding of the attributes of design.
BM H: The design process includes defining a problem, brainstorming, researching and generating ideas, identifying criteria and specifying constraints, exploring possibilities, selecting an approach, developing
a design proposal, making a model or prototype, testing and evaluating the design using specifications, refining the design, creating or making it, and communicating processes and results.

**BM J:** The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.

**BM K:** Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other.

**Standard 9:** **Students will develop an understanding of engineering design.**

**BM I:** Established design principles are used to evaluate existing designs, to collect data, and to guide the design process.

**BM K:** A prototype is a working model used to test a design concept by making actual observations and necessary adjustments.

**Standard 11:** **Students will develop abilities to apply the design process.**

**BM O:** Refine a design by using prototypes and modeling to ensure quality, efficiency, and productivity of the final product.

**BM P:** Evaluate the design solution using conceptual, physical, and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed.

**BM Q:** Develop and produce a product or system using a design process.

**Standard 12:** **Students will develop the abilities to use and maintain technological products and systems.**

**BM L:** Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

**BM M:** Diagnose a system that is malfunctioning and use tools, materials, machines, and knowledge to repair it.

**BM N:** Troubleshoot, analyze, and maintain systems to ensure safe and proper function and precision.

**Standard 13:** **Students will develop the abilities to assess the impacts of products and systems.**

**BM J:** Collect information and evaluate its quality.

---

**National Science Education Standards**

**Unifying Concepts and Processes:** As a result of activities in grades K-12, all students should develop understanding and abilities aligned with the following concepts and processes.

- Systems, order, and organization
- Evidence, models, and explanation
- Form and function

Science and Technology Standard E: As a result of activities in grades 9-12, all students should develop
- Abilities of technological design
- Understandings about science and technology

Principles and Standards for School Mathematics

Problem Solving
Instructional programs from pre-kindergarten through grade 12 should enable all students to build new mathematical knowledge through problem solving; solve problems that arise in mathematics and in other contexts; apply and adapt a variety of appropriate strategies to solve problems; monitor and reflect on the process of mathematical problem solving.

Connections
Instructional programs from pre-kindergarten through grade 12 should enable all students to recognize and use connections among mathematical ideas; understand how mathematical ideas interconnect and build on one another to produce a coherent whole; recognize and apply mathematics in contexts outside of mathematics.

Standards for English Language Arts

Standard 4
Students adjust their use of spoken, written, and visual language (e.g. conventions, style, vocabulary) to communicate effectively with a variety of audiences and for different purposes.

Standard 8
Students use a variety of technological and informational resources (e.g. libraries, databases, computer networks, video) to gather and synthesize information and to create and communicate knowledge.

Standard 12
Students use spoken, written and visual language to accomplish their own purposes (e.g. for learning, enjoyment, persuasion, and the exchange of information).

Performance Objectives

It is expected that students will:

- Correspond with professionals and experts to acquire the resources needed to build their prototypes.
- Build a functional prototype.
- Evaluate their prototypes to decide where changes must be made and document those changes.
Assessment

Application
- Students will analyze prior projects that have been created by former EDD students and compare how the materials listing changed in cost and availability over time.

Perspective
- Students will consider how they might improve their prototypes if they are unable to acquire the necessary resources.

Empathy
- If you owned or operated a company and an EDD student asked for your time or help, what would you expect of that student?

Essential Questions
1. How does having a highly functional prototype relate to testing?
2. Why is it important to have clear, concise directions for the assembly of a product?
3. What steps can be taken to lower the cost of your prototype?

Key Terms

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change Order</td>
<td>Documentation of a change to a design after the design has been finalized.</td>
</tr>
<tr>
<td>Fabricate</td>
<td>To make by art or skill and labor.</td>
</tr>
</tbody>
</table>

Day-by-Day Plans

Time: 50 days

NOTE: In preparation for teaching this lesson, it is strongly recommended that the teacher read the Lesson 4.2 Teacher Notes.

Days 1-50:
- The teacher will present Concepts, Key Terms, and Essential Questions in order to provide a lesson overview.
- The teacher will present Drawing Revisions.ppt.
- Students will take notes during the presentation.
- The teacher will distribute, explain, and assign Project 4.2.1 Build the Prototype and Project 4.2.1 Build the Prototype Rubric.
Student teams will create their prototypes and document the process closely in their engineering notebooks, including all change orders.

**Instructional Resources**

**Presentations**

**Drawing Revisions**

**Word Documents**

**Project 4.2.1 Build the Prototype**

**Change Orders Template**

**Answer Keys and Rubrics**

**Project 4.2.1 Build the Prototype Rubric**

**Teacher Guidelines**

**Teacher Notes**

**Reference Sources**


National Council of Teachers of English (NCTE) and International Reading Association (IRA) (1996). *Standards for the English language arts*. Newark, DE: IRA; Urbana, IL: NCTE.


Lesson 5.1 Plan the Test Phase

Preface

Why test at all? In engineering and science, a test is conducted to either prove a hypothesis or to answer a question. For instance, a tensile test can answer the question, “How much tension can this material safely withstand?” The strength of a material can only be determined by testing it under very precise and controlled circumstances. Or perhaps a skateboard deck was designed to withstand repetitive loading resulting from a 200 pound person jumping 24 in. high and landing on the deck over and over. Testing can help prove the hypothesis that the deck can safely withstand the design loads. In EDD, students will need to determine either what question they are trying to answer or how they can prove that their prototype performs as designed. Either way, it is important to identify exactly what data is needed and exactly how the test will be conducted.

Industry relies upon the American Standard Testing Methods (ASTM) and International Standards Organization (ISO) for testing procedures. Perhaps you have seen a company advertise that it is ISO 9001 certified – this means that the company has established a rigorous quality control of its materials and manufacturing processes that are internationally recognized.

If they can access the ASTM Standards, students can research testing methods. The actual documents are very expensive, so a visit to a local library may be necessary. If that is not possible, try to provide a copy of several test procedures for students to examine. Each organization has test procedures that cover most technical situations one might encounter. Many of these are extremely elaborate, costly, time consuming, and require expensive equipment operated by highly trained personnel. After showing students the national or global standard, you can allow them to use less rigorous tests. This will reinforce the importance of testing standards and industry accepted procedures but will allow more realistic testing situations in your classroom.

To yield useful results, students must first determine exactly what they are trying to discover or prove – they must define the test criteria based on the design specifications. Second, they must devise a test method that will allow them to safely gather data in a technically acceptable manner and that will demonstrate the success (or failure) of the design to meet the design specifications.
Ideally every feature of a group’s prototype should be validated by a test. Teams may perform several different tests which may be conducted at different phases of the construction process. Encourage students to keep in mind that the collected test data will be evaluated against the criteria they establish in order to determine success or failure. Whether the prototype is successful is not the point.

To define and justify the testing method, students need to demonstrate that they are using sound engineering, scientific, and mathematical principles. When applicable, tests that use parts of an ASTM or ISO procedure will generally be easier to define and justify. However, there will be conditions under which it is not reasonable or possible to follow these official procedures, or official procedures do not exist, so students will have to improvise.

At the end of this lesson, teams should be ready to execute the testing procedures that they devise for their prototype.

Concepts
1. In order to gather useful data, specific criteria for success or failure of a test must be determined before testing begins.
2. Prototype testing is a controlled procedure that is used to evaluate a specific aspect of a design solution.
3. A detailed description of the testing procedure helps to ensure that the results of the design solution testing are valid.
4. Data can be classified as either quantitative because it can be measured or qualitative because it describes a quality or categorization.

Standards and Benchmarks Addressed

Standards for Technological Literacy

Standard 1: Students will develop an understanding of the characteristics and scope of technology.

BM J: The nature and development of technological knowledge and processes are functions of the setting.

BM L: Inventions and innovations are the results of specific, goal-directed research.

Standard 2: Students will develop an understanding of the core concepts of technology.

BM Z: Selecting resources involves trade-offs between competing values, such as availability, cost, desirability, and waste.

BM AA: Requirements involve the identification of the criteria and constraints of a product or system and the determination of how they affect the
Optimization is an ongoing process or methodology of designing or making a product and is dependent on criteria and constraints.

New technologies create new processes.

**Standard 3:** Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.

Technological progress promotes the advancement of science and mathematics. Likewise, progress in science and mathematics leads to advances in technology.

**Standard 8:** Students will develop an understanding of the attributes of design.

The design process includes defining a problem, brainstorming, researching and generating ideas, identifying criteria and specifying constraints, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype, testing and evaluating the design using specifications, refining the design, creating or making it, and communicating processes and results.

The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.

**Standard 9:** Students will develop an understanding of engineering design.

Established design principles are used to evaluate existing designs, to collect data, and to guide the design process.

Engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.

A prototype is a working model used to test a design concept by making actual observations and necessary adjustments.

The process of engineering design takes into account a number of factors.

**Standard 10:** Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

Many technological problems require a multidisciplinary approach.

**Standard 11:** Students will develop abilities to apply the design process.

Refine a design by using prototypes and modeling to ensure quality, efficiency, and productivity of the final product.

Evaluate the design solution using conceptual, physical, and
mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed.

**BM Q:** Develop and produce a product or system using a design process.

**BM R:** Evaluate final solutions and communicate observation, processes, and results of the entire design process, using verbal, graphic, quantitative, virtual, and written means, in addition to three-dimensional models.

**Standard 12:** Students will develop the abilities to use and maintain technological products and systems.

- **BM L:** Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.
- **BM N:** Troubleshoot, analyze, and maintain systems to ensure safe and proper function and precision.
- **BM O:** Operate systems so that they function in the way they were designed.
- **BM P:** Use computers and calculators to access, retrieve, organize and process, maintain, interpret, and evaluate data and information in order to communicate.

**Standard 13:** Students will develop the abilities to assess the impacts of products and systems.

- **BM J:** Collect information and evaluate its quality.
- **BM K:** Synthesize data, analyze trends, and draw conclusions regarding the effect of technology on the individual, society, and environment.
- **BM L:** Use assessment techniques, such as trend analysis and experimentation to make decisions about the future development of technology.

**Standard 17:** Students will develop an understanding of and be able to select and use information and communication technologies.

- **BM Q:** Technological knowledge and processes are communicated using symbols, measurement, conventions, icons, graphic images, and languages that incorporate a variety of visual, auditory, and tactile stimuli.
National Science Education Standards

Unifying Concepts and Processes: As a result of activities in grades K-12, all students should develop understanding and abilities aligned with the following concepts and processes.

- Systems, order, and organization
- Evidence, models, and explanation
- Change, constancy, and measurement
- Form and function

Science As Inquiry Standard A: As a result of activities in grades 9-12, all students should develop

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Science and Technology Standard E: As a result of activities in grades 9-12, all students should develop

- Abilities of technological design
- Understandings about science and technology

Principles and Standards for School Mathematics

Measurement
Instructional programs from pre-kindergarten through grade 12 should enable all students to understand measurable attributes of objects and the units, systems, and processes of measurement; apply appropriate techniques, tools, and formulas to determine measurements.

Data Analysis and Probability
Instructional programs from pre-kindergarten through grade 12 should enable all students to formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them; select and use appropriate statistical methods to analyze data; develop and evaluate inferences and predictions that are based on data; understand and apply basic concepts of probability.

Problem Solving
Instructional programs from pre-kindergarten through grade 12 should enable all students to build new mathematical knowledge through problem solving; solve problems that arise in mathematics and in other contexts; apply and adapt a variety of appropriate strategies to
solve problems; monitor and reflect on the process of mathematical problem solving.

**Connections**  
Instructional programs from pre-kindergarten through grade 12 should enable all students to recognize and use connections among mathematical ideas; understand how mathematical ideas interconnect and build on one another to produce a coherent whole; recognize and apply mathematics in contexts outside of mathematics.

**Representation**  
Instructional programs from pre-kindergarten through grade 12 should enable all students to create and use representations to organize, record, and communicate mathematical ideas; select, apply, and translate among mathematical representations to solve problems; use representations to model and interpret physical, social, and mathematical phenomena.

**Standards for English Language Arts**

**Standard 5**  
Students employ a wide range of strategies as they write and use different writing process elements appropriately to communicate with different audiences and for a variety of purposes.

**Standard 8**  
Students use a variety of technological and informational resources (e.g. libraries, databases, computer networks, video) to gather and synthesize information and to create and communicate knowledge.

**Performance Objectives**

*It is expected that students will:*

- Select and describe a valid testing method that will be used to accurately evaluate the effectiveness of their design solution in solving the problem.
- Prepare a description of the testing method that will be used to validate and verify the design solution.
- Create a valid justification for the selected testing method.
- Devise a list of testing criteria that will be used to evaluate the prototype and determine the success or failure of the design solution.
- Identify, define, and implement necessary modifications to testing methods based on expert feedback and ongoing research.
- Document project progress in an engineering notebook.
Assessment

Application

Students will explain their testing criteria to a non-team member for suggestions in refinement to the prototype testing. They will take notes, record suggestions, and then determine whether any suggestions are appropriate to use.

Essential Questions

1. Why are test criteria important in test design?
2. How do you know that you have enough step-by-step detail in your test procedure?
3. What measurement practices are used to analyze your test results?
4. What is the significance of seeking input from experts or non-team members?

Key Terms

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accuracy</td>
<td>The closeness of a measurement to the actual value of the quantity being measured.</td>
</tr>
<tr>
<td>Bias</td>
<td>Inclination or prejudice in favor of a particular person, thing, or viewpoint.</td>
</tr>
<tr>
<td>Calibrate</td>
<td>To check, adjust, or determine by comparison with a standard.</td>
</tr>
<tr>
<td>Evaluation</td>
<td>The collection and processing of information and data in order to determine the significance, worth, or condition of something, usually by careful appraisal and study and to provide direction for improvements.</td>
</tr>
<tr>
<td>Integrity</td>
<td>Steadfast adherence to a strict moral or ethical code. Alternately, the state of a system where it is performing its intended functions without being degraded or impaired by changes or disruptions in its internal or external environments.</td>
</tr>
<tr>
<td>Margin of Error</td>
<td>A statistic expressing the amount of random sampling error in a survey's results. The larger the margin of error, the less confidence one should have that the poll's reported results are close to the &quot;true&quot; figures; that is, the figures for the whole population.</td>
</tr>
<tr>
<td>Qualitative</td>
<td>A description or distinction of an object or idea that is based on some quality rather than on some quantity.</td>
</tr>
<tr>
<td><strong>Qualitative Data</strong></td>
<td>Values that possess names or labels.</td>
</tr>
<tr>
<td>----------------------</td>
<td>--------------------------------------</td>
</tr>
<tr>
<td><strong>Quantitative</strong></td>
<td>A description or distinction of an object or idea that is a measurement based on some quantity or number rather than on some quality.</td>
</tr>
<tr>
<td><strong>Quantitative Data</strong></td>
<td>Values that represent a measurable quantity.</td>
</tr>
<tr>
<td><strong>Reliability</strong></td>
<td>1. A quality of a measurement indicating the degree to which the measure is consistent; that is, over repeated measurements would give the same result. 2. The probability of satisfactory operation of the product in a given environment over a specified time interval.</td>
</tr>
<tr>
<td><strong>Repeatability</strong></td>
<td>The property or quality of a test to give consistent results in repeated measurements.</td>
</tr>
<tr>
<td><strong>Test</strong></td>
<td>Examination, evaluation, observation, or trial used (under actual or simulated environmental or operating conditions) to determine and document capabilities, characteristics, effectiveness, reliability, and/or suitability of a material, product, or system.</td>
</tr>
<tr>
<td><strong>Test Criteria</strong></td>
<td>Benchmarks or standards against which test procedures and outcomes are compared. The plural of criterion is criteria.</td>
</tr>
<tr>
<td><strong>Test Procedure</strong></td>
<td>A particular method in which a product or piece of equipment is placed under every day or extreme conditions and is examined for its proper function, durability, etc.</td>
</tr>
<tr>
<td><strong>Test Reliability</strong></td>
<td>The degree to which an experiment or evaluation procedure gives consistent results each time it is employed.</td>
</tr>
<tr>
<td><strong>Test Validity</strong></td>
<td>The degree to which a test procedure measures what it was designed to measure.</td>
</tr>
</tbody>
</table>

**Day-by-Day Plans**

*Time: 5 days*

**NOTE:** In preparation for teaching this lesson, it is strongly recommended that the teacher read the Lesson 5.1 Teacher Notes.
Day 1:
- The teacher will present Concepts, Key Terms, and Essential Questions in order to provide a lesson overview.
- The teacher will present Testing Procedures.ppt as an overview of the lesson.
- Students will take notes during the presentation on a printout of the presentation for future reference.
- The teacher will distribute, explain, and assign Activity 5.1.1 Test Criteria.
- Optional: The teacher may wish to assign Unit 5 Key Terms Crossword Puzzle after all key terms have been introduced.

Day 2:
- Student teams will complete Activity 5.1.1 Test Criteria and conclusion questions individually.

Days 3-5:
- The teacher will check Activity 5.1.1 Test Criteria conclusion questions and engineering notebooks for completion and then lead a class discussion to assess student understanding.
- The teacher will distribute, explain, and assign Project 5.1.2 Test Procedure and Project 5.1.2 Test Procedure Rubric.
- Student teams will complete Project 5.1.2 Test Procedure as a group but will complete the conclusion questions individually.
- The teacher will check Project 5.1.2 Test Procedure conclusion questions and engineering notebooks for completion and then lead a class discussion to assess student understanding.
- The teacher will assess the Project 5.1.2 Test Procedure for each team using the Project 5.1.2 Test Procedure Rubric.

Instructional Resources
Presentations
Testing Procedures
Word Documents
Activity 5.1.1 Test Criteria
Project 5.1.2 Test Procedure
Unit 5 Key Terms Crossword Puzzle
Answer Keys and Rubrics
Project 5.1.2 Test Procedure Rubric
Unit 5 Key Terms Crossword Puzzle Answer Key
Teacher Guidelines
Teacher Notes
Reference Sources


National Council of Teachers of English (NCTE) and International Reading Association (IRA) (1996). *Standards for the English language arts*. Newark, DE: IRA; Urbana, IL: NCTE.


Lesson 5.2 Test the Prototype

Preface

Many engineering and product failures are well documented. Most of the infamous examples involve tragedies such as bridge collapses, oil leaks, or an event that has a major negative impact on the environment or people. In fact, many engineering and product failures occur that few people ever hear about. Some products fail because they do not sell – they may not have been marketed well or they may not be desirable. But often a product fails because it does not perform the intended or advertised function or because it breaks easily. A product that does not perform the function for which it was purchased has little value at any cost. A lot can be learned from visiting the clearance aisle where many failed consumer products end up.

Testing is intended to verify that a product does, in fact, successfully solve the problem that it was intended to solve. While decisions involving sales and marketing can be subjective, well-designed and implemented tests can provide clear evidence that the product will safely meet consumer needs and perform its intended function.

Students designed their test(s) in the previous lesson. In this lesson they will carry out their tests and determine whether or not their designs meet the product specifications. Based on testing results, students may have to face some tough decisions about their next steps. If the results of the test(s) indicate that their design does not meet the expectations, they may have to return to a previous step in the design process to rethink and revise the design. The critical design review should provide clarity about how to move forward.

Concepts

1. The results of prototype testing are used to refine the design and to improve the design solution.
2. Design reviews are used at crucial stages of the design process to gather input and perspective in order to determine how to proceed with a design.

Standards and Benchmarks Addressed

Standards for Technological Literacy

Standard 1: Students will develop an understanding of the characteristics and scope of technology.
BM L: Inventions and innovations are the results of specific, goal-directed research.

Standard 2: Students will develop an understanding of the core concepts of technology.
BM W: Systems’ thinking applies logic and creativity with appropriate compromises in complex real-life problems.

BM Z: Selecting resources involves trade-offs between competing values, such as availability, cost, desirability, and waste.

BM AA: Requirements involve the identification of the criteria and constraints of a product or system and the determination of how they affect the final design and development.

BM BB: Optimization is an ongoing process or methodology of designing or making a product and is dependent on criteria and constraints.

Standard 3: **Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.**

BM G: Technology transfer occurs when a new user applies an existing innovation developed for one purpose in a different function.

BM H: Technological innovation often results when ideas, knowledge, or skills are shared within a technology, among technologies, or across other fields.

Standard 7: **Students will develop an understanding of the influence of technology on history.**

BM G: Most technological development has been evolutionary, the result of a series of refinements to a basic invention.

Standard 8: **Students will develop an understanding of the attributes of design.**

BM H: The design process includes defining a problem, brainstorming, researching and generating ideas, identifying criteria and specifying constraints, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype, testing and evaluating the design using specifications, refining the design, creating or making it, and communicating processes and results.

Standard 9: **Students will develop an understanding of engineering design.**

BM I: Established design principles are used to evaluate existing designs, to collect data, and to guide the design process.

BM K: A prototype is a working model used to test a design concept by making actual observations and necessary adjustments.

Standard 11: **Students will develop abilities to apply the design process.**
BM M: Identify the design problem to solve and decide whether or not to address it.

BM O: Refine a design by using prototypes and modeling to ensure quality, efficiency, and productivity of the final product.

BM Q: Develop and produce a product or system using a design process.

BM R: Evaluate final solutions and communicate observation, processes, and results of the entire design process, using verbal, graphic, quantitative, virtual, and written means, in addition to three-dimensional models.

Standard 12: Students will develop the abilities to use and maintain technological products and systems.
BM L: Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

BM P: Use computers and calculators to access, retrieve, organize and process, maintain, interpret, and evaluate data and information in order to communicate.

Standard 13: Students will develop the abilities to assess the impacts of products and systems.
BM J: Collect information and evaluate its quality.

National Science Education Standards

Unifying Concepts and Processes: As a result of activities in grades K-12, all students should develop understanding and abilities aligned with the following concepts and processes.
- Systems, order, and organization
- Evidence, models, and explanation
- Change, constancy, and measurement
- Form and function

Science As Inquiry Standard A: As a result of activities in grades 9-12, all students should develop
- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry
Science and Technology Standard E: As a result of activities in grades 9-12, all students should develop
- Abilities of technological design
- Understandings about science and technology

Principles and Standards for School Mathematics

Number and Operations
Instructional programs from pre-kindergarten through grade 12 should enable all students to understand numbers, ways of representing numbers, relationships among numbers, and number systems; understand meanings of operations and how they relate to one another; compute fluently and make reasonable estimates.

Measurement
Instructional programs from pre-kindergarten through grade 12 should enable all students to understand measurable attributes of objects and the units, systems, and processes of measurement; apply appropriate techniques, tools, and formulas to determine measurements.

Data Analysis and Probability
Instructional programs from pre-kindergarten through grade 12 should enable all students to formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them; select and use appropriate statistical methods to analyze data; develop and evaluate inferences and predictions that are based on data; understand and apply basic concepts of probability.

Problem Solving
Instructional programs from pre-kindergarten through grade 12 should enable all students to build new mathematical knowledge through problem solving; solve problems that arise in mathematics and in other contexts; apply and adapt a variety of appropriate strategies to solve problems; monitor and reflect on the process of mathematical problem solving.

Communication
Instructional programs from pre-kindergarten through grade 12 should enable all students to organize and consolidate their mathematical thinking through communication; communicate their mathematical thinking coherently and clearly to peers, teachers, and others; analyze and evaluate the mathematical thinking and strategies of others; use the language of mathematics to express mathematical ideas precisely.
Connections

Instructional programs from pre-kindergarten through grade 12 should enable all students to recognize and use connections among mathematical ideas; understand how mathematical ideas interconnect and build on one another to produce a coherent whole; recognize and apply mathematics in contexts outside of mathematics.

Standards for English Language Arts

Standard 4

Students adjust their use of spoken, written, and visual language (e.g. conventions, style, vocabulary) to communicate effectively with a variety of audiences and for different purposes.

Standard 8

Students use a variety of technological and informational resources (e.g. libraries, databases, computer networks, video) to gather and synthesize information and to create and communicate knowledge.

Standard 12

Students use spoken, written and visual language to accomplish their own purposes (e.g. for learning, enjoyment, persuasion, and the exchange of information).

Performance Objectives

*It is expected that students will:*

- Conduct testing of their prototype.
- Design and participate in a critical design review to evaluate their prototype and determine how their project will proceed.
- Identify, define, and implement necessary modifications to their design based upon their test results.
- Document their project’s progress in their engineering notebook.

Assessment

*Interpretation*

- Students will analyze the importance of the process used by experts to determine the validity of test results. They will use the same process to analyze their test results. Students should include how the use of the process differs from simply looking at the results.
Self-knowledge

☐ Students will describe what they have learned from completing the testing phase of their design solution and reflect on what is left to complete. Students will note questions that are still unanswered.

Essential Questions

1. What information can be gained by evaluating your test results?
2. How do you know that your test procedure is successful?
3. What do you do if testing shows that the prototype will not solve the problem?

Key Terms

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Critical Design Review</td>
<td>A review held when a deliverable has reached a point where viability of the design can be judged.</td>
</tr>
</tbody>
</table>

Day-by-Day Plans

Time: 15 days

NOTE: In preparation for teaching this lesson, it is strongly recommended that the teacher read the Lesson 5.2 Teacher Notes.

Day 1:

☐ The teacher will present Concepts, Key Terms, and Essential Questions in order to provide a lesson overview.

☐ The teacher will present When Tests Fail.ppt as an overview of the lesson.

☐ Students will take notes on a printout for future reference during the presentation.

☐ NOTE: The teacher should briefly introduce Project 5.2.2 Critical Design Review. Students are encouraged to invite experts for this project and should begin arranging times and inviting their guests now.

Days 2-6:

☐ The teacher will distribute, explain, and assign Project 5.2.1 Test and Evaluate the Prototype and Prototype Testing Rubric.

☐ The Prototype Testing Rubric is not specific to a project but rather to the entire lesson.

☐ Student teams will complete Activity 5.2.1 Test and Evaluate the Prototype and conclusion questions individually.

Days 7-9:

☐ The teacher will assess Activity 5.2.1 Test and Evaluate the Prototype using Prototype Testing Rubric and check conclusion questions for completion.

☐ The teacher will distribute, explain, and assign Project 5.2.2 Critical Design Review.
☐ Student teams will plan and conduct the review with the instructor, mentors, and two students from another team.

☐ Students will complete Project 5.2.2 Critical Design Review and conclusion questions individually.

**Days 10-15:**

☐ The teacher will check Activity 5.2 Critical Design Review conclusion questions and engineering notebooks for completion and then lead a class discussion to assess student understanding.

☐ The teacher will distribute, explain, and assign **Project 5.2.3 Redesign and Refine**.

☐ Students will complete Project 5.2.3 Redesign and Refine and conclusion questions individually.

☐ The teacher will assess Project 5.2.1 Test and Evaluate the Prototype, Project 5.2.2 Critical Design Review, and Project 5.2.3 Redesign and Refine using Prototype Testing Rubric.

**Instructional Resources**

Presentations

*When Tests Fail*

Word Documents

*Project 5.2.1 Test and Evaluate the Prototype*

*Project 5.2.2 Critical Design Review*

*Project 5.2.3 Redesign and Refine*

Answer Keys and Rubrics

*Prototype Testing Rubric*

Teacher Guidelines

*Teacher Notes*

**Reference Sources**


National Council of Teachers of English (NCTE) and International Reading Association (IRA) (1996). *Standards for the English language arts*. Newark, DE: IRA; Urbana, IL: NCTE.


Lesson 6.1 Documentation and Presentation

Preface

From high-level research to simple weather observations, all scientific endeavors yielding useful data must be written and reported in a meaningful way in order to share the gathered information. Without the sharing of information, there is very little purpose in gathering it. Project documentation for this course can take on many different forms. Process documentation in the form of a project portfolio (hard copy or electronic) is required from all student teams. In addition, student teams should provide outcome documentation. Choices for output documentation formats that are presented in this lesson include PowerPoint presentation, three panel display board, or website creation.

In a practical sense, the mastery of research techniques and the ability to organize, evaluate, and present information are professional skills at which all students should become proficient. Many reports used in business and industry today are the result of meticulous research procedures. Most college papers are a form of technical research writing. Knowing where to find information, how to document original research, and how best to organize and present this information are valuable skills in many professional and scholarly undertakings. In addition, the selection of meaningful visual aids and written text are as important to the success of a presentation as the dialog used by the presenter. Both emphasize important points being made in the presentation and often convey information better than dialog.

The goal of this lesson is to introduce students to the necessary skills to convey information about their project. They will explore a variety of formats with which to present a summary of their research project.

Concepts

1. The use of presentation software allows designers to present visual aids and project information in a professional manner.

2. The media format used for a presentation is chosen in order to effectively communicate the design solution process to a target audience.
3. Presentations and displays of work provide the means to effectively promote and justify the implementation of a project.

4. A well-done presentation can enhance the perception of the quality of work completed for a team project.

Standards and Benchmarks Addressed

**Standards for Technological Literacy**

**Standard 1:** Students will develop an understanding of the characteristics and scope of technology.

**BM L:** Inventions and innovations are the results of specific, goal-directed research.

**Standard 3:** Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.

**BM H:** Technological innovation often results when ideas, knowledge, or skills are shared within a technology, among technologies, or across other fields.

**Standard 6:** Students will develop an understanding of the role of society in the development and use of technology.

**BM I:** The decision whether to develop a technology is influenced by societal opinions and demands, in addition to corporate cultures.

**BM J:** A number of different factors, such as advertising, the strength of the economy, the goals of a company and the latest fads contribute to shaping the design of and demand for various technologies.

**Standard 7:** Students will develop an understanding of the influence of technology on history.

**BM G:** Most technological development has been evolutionary, the result of a series of refinements to a basic invention.

**Standard 8:** Students will develop an understanding of the attributes of design.

**BM H:** The design process includes defining a problem, brainstorming, researching and generating ideas, identifying criteria and specifying constraints, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype, testing and evaluating the design using specifications, refining the design, creating or making it, and communicating processes and results.

**BM J:** The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.
Standard 11: Students will develop abilities to apply the design process.  
BM R: Evaluate final solutions and communicate observation, processes, and results of the entire design process, using verbal, graphic, quantitative, virtual, and written means, in addition to three-dimensional models.

Standard 12: Students will develop the abilities to use and maintain technological products and systems.  
BM L: Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

BM P: Use computers and calculators to access, retrieve, organize and process, maintain, interpret, and evaluate data and information in order to communicate.

Standard 17: Students will develop an understanding of and be able to select and use information and communication technologies.  
BM P: There are many ways to communicate information, such as graphic and electronic means.

BM Q: Technological knowledge and processes are communicated using symbols, measurement, conventions, icons, graphic images, and languages that incorporate a variety of visual, auditory, and tactile stimuli.

National Science Education Standards

Unifying Concepts and Processes: As a result of activities in grades K-12, all students should develop understanding and abilities aligned with the following concepts and processes.

☐ Evidence, models, and explanation
☐ Form and function

Science As Inquiry Standard A: As a result of activities in grades 9-12, all students should develop

☐ Abilities necessary to do scientific inquiry
☐ Understanding about scientific inquiry

Science and Technology Standard E: As a result of activities in grades 9-12, all students should develop

☐ Abilities of technological design
☐ Understandings about science and technology
Principles and Standards for School Mathematics

Communication
Instructional programs from pre-kindergarten through grade 12 should enable all students to organize and consolidate their mathematical thinking through communication; communicate their mathematical thinking coherently and clearly to peers, teachers, and others; analyze and evaluate the mathematical thinking and strategies of others; use the language of mathematics to express mathematical ideas precisely.

Representation
Instructional programs from pre-kindergarten through grade 12 should enable all students to create and use representations to organize, record, and communicate mathematical ideas; select, apply, and translate among mathematical representations to solve problems; use representations to model and interpret physical, social, and mathematical phenomena.

Standards for English Language Arts

Standard 4
Students adjust their use of spoken, written, and visual language (e.g. conventions, style, vocabulary) to communicate effectively with a variety of audiences and for different purposes.

Standard 8
Students use a variety of technological and informational resources (e.g. libraries, databases, computer networks, video) to gather and synthesize information and to create and communicate knowledge.

Performance Objectives

It is expected that students will:

- Gather data and information compiled throughout the project and create a project portfolio and presentation of their design solution.
- Identify appropriate techniques for delivering formal presentations.
- Orally present an effective technical presentation on the chosen design solution.
Assessment

Application

☐ Students will draw upon their previous experiences giving presentations in EDD and other courses to consider ways to improve their final EDD presentations.

Perspective

☐ Students will explain how to use the skills obtained in EDD to prepare for an interview at a college or in the workforce.

Essential Questions

1. How does my documentation support or enhance the overall project?
2. How does the quality of presentation affect the perception of the overall project?
3. How have my efforts contributed to and supported the overall project?
4. What would I do differently if given the chance to work on a similar project?

Key Terms

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expository</td>
<td>Serving to expound, set forth, or explain.</td>
</tr>
<tr>
<td>Juried Presentation</td>
<td>A showing or viewing of something that has been assessed by a group of judges or evaluators.</td>
</tr>
<tr>
<td>Peer Review</td>
<td>Evaluation of scientific, academic, or professional work by others working in the same field.</td>
</tr>
<tr>
<td>Project Portfolio</td>
<td>Documentation that portrays and highlights the development of a specific project.</td>
</tr>
<tr>
<td>Self Assessment</td>
<td>An assessment technique used to enhance learning and understanding through self-evaluation.</td>
</tr>
<tr>
<td>Tradeshow</td>
<td>An organized gathering of members of a particular industry during which they display or demonstrate their products and services for potential customers. Trade shows are often open only to members of the media and people associated with the particular industry.</td>
</tr>
</tbody>
</table>
Day-by-Day Plans

Time: 10 days

NOTE: In preparation for teaching this lesson, it is strongly recommended that the teacher read the Lesson 6.1 Teacher Notes.

Day 1:
- The teacher will present Concepts, Key Terms, and Essential Questions in order to provide a lesson overview.
- The teacher will highlight the content of Technical Writing.ppt and provide handouts as a student resource.

Days 2-5:
- The teacher will distribute, explain, and assign Project 6.1.1 Project Portfolio and Project 6.1.1 Project Portfolio Rubric or another assessment tool(s).
- Optional – If teams are doing a tradeshow format, the teacher will distribute, explain, and assign Optional – Three Panel Display.
- Student teams will complete Project 6.1.1 Project Portfolio conclusion questions individually.

Days 6-10:
- The teacher will check Project 6.1.1 Project Portfolio conclusion questions and engineering notebooks for completion and assess the project portfolio using Project 6.1.1 Project Portfolio Rubric.
- The teacher will distribute, explain, and assign Project 6.1.2 Process and Results Presentation and Presentation Checklist.
- The teacher will present Presentation Mistakes.ppt as an overview of the lesson.
- Students will take notes on a printout for future reference during the presentation.
- Student teams will complete Project 6.1.2 Process and Results conclusion questions individually.
- The teacher will distribute and explain the checklists, rubrics, and evaluations that will be used for the final presentation. This may include the Rule of Quarters Evaluation, Oral Presentation Rubric, Juried Response Rubric, a modification of one of these, or other assessment tools.
- The teacher will distribute and explain the Team Evaluation and Personal Evaluation Rubric.
- Students will complete the Team Evaluation and Personal Evaluation Rubric.
- The teacher will check Project 6.1.2 Process and Results conclusion questions, engineering notebooks, Team Evaluation, and Personal Evaluation Rubric for completion and then lead a class discussion to assess student understanding.
Instructional Resources

Presentations

Technical Writing
Presentation Mistakes

Word Documents

Project 6.1.1 Project Portfolio
Project 6.1.2 Process and Results Presentation
Presentation Checklist
Optional – Three Panel Display
Team Evaluation

Answer Keys and Rubrics

Project 6.1.1 Project Portfolio Rubric
Rule of Quarters Evaluation
Team Evaluation Rubric
Oral Presentation Rubric
Juried Response Rubric
Personal Evaluation Rubric

Teacher Guidelines

Teacher Notes

Reference Sources


National Council of Teachers of English (NCTE) and International Reading Association (IRA) (1996). *Standards for the English language arts*. Newark, DE: IRA; Urbana, IL: NCTE.


Glossary

A

Accountability: The concept of being held responsible to oneself and others for actions and consequences of actions either committed or omitted. Accountability is basically being able to be taken at face value for your words and actions.

Accuracy: 1. The closeness of a measurement to the actual value of the quantity being measured. 2. The condition or quality of being true, correct, or exact; precision; exactness.

Accurate: Correct in all details.

Advertise: To present or describe a product, service, or event in a public medium so as to promote sales.

Aesthetic: 1. Concerned with beauty or the appreciation of beauty. 2. Of pleasing appearance.

Alternatives: A possible or existing solution to a problem, different from existing solutions.


American Psychological Association (APA): A scientific organization which has set one standard format for written technical reports.

American Society of Mechanical Engineers (ASME): 1. A professional engineering organization that is known for setting codes and standards for mechanical devices in the
United States. ASME drawing standards are found in the Y-14M publications. 2. The acronym for the American Society of Mechanical Engineers.

**American Standard Testing Methods (ASTM):** A testing method that defines the way a test is performed. The result of the test may be used to assess compliance with a specification. The ASTM is an international standards-developing organization that develops and publishes voluntary technical standards using a consensus process for a wide range of materials, products, systems, and services.

**Analysis:** A systematic examination of a problem or complex entity in order to provide new information from what is already known.

**Articulate:** To clearly express an idea or feeling.

**Artifact:** Handmade object or other result of human activity such as a design or document.

**Assembly:** A group of machine or handmade parts that fit together to form a self-contained unit.

**Assessment:** An evaluation technique for technology that requires analyzing benefits and risks, understanding the trade-offs, and then determining the best action to take in order to ensure that the desired positive outcomes outweigh the negative consequences.

**Association:** A professional body or professional organization, also known as a professional association or professional society, is an organization, usually non-profit, that exists to further a particular profession, to protect both the public interest and the interests of professionals.

**Assumptions:** Beliefs about what is true, usually describing the context of a project.

**Audience:** The assembled spectators or listeners at an event.
**Audience Analysis:** The understanding of the consumer group for which the design is targeted. This would include the audiences, demographics, physical location, amount of time available to view the design, and interest in the subject matter.

**Available Market:** Prospects who are willing and capable buyers (have sufficient resources) and who have access to a particular market or service.

**Benchmark:** A standard or set of standards used as a point of reference for evaluating performance or level of quality.

**Bias:** Inclination or prejudice in favor of a particular person, thing, or viewpoint.

**Bibliography:** A list of all sources referenced during research. The bibliography format is specified (See APA or MLA) and is usually found at the end of a written document.

**Bioengineering:** Engineering applied to biological and medical systems, such as biomechanics, biomaterials, and biosensors. Bioengineering also includes biomedical engineering as in the development of aids or replacements for defective or missing body organs.

**Biotechnology:** Any technique that uses living organisms, or parts of organisms, to make or modify products, improve plants or animals, or to develop microorganisms for specific uses.

**Body Language:** The conscious and unconscious bodily movements by which feelings are communicated.

**Boolean:** The logical combination of statements, such as “AND,” “OR,” “NOT,” to form search commands used by search engines.
**Brainstorming:** A group technique for solving problems, generating ideas, stimulating creative thinking, etc. by unrestrained spontaneous participation in discussion.

**Brevity:** 1. Concise and exact use of words. 2. Shortness of time.

**Business card:** A small card with a person’s name and professional information, such as occupation, business phone number, and email address.

**Business plan:** A formal statement that summarizes the goals, strategies, and actions that a company anticipates taking to ensure survival and growth of the business.

**By-product:** Something produced in the making of something else; a secondary result; a side effect.

**Calibrate:** To check, adjust, or determine by comparison with a standard.

**Capital:** One of the basic resources used in a technological system. Capital or money is the accumulated finances and goods devoted to the production of other goods.

**Chain of Events Pattern:** A pattern used in informative speeches where information is presented in a pattern of development directly related to a series of steps, each one dependent on the previous step.

**Change Order:** Documentation of a change to a design after the design has been finalized.

**Chemical Technology:** Any technological process that modifies, alters, or produces chemical substances, elements, or compounds.
**Chronological Pattern:** A pattern used in informative speeches where information is presented in order based on time.

**Clarity:** The state or quality of being clear and easily perceived or understood.

**Closed-Loop Recycling:** Recycling material back to the same type.

**Communication:** The successful transmission of information through a common system of symbols, signs, behavior, speech, writing, or signals.

**Communication System:** A system that forms a link between a sender and a receiver, making possible the exchange of information.

**Competition:** 1. Open market rivalry in which every seller tries to get what other sellers are seeking at the same time – sales, profit, and market share – by offering the best practicable combination of price, quality, and service. 2. Contests used to show or expose work to different forms of evaluation and comparisons to alternate solutions.

**Concept:** A general idea, thought, or understanding.

**Conceptual:** Of or relating to concepts or mental conception; existing in the imagination.

**Concise:** A statement which is brief, factual, accurate, and which lacks superfluous wording and information.

**Conclusion:** A judgment or decision reached after deliberation. The outcome or result of an act or process.

**Concept:** An idea or thought.
**Consequence:** An effect that naturally follows and is caused by a previous action or condition; referred to as an outcome.

**Constraint:** 1. A limit to a design process. Constraints may be such things as appearance, funding, space, materials, and human capabilities. 2. A limitation or restriction.

**Construction:** The systematic act or process of building, erecting, or constructing buildings, roads, or other structures.

**Consumer:** One who uses commodities.

**Control:** An arrangement of chemical, electronic, electrical, and mechanical components that commands or directs the management of a system.

**Control Group:** In a multiple group experiment, the control group is the group which is tested without any modifications. The control group exists to validate the changes which may occur in other groups that are tested using a proposed hypothesis.

**Convention:** A technique, practice, or procedure that is established by usage and widely accepted.

**Copyright:** Exclusive legal rights to reproduce, publish, sell, or distribute the matter and form of something (as a literary, musical, or artistic work).

**Correlate:** A mathematical process used to determine if an observed outcome is attributable to an imposed condition. A correlation of 1.00 indicates absolute dependency. A correlation of zero indicates a purely random outcome.

**Cost-benefit Analysis:** A tool widely used in business that involves a quantitative investigation of the dollar benefits of a particular program versus the cost.
**Cost Effective:** In economics, cost-effectiveness refers to the comparison of the relative expenditure (costs) and outcomes (effects) associated with two or more courses of action.

**Criteria:** A standard, rule, or test by which something can be judged; a means of judging.

**Critical Design Review:** A review held when a deliverable has reached a point where viability of the design can be judged.

**Critical Thinking:** The ability to acquire information, analyze and evaluate it, and reach a conclusion or answer by using logic and reasoning skills.

**Critique:** A detailed analysis and assessment.

**Culture:** The beliefs, traditions, habits, and values controlling the behavior of the majority of the people in a social-ethnic group. These include methods for addressing problems of survival and existence as a continuing group.

**Custom Production:** A type of production in which products are designed and built to meet the specific needs and wants of an individual.

**Data:** 1. Raw facts and figures that can be used to draw a conclusion. 2. Information organized for analysis or used as the basis for a decision; numerical information in a form suitable for processing by computer.

**Data Element:** An individual value or bit of information.

**Data Set:** A group of individual values or bits of information that are related in some way or have some common characteristic or attribute.
**Decision Making**: The act of examining several possible behaviors and selecting from them the one most likely to accomplish the individual’s or group’s intention. Cognitive process, such as reasoning, planning, and judgment are involved.

**Decision Matrix**: A graphical tool consisting of columns and rows that is used to compare alternatives while considering a list of specifications and constraints.

**Deductive Reasoning**: Logical conclusions drawn from facts already gathered.

**Deliverables**: The end product; that which will be delivered; often used in the plural.

**Demographics**: The statistical data of a population, especially those showing average age, income, education, and other related topics.

**Dependant Variable**: In research, variables that are a consequence of or dependent upon some outside condition.

**Descriptive Abstract**: A written summary that provides an overview of the purpose and contents of a report but that offers no major facts.

**Design**: 1. An iterative decision-making process that produces plans by which resources are converted into products or systems that meet human needs and wants or solve problems. 2. A plan or drawing produced to show the look and function or workings of something before it is built or made. 3. A decorative pattern.

**Design Brief**: A written plan that identifies a problem to be solved, its criteria, and its constraints. The design brief is used to encourage thinking of all aspects of a problem before attempting a solution.

**Design Principle**: Design rules regarding rhythm, balance, proportion, variety, emphasis, and harmony, used to evaluate existing designs and guide the design process.
**Design Process:** A systematic problem-solving strategy, with criteria and constraints, used to develop many possible solutions to solve a problem or satisfy human needs and wants and to winnow (narrow) down the possible solutions to one final choice.

**Design Proposal:** A written plan of action for a solution to a proposed problem.

**Design Statement:** A part of a design brief that challenges the designer, describes what a design solution should do without describing how to solve the problem, and identifies the degree to which the solution must be executed.

**Designer:** A person who designs any of a variety of things. This usually implies the task of creating drawings or in some ways uses visual cues to organize his or her work.

**Detailed Sketches:** Sketches that communicate the information needed to build a model of a product or structure.

**Develop:** To change the form of something through a succession of states or stages, each of which is preparatory to the next. The successive changes are undertaken to improve the quality of or refine the resulting object or software.

**Displays of Work:** Public exhibits of work to allow others to learn about a project and to receive peer evaluation.

**Documentation:** 1. The documents that are required for something, or that give evidence or proof of something. 2. Drawings or printed information that contains instructions for assembling, installing, operating, and servicing.

**Downcycling:** Recycling of a material to a lower grade of physical or commercial value.
**Ecological Design:** A method of design that is environmentally benign and economically viable.

**Efficient:** Operating or performing in an effective and competent manner with a minimum of wasted time, energy, or waste products.

**Emphasis:** Special importance, value, or prominence given to something.

**Energy:** The ability to do work. Energy is one of the basic resources used by a technological system.

**Engineer:** A person who is trained in and uses technological and scientific knowledge to solve practical problems.

**Engineering Change Order:** An order that specifies the change to a design or engineered project.

**Engineering Design:** The systematic and creative application of scientific and mathematical principles to practical ends, such as the design, manufacture, and operation of efficient and economical structures, machines, processes, and systems.

**Engineering Design Process:** A decision making process (often iterative) in which the basic sciences, mathematics, and engineering sciences are applied to convert resources optimally to meet a stated objective.

**Engineering Design Process Portfolio Scoring Rubric (EDPPSR):** A detailed rubric developed by a group of post-secondary educators and led by the University of Maryland aimed at organizing and assessing the engineering design process. The rubric was started in March of 2010 and is in a process of research and validation that will take place over three years.
**Engineering Notebook**: Also referred to as an Engineer’s Logbook, a Design Notebook, or Designer’s Notebook. 1. A record of design ideas generated in the course of an engineer’s employment that others may not claim as their own. 2. An archival record of new ideas and engineering research achievements.

**Entrepreneur**: A person who organizes and manages a business undertaking, assuming the risk for the sake of the profit.

**Environmental Protection Agency (EPA)**: EPA is the acronym for the Environmental Protection Agency.

**Ergonomics**: The study of the problems of people in adjusting to their environment; esp., the science that seeks to adapt work or working conditions to the worker.

**Ethical**: Conforming to an established set of principles or accepted professional standards of contact.

**Ethics**: The system or code of morals of a particular person, religion, group, profession, etc.

**Evaluate**: To form an idea of the amount or value of; assess.

**Evaluation**: The collection and processing of information and data in order to determine the significance, worth, or condition of something, usually by careful appraisal and study, and to provide direction for improvements.

**Evolution**: A gradual development.

**Executive Summary**: A persuasive summary that provides an overview of the purpose and contents of a report; identifies the issue or need that led to the report, and includes condensed conclusions and recommendations.
**Expert:** Someone recognized as a reliable source of knowledge, technique, or skill whose judgment is accorded authority and status by the public or their peers. The expert differs from the specialist in that a specialist has to *be able to solve* a problem and an expert has to *know its solution*.

**Experimentation:** 1. The act of conducting a controlled test or investigation. 2. The act of trying out a new procedure, idea, or activity.

**Expository:** Serving to expound, set forth, or explain.

**Extrapolate:** The process of extending a graph of collected data points beyond its end to predict an outcome, in lieu of actually performing the experiment at the extrapolated value.

**Extrinsic Motivation:** Motivation that comes from the outside. Is either literally apart from the issue in question or derived from something external to it.

**Fabricate:** To make by art or skill and labor.

**Fact:** A statement or piece of information that is true or a real occurrence.

**Feasible:** Capable of being done, performed, executed, or effected; practicable.

**Feedback:** Using all or a portion of the information from the output of a system to regulate or control the process or inputs in order to modify the output.

**Finite Element Analysis (FEA):** A computerized numerical analysis technique used for solving differential equations to primarily solve mechanical engineering problems relating to stress analysis.
Fit: The ability of an item to physically interface or interconnect with or become an integral part of another system.

Fluid Power: Energy transmitted and controlled by means of a pressurized fluid, either liquid or gas. The term fluid power applies to both hydraulics and pneumatics.

Focus Group: Small number of people (typically 8) brought together with a moderator to focus on a specific product or topic. Aimed at a discussion instead of on individual responses to formal questions, the process produces qualitative data (preferences and beliefs) that may or may not be representative of the general population.

Forecast: A statement about future trends, usually as a probability, made by examining and analyzing available information. A forecast is also a prediction about how something will develop, usually as a result of study and analysis of available pertinent data.

Form: 1. The shape, size, mass, weight, and other visual parameters which uniquely characterize an item. 2. Having the three dimensions of length, width, and depth. Also referred to as a solid.

Form, Fit, and Function: Physical, functional, and performance characteristics or specifications that uniquely identify a component or device and determine its interchangeability in a system.

Formula: A mathematical relationship or rule expressed in symbols.

Freehand: Done manually without the aid of instruments such as rulers.

Frequency: The rate at which something occurs over a particular period or in a given sample.
**Function:** 1. The action or actions that an item is designed to perform. 2. The kind of action or activity proper to a person, thing, or institution; role.

**Functioning Prototype:** A model intended to finalize the operational elements of your invention before it goes into production.

**Gantt Chart:** A time and activity bar chart representing a time schedule that is used for planning, managing, and controlling major programs that have a distinct beginning and end.

**General Notes:** Notes placed separate from the views; relate to the entire drawing.

**Graph:** A diagram showing the relation between variable quantities, typically of two variables measured along a pair of lines at right angles.

**Graphic Design:** The art of combining text and pictures in advertisements, magazines, books, etc.

**Hand Tool:** A tool powered by human muscle rather than a motor or engine.

**Histogram:** A graph of vertical bars representing the frequency distribution of a set of data.

**Hydraulics:** A type of fluid power that uses pressurized liquid; for example, oil or water.

**Hydroponics:** A technique of growing plants without soil, in water or sometimes an inert medium, such as sand containing dissolved nutrients.
**Hypertext Markup Language (HTML)**: The computer language used to create World Wide Web pages, with hyperlinks and markup for text formatting.

**Hypothesis**: The predicted outcome of the solution to a problem statement. When a researcher thinks he has a possible solution, it becomes his hypothesis. An experiment is then designed to test the hypothesis.

**Incremental Testing**: Testing components or subsystems in isolation that will be integrated into a larger system.

**Independent Variable**: A factor that is measurably separate and distinct from the dependent variable but that may still relate to the dependent variable.

**Inductive Reasoning**: Logical conclusions drawn from inferred, presumed, and extrapolated data.

**Illustrate**: 1. To provide a book or periodical with pictures. 2. To make clear by using examples or charts.

**Impact**: The effect or influence of one thing on another. Some impacts are anticipated, and others are unanticipated.

**Information**: One of the basic resources used by technological systems. Data and facts that have been organized and communicated in a coherent and meaningful manner.

**Innovation**: An improvement of an existing technological product, system, or method of doing something.

**Input**: Something put into a system, such as resources, in order to achieve a result.
**Inquiry Methods:** Scientifically specific methods of forming and then answering questions germane to the larger problem at hand.

**Innovation:** An improvement of an existing technological product, system, or method of doing something.

**Innovation Portal:** An online center on which students can build secure digital portfolios of their original design work and connect that work to a variety of opportunities. The template for portfolio building is organized around the Engineering Design Process Portfolio Scoring Rubric (EDPPSR).

**Integrity:** Steadfast adherence to a strict moral or ethical code. Alternately, the state of a system where it is performing its intended functions without being degraded or impaired by changes or disruptions in its internal or external environments.

**Intellectual Property:** Any product of someone's intellect that has commercial value, especially copyrighted material, patents, and trademarks.

**Inter Library Loan:** The process of accessing material from a library other than your home library. Libraries mutually make their collections available to patrons of other libraries, and this system of requesting and obtaining materials is known as the Inter Library Loan.

**Intermodalism:** The use of more than one form of transportation.

**International Organization for Standardization (ISO):** A non-governmental global organization whose principal activity is the development of technical standards through consensus.

**Internet:** The worldwide, publicly accessible network of interconnected computer networks that transmit data by packet switching using the standard Internet Protocol (IP). It is a "network of networks."

**Interpolate:** The process of using a graph of collected data points within its own range of data to predict an outcome, in lieu of actually performing the experiment at the interpolated value.

**Interview:** 1. A formal meeting, in person, with the specific purpose of obtaining information. The interviewer asks the questions, the interviewee answers them. 2. A conversation in which facts or opinions are sought.

**Intonation:** The rise and fall of the voice in speaking.

**Intrapreneur:** A person in a corporation who is given the freedom and resources to initiate products, business ventures, etc.

**Intrinsic Motivation:** Motivation that comes from within.

**Invention:** A new product, system, or process that has never existed before, created by study and experimentation.

**Iterative Process:** A process for arriving at a decision or a desired result by repeating rounds of analysis or a cycle of operations.

**Journal:** A book containing all information relevant to the purpose of the journal. For this course, the journal contains sections for contact information, correspondence and conversation, sketches and drawings, reference citations, collected data, and a chronological section like a personal diary.
**Juried Presentation:** A showing or viewing of something that has been assessed by a group of judges or evaluators.

**Jury:** A panel of individuals that assess a design project with a formal presentation.

**Justify:** To give a good explanation or reason for something.

**Justifiable:** Capable of being shown as reasonable or merited according to accepted standards.

**Kinetic Energy:** The energy possessed by a body as a result of its motion.

**Licensing:** The granting of permission to use intellectual property rights, such as trademarks, patents, or technology, under defined conditions.

**Management:** 1. The act of directing the design, development, production, and marketing of a product or system. 2. The act of controlling production processes and ensuring that they operate efficiently and effectively.

**Manufacturing Process:** The transformation of raw material into finished goods through one or more of the following: casting and molding; shaping and reshaping for forming; shearing, pulverizing, machining for material removal; or joining by transforming using heat or chemical reaction to bond materials.
**Margin of Error:** A statistic expressing the amount of random sampling error in a survey's results. The larger the margin of error, the less confidence one should have that the poll's reported results are close to the "true" figures; that is, the figures for the whole population.

**Market:** 1. A subset of the population considered to be interested in the buying of goods or services. 2. A place where goods are offered for sale.

**Marketing:** The act or process of offering goods or services for sale.

**Market Research:** The activity of gathering information whereby a specific market is identified and its size and other characteristics are measured.

**Market Share:** Percentage of total sales volume in a market captured by a brand, product, or firm.

**Material:** The tangible substance, such as chemical, biological, or mixed that goes into the makeup of a physical object. One of the basic resources used in a technological system.

**Material Cost Analysis:** The process, whether explicitly or implicitly, of considering the total expected material costs against the total expected benefits of using one type of material over another or in using one or more actions in order to choose the best or most profitable option.

**Mathematics:** The science of patterns and order and the study of measurement, properties, and the relationships of quantities; using numbers and symbols.

**Matrix:** A two-dimensional or three-dimensional array with information or a rectangular array of scalar numbers with various uses, such as identifying common ideas or representing graph data.

**Mean:** The average or central value of a set of quantities.
**Measure:** To determine the size, amount, or degree of something by comparison with a standard unit.

**Measurement:** The process of using dimensions, quantity, or capacity by comparison with a standard in order to mark off, apportion, lay out, or establish dimensions.

**Mechanism:** An assembly of moving parts completing a complete functional motion.

**Media:** Various formats that are used for presenting information, such as television, radio, and computers.

**Media Center:** A media center integrates all forms of media, entertainment, and communication functions, such as TV-reception, broadband Internet access, telephone, cable, and video into one graphical user interface (GUI). Media centers are often operated with a remote control, connected to a television set for video output, and can often function as a normal personal computer. They are designed to receive, store, and play back digital media with a simple, portable, and cost-saving system.

**Median:** Referring to the middle term or mean of the middle two terms of a series of values arranged in order of magnitude.

**Mediation:** The act or process of using an intermediary to effect an agreement or reconciliation.

**Mentor:** An experienced person in an organization or institution who trains and counsels new employees or students.

**Meter:** The fundamental unit of length in the metric system, equal to 100 centimeters or approximately 39.37 inches.

**Methodologies:** The system of principles, practices, and procedures applied to a specific branch of knowledge. The branch of logic dealing with the general principles of the formation of knowledge.
**Metric System:** The decimal measuring system based on the meter, liter, and gram as units of length, capacity, and weight or mass.

**Milestones:** Key dates, usually when a particularly important deliverable must be delivered.

**MLA Style Manual:** A writing style guide that is published by the Modern Language Association and is widely used in academia for writing and the documentation of research in the humanities. MLA style uses a works cited page listing works cited in one's text and notes, either footnotes or endnotes, which is placed after the main body of a term paper, article, or book.

**Mock-up:** Also referred to as an Appearance Model. A model or replica of a machine or structure for instructional or experimental purposes.

**Mode:** The value that occurs most frequently in a given data set.

**Model:** A visual, mathematical, or three-dimensional representation in detail of an object or design, often smaller than the original. A model is often used to test ideas, make changes to a design, and to learn more about what would happen to a similar, real object.

**Moral:** Good or right in conduct or character.

**Multiview Projection:** A system used to view an object. The six mutually perpendicular directions any object may be viewed are top, front, right-side, rear, left-side, and bottom. Top, front, and right-side views are also referred to as the three regular views because they are the three views most frequently used.
Natural Material: Material found in nature, such as wood, stone, gases, and clay.

Nomenclature: The specific words and phrases or terminology used by a field of study. Many technical and scientific fields utilize specific terminology that professionals understand and use as common language.

Non-biodegradable: The inability of a substance to be broken down or decomposed and therefore retaining its form for an extend period of time.

Non-durable Goods: Items that do not last and are constantly consumed, such as paper products.

Nonrenewable Resource: A resource or raw material that cannot be grown or replaced once used.

Normal Distribution: A function that represents the distribution of variables as a symmetrical bell-shaped graph.

Obsolescence: Loss in the usefulness of a product or system because of the development of an improved or superior way of achieving the same goal.

Occupation Safety and Health Administration (OSHA): A government organization whose mission is to assure the safety and health of America’s workers by setting and enforcing standards; providing training, outreach, and education; establishing partnerships; and encouraging continual improvement in workplace safety and health.
**Optimization**: The process of fine-tuning data, software, processes, or designs to increase efficiency, improve performance, and produce the best possible results.

**Orthographic Projection**: A method of representing three-dimensional objects on a plane having only length and breadth. Also referred to as Right Angle Projection.

**Outcome Documentation**: A presentation of the important findings, data, and work on which the final form of a product or system is based.

**Output**: The results of the operation of any system.

**Parameter**: 1. A fact or circumstance that restricts how something is done or what can be done. A synonym for criterion or criteria and constraints. 2. Mathematically or in physics: A variable kept constant during an experiment, calculation, or similar usage.

**Parts List**: A list of materials or parts specified for a project. Also referred to as a bill of materials or BOM.

**Patent**: A grant made by a government that gives an individual or body the sole right to make, use, and sell an invention for a set period of time.

**Patent Infringement**: A patent provides the proprietor of that patent with the right to exclude others from utilizing the invention claimed in that patent. When a person utilizes that invention without the permission of the patent proprietor, they have committed a patent infringement.

**Patent Licensing**: A patent is not a right to practice or use an invention. Rather, a patent provides the right to exclude others from making, using, selling, offering for sale, or importing the patented invention for the term of the patent, usually 20 years from the filing
A patent does not exclude others from conducting research (e.g., for academic purposes) on the invention or from developing further inventions based on the patented invention. In order for a patent to be granted, or to take legal effect, the patent application must meet the legal requirements related to patentability.

**Patent Search:** A formal inquiry to the U.S. Patent Office on a specific technical item. Today, patent searches are most often completed via the Internet.

**Peer Review:** Evaluation of scientific, academic, or professional work by others working in the same field.

**People:** One of the basic resources in technology systems. Humans design, develop, produce, use, manage, and assess products and systems.

**Perspective Drawing:** A form of pictorial drawing in which vanishing points are used to provide the depth and distortion that is seen with the human eye. Perspective drawings can be drawn using one, two, and three vanishing points.

**Persuasion:** The act of persuading or the state of being persuaded. The ability or power to persuade. A strong conviction or belief.

**Persuasive:** 1. Good at persuading someone to do or believe something. 2. Providing sound reasoning or argument.

**Plan:** A set of steps, procedures, or programs worked out beforehand in order to accomplish an objective or goal.

**Planning:** The project phase concerned with breaking the project into manageable chunks and planning how best to proceed.

**Pneumatics:** A type of fluid power that uses compressed air or other neutral gases.
**Portfolio:** 1. Written record of the development of a project from inception to completion. The three types of portfolios are formative, summative, and marketing. 2. Collection of an individual’s work and accomplishments that is useful to demonstrate the individual’s performance and capabilities. Portfolios are used for college entry and employment applications.

**Potential Energy:** The energy of a particle, body, or system that is determined by its position or structure.

**Power:** 1. Amount of work done in a given period of time. 2. Source of energy or motive force by which a physical system or machine is operated.

**Power System:** A technological system that transforms energy resources to power.

**Power Tool:** A tool, usually itself a machine and usually power-driven, used for machining. Examples include hand-held electric drills, lathes, milling machines, shapers, planers, hobbers, drill presses, jig borers, and others.

**Precise:** Exact in measuring or recording.

**Precision:** The state of being precise or exact.

**Preliminary:** Coming before or leading up to the main matter, action, or business; preparatory.

**Presentation Prototype:** A three-dimensional representation of your invention that offers greater visual impact than a drawing; mockup.

**Problem:** An unwelcome or harmful matter needing to be dealt with.

**Problem Identification:** The recognition of an unwelcome or harmful matter needing to be dealt with.
**Problem Solving:** The process of understanding a problem, devising a plan, carrying out the plan, and evaluating the plan in order to solve a problem or meet a need or want.

**Problem Statement:** 1. Part of a design brief that clearly and concisely identifies a client’s or target consumer’s problem, need, or want. 2. Sometimes referred to as the first step in a problem solving process.

**Process:** 1. Human activities used to create, invent, design, transform, produce, control, maintain, and use products or systems. 2. Systematic sequence of actions that combines resources to produce an output.

**Process Documentation:** Step-by-step record of the process used throughout a project or task.

**Produce:** To create, develop, manufacture, or construct a human-made product.

**Product:** A good, idea, method, information, object, service, etc., that is the end result of a process and satisfies a need or want. It is usually a bundle of tangible and intangible attributes (benefits, features, functions, uses).

**Product Development Lifecycle:** The succession of stages a product goes through from inception, development, and use to eventual withdrawal from the marketplace. Product life cycle stages include research and development, introduction, market development, exploitation, maturation, saturation, and finally decline. For purposes of this course, the product development lifecycle is depicted in a flowchart format.

**Product Life:** Period over which a product progresses from its introduction to its withdrawal from the market.

**Professional Organization:** An organization of and for professional people.
**Professionalism:** The competence or skill expected of a professional.

**Project Life Cycle:** The phases that any project progresses through (initiating, planning, executing, controlling, and closing).

**Project Management:** Planning, organizing, and managing resources to successfully complete a project.

**Project Organization Chart:** A diagram showing everyone involved in the project team, project board, key stakeholders, and resources.

**Project Portfolio:** Documentation that portrays and highlights the development of a specific project.

**Pros and Cons:** For and against; as a collective noun, the positive and negative attributes.

**Protocol:** The accepted code of behavior in a particular situation.

**Prototype:** A full-scale working model used to test a design concept by making actual observations and necessary adjustments.

**Provisional Patent:** A less expensive and detailed application that allows one year’s protection to provide time to further investigate or pursue licensing before filing a regular patent application.

**Qualitative:** A description or distinction of an object or idea that is based on some quality rather than on some quantity.

**Qualitative Data:** Values that possess names or labels.
**Quality:** The degree of excellence of something as measured against other similar things.

**Quality Control:** An aggregate of activities (as design analysis and inspection for defects) designed to ensure adequate quality, especially in manufactured products.

**Quantitative:** A description or distinction of an object or idea that is a measurement based on some quantity or number rather than on some quality.

**Quantitative Data:** Values that represent a measurable quantity.

**Range:** The measure of variation that is the difference between the highest and lowest scores.

**Ratio:** The quantitative relation between two amounts showing the number of times one value contains or is contained within the other.

**Recycle:** To reclaim or reuse old materials in order to make new products.

**Refinement:** The act, or the result of refining a design or design idea; the removal of impurities or a high-class style improvement.

**Reliability:** 1. A quality of a measurement indicating the degree to which the measure is consistent, that is, over repeated measurements would give the same result. 2. The probability of satisfactory operation of the product in a given environment over a specified time interval.
**Renewable**: Designation of a commodity or resource, such as solar energy or firewood, that is inexhaustible or capable of being replaced by natural ecological cycles or sound management practices.

**Repeatability**: The property or quality of a test to give consistent results in repeated measurements.

**Requirements**: The parameters placed on the development of a product or system. The requirements include the safety needs, the physical law that will limit the development of an idea, the available resources, the cultural norms, and the use of criteria and constraints.

**Research**: The systematic study of materials and sources in order to establish facts and reach new conclusions.

**Research and Development (R&D)**: The practical application of scientific and engineering knowledge for discovering new knowledge about products, processes, and services, and then applying that knowledge to create new and improved products, processes, and services that fill market needs.

**Research Methodologies**: Certain stepwise methods that have been adopted by the technical and scientific communities for conducting research.

**Resource**: The elements needed to get a job done. In a technological system, the basic technological resources are energy, capital, information, machines and tools, materials, people, and time.

**Responsibilities**: Actions for which an individual is held responsible.

**Resume**: A short document listing qualifications and experiences of an individual or organization.

**Reverse Engineering**: The process of taking something apart and analyzing its workings in detail, usually with the intention to understand function, prepare documentation, electronic
data, or construct a new or improved device or program, without actually copying from the original.

**Risk:** The chance or probability of loss, harm, failure, or danger.

**Royalties:** A share of the proceeds or product paid to the owner of a right, as a patent, for permission to use it or operate under it.

**Safety:** The condition or feeling of being safe; security; certainty.

**Sample:** Portion, piece, or segment that is representative of a whole. A set of elements drawn from and analyzed to estimate the characteristics of a population.

**Scale:** A proportion between two sets of dimensions used in developing accurate, larger or smaller prototypes or models of design ideas.

**Scale Model:** An enlarged or reduced representation of an object that is usually intended for study purposes.

**Schematic:** A drawing or diagram of a chemical, electrical, or mechanical system.

**Science:** The study of the natural world through observation, identification, description, experimental investigation, and theoretical explanations.

**Scientific Approach:** A way of seeking knowledge that involves both inductive and deductive reasoning to develop hypotheses that are then subjected to rigorous and objective testing.
**Scientific Inquiry:** The use of questioning and close examination using the methodology of science.

**Scientific Method:** A method of discovering knowledge about the natural world based in making falsifiable predictions, also called hypotheses, testing them empirically, and developing peer-reviewed theories that best explain the known data.

**Scope:** The work involved in the definition, design, and production of a product, service, or result with the specified features and functions.

**Scope Creep:** The expansion of the scope of a project beyond the initial planning of the project.

**Self-Assessment:** An assessment technique used to enhance learning and understanding through self-evaluation.

**Service Life:** Period over which an asset (machine, property, computer system, etc.) is expected to be usable, with normal repairs and maintenance, for the purpose for which it was acquired.

**Simple Machine:** Any of several elementary mechanisms that are used to transmit or modify force or motion. Simple machines include the lever, wheel and axle, pulley, screw, wedge, and inclined plane.

**Sketch:** A rough drawing representing the main features of an object or scene and often made as a preliminary study.

**Skill:** An ability that has been acquired by training or experience.

**Solution:** 1. A method or process for solving a problem. 2. The answer to or disposition of a problem.
Specifications: A detailed, exact statement of particulars, especially a statement prescribing materials, dimensions, and quality of work for something to be built, installed, or manufactured.

Stakeholders: All those who are involved, interested in, or affected by the project.

Standardization: The act of checking or adjusting by comparison with a standard.

State of the Art: The current upper limit of technical development in the field being considered.

Statement of Work (SOW): A document used in the Product Development Life Cycle. A company will send a SOW to notify a client of work about to be undertaken and agreed pricing, which specifies the project and responsibilities of the parties involved. There is an executive summary, which summarizes the entire statement of work document in paragraph form.

Statistics: Collection of methods for planning experiments, obtaining data, organizing, summarizing, presenting, analyzing, interpreting, and drawing conclusions based on data.

Statistical Analyses: The mathematics of the collection, organization, and interpretation of numerical data. The employment of statistics or the principles of statistics.

Structure: Something that has been constructed or built of many parts and held or put together in a particular way.

Subsystem: A division of a system that, in itself, has the characteristics of a system.

Survey: In marketing, a detailed study of a market or geographical area to gather data on attitudes, impressions, opinions, satisfaction level, etc., by polling a section of the population.
**Sustainable:** Characterized by a practice that sustains a given condition without destroying or depleting natural resources, polluting the environment, etc.

**Sustainable Design:** Design that is environmentally benign, economically viable, and socially equitable.

**System:** A group of interacting, interrelated, or interdependent elements or parts that function together as a whole to accomplish a goal.

**Systems-Oriented Thinking:** A technique for looking at a problem in its entirety, looking at the whole, as distinct from each of its parts or components. Systems-oriented thinking takes into account all of the variables and relates social and technological characteristics.

**Target Market:** A specific group of consumers at which a company aims its products and services.

**Task:** The activities undertaken to achieve deliverables.

**Technical Drawing:** A drawing that is used to show the material, size, and shape of a product for manufacturing purposes.

**Technical Research Paper:** A document that conveys the results of scientific and technical research and provides recommendations for action.

**Technical Working Drawing:** A drawing that is used to show the material, size, and shape of a product for manufacturing purposes.

**Technical Writing:** A subset of technical communication, technical writing is a broad term used to describe specialized correspondence in fields as diverse as computer hardware and software, chemistry, the aerospace industry, robotics, finance, consumer electronics, and biotechnology. Technical writing communicates technical (specialized) information, generally
in the form of printed or printable documentation (e.g., PDF) and online help. The type and form of the produced documentation depends on the needs of the audience and on the product being documented.

**Test:** Examination, evaluation, observation, or trial used (under actual or simulated environmental or operating conditions) to determine and document capabilities, characteristics, effectiveness, reliability, and/or suitability of a material, product, or system.

**Test Criteria:** Benchmarks or standards against which test procedures and outcomes are compared. The plural of criterion is *criteria*.

**Test Procedure:** A particular method in which a product or piece of equipment is placed under everyday or extreme conditions and is examined for its proper function, durability, etc.

**Test Reliability:** The degree to which an experiment or evaluation procedure gives consistent results each time it is employed.

**Test Validity:** The degree to which a test procedure measures what it was designed to measure.

**Theory:** A hypothesis substantiated by experimental validation.

**Three-Panel Kiosk Display:** A style of display that is portable and consists of a left, center, and right section. The three-panel display folds up into a suitcase sized transportable accessory, which is well suited to a traveling businessman or presenter. This type of display provides a large surface area to display visual information on a topic.

**Time Line Chart:** A one-axis chart used to display past and future events, activities, or requirements in the order in which they occurred or are expected to occur for the purposes of analysis and communication.

**Time Management:** The practice of using one’s time effectively.
**Tool**: A device that is used by humans to complete a task.

**Trade-off**: An exchange of one thing in return for another: especially relinquishment of one benefit or advantage for another regarded as more desirable.

**Trade Secret**: Any device, method, formula, etc. known to the manufacturer who uses it but not to competitors.

**Tradeshow**: An organized gathering of members of a particular industry during which they display or demonstrate their products and services for potential customers. Trade shows are often open only to members of the media and people associated with the particular industry.

**Trademark**: A symbol, design, word, letter, etc. used by a manufacturer or dealer to distinguish a product or products from those of competitors.

**Trend Analysis**: 1. The study of the history of any type of product or system, such as the change in design, the price, and required volume over time to attempt to predict future needs or wants. 2. A comparative study of the component parts of a product or system and the tendency of a product or system to develop in a general direction over time.

**Trial and Error**: A method of solving problems in which many solutions are tried until errors are reduced or minimized.

**Troubleshoot**: To locate and find the cause of problems related to technological products or systems.
**Valid:** Well-founded on evidence and corresponds accurately to the real world.

**Validity:** The property of being true.

**Value:** The quality, positive or negative, which renders something desirable.

**Value Creation:** The expression of the business benefits of the project, either in terms of cost savings, efficiency gains, increased sales, or reduced risk.

**Verify:** To confirm or test the truth or accuracy of something.

**Virtual:** Simulation of the real thing in such a way that it presents reality in essence or in effect though not in actual fact.

**Vitae:** A written account of one’s life including education, qualifications, and experiences of an individual or organization.

**Work:** The transfer of energy from one physical system to another expressed as the product of a force and the distance through which it moves a body in the direction of that force.

**Working Drawings:** Drawings that convey all of the information needed to manufacture and assemble a product.
**Working Sketches**: Sketches that convey all of the information needed to manufacture and assemble a design.