DELAWARE VALLEY SCHOOL DISTRICT

PLANNED INSTRUCTION

A PLANNED COURSE FOR:

Engineering 4: Engineering Design & Development

Grade: *seniors who have completed Engineering 1-3*

Date of Board Approval: 2012

DELAWARE VALLEY SCHOOL DISTRICT

PLANNED INSTRUCTION

Title of Planned Instruction: **Engineering 4: Engineering Design and Development**

Subject Area: Engineering **Grade Level:** 11 &12

Course Description: In this capstone course, students work in teams to design and develop an original solution to an approved open-ended technical problem by applying the engineering design process and using skills developed in the previous three engineering courses. Students perform research to choose, validate, and justify a technical problem. After carefully defining the problem, teams design, build, and test their solutions. Local industry professionals provide mentoring for the students. Finally, student teams present and defend their original solution to an outside panel. This course is appropriate for 12 grade students who have successfully completed Introduction to Engineering Design, Principles of Engineering, and Digital Electronics.

Time/Credit for the Course: 2 semesters, 1Credit

Curriculum Writing Committee: PLTW

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 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

Term	Definition
Closed-Loop Recycling	Recycling a material back to the same type.
Copyright	Exclusive legal rights to reproduce, publish, sell, or distribute the matter and form of something (as a literary, musical, or artistic work).
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.
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	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.
Entrepreneur	A person who organizes and manages a business undertaking, assuming the risk for the sake of the profit.
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).
Intellectual Property	Any product of someone's intellect that has commercial value, especially copyrighted material, patents, and trademarks.
Intrapreneur	A person in a corporation who is given the freedom and resources to initiate products, business ventures, etc.
Invention	A new product, system, or process that has never existed before, created by study and experimentation.
Licensing	The granting of permission to use intellectual property rights, such as trademarks, patents, or technology, under defined conditions.
Patent	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.

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.
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.
Sustainable Design	Design that is environmentally benign, economically viable, and socially equitable.
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

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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.

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

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 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

Key Term	Definition
Assumptions	Beliefs about what is true, usually describing the context of a project.
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.
Deliverables	The end product; that which will be delivered; often used in the plural.
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 working drawings of something before it is built or made.
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.
Milestones	Key dates, usually when a particularly important deliverable must be delivered.
Outcome Documentation	A presentation of the important findings, data, and work on which the final form of a product or system is based.
Planning	The project phase concerned with breaking the project into manageable chunks and planning how best to proceed.
Process Documentation	A step-by-step record of the process used throughout a project or task.
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.
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.
Stakeholders	All those who are involved, interested in, or affected by the project.
Tasks	The activities undertaken to achieve deliverables.
Value Creation	The expression of the business benefits of the project, either in terms of cost savings, efficiency gains, increased sales, or reduced risk.

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 Activity1.2.3 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

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Pacific Yurts Inc. (2009). *What is a yurt?* Retrieved November 1, 2009, from http://www.yurts.com/what/default.aspx

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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

Term	Definition
Artifact	Handmade object or other result of human activity such as a design or document.
Brainstorming	A group technique for solving problems, generating ideas, and stimulating creative thinking through unrestrained spontaneous participation in discussion.
Decision Matrix	A graphical tool consisting of columns and rows that is used to compare alternatives while considering a list of specifications and constraints.
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.
Justifiable	Capable of being shown as reasonable or merited according to accepted standards.
Mentor	An experienced person in an organization or institution who trains and counsels new employees or students.
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

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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 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.

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

Term	Definition
Available Market	Prospects who are willing and capable (have sufficient resources) buyers and 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.
Competition	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.
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.
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

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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

Term	Definition
Concept	A general idea, thought, or understanding.
Conceptual	Of, or relating to, concepts or mental conception.
Constraint	A limitation or restriction.
Consumer	One who uses commodities.
Criteria	A means of judging. A standard, rule, or test by which something can be judged.
Decision Matrix	A table used to compare design options by rating the options based on design criteria or specifications.
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.
Feasible	Capable of being done, performed, executed, or affected; practicable.
Iterative Process	A **process** for arriving at a decision or a desired result by repeating rounds of analysis or a cycle of operations.
Optimization	The process of fine-tuning data, software, processes, or designs to increase efficiency, improve performance, and produce the best possible results.
Parameter	A fact or circumstance that restricts how something is done or what can be done.
Preliminary	Coming before or leading up to the main matter, action, or business; preparatory.
Product Life	Period over which a product progresses from its introduction to its withdrawal from the market.
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.
Specification	A detailed, exact statement of particulars, especially a statement prescribing materials, dimensions, and quality of work for something to be built, installed, or manufactured.

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 Specifiations.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

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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

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

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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

Term	Definition
Fit	The ability of an item to physically interface or interconnect with or become an integral part of another system.
Form	The shape, size, mass, weight, and other visual parameters which uniquely characterize an item.
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.
Function	The action or actions that an item is designed to perform.
Functioning Prototype	A model intended to finalize the operational elements of your invention before it goes into production.

Incremental Testing	Testing components or subsystems in isolation that will be integrated into a larger system.
Presentation Prototype	A three-dimensional representation of your invention that offers greater visual impact than a drawing.
Prototype	A full-scale working model used to test a design concept by making actual observations and necessary adjustments.
Subsystem	A division of a system that, in itself, has the characteristics of a system.
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

Prototypes

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

Bellis, M. (n.d.) *Making a prototype*. Retrieved from http://inventors.about.com/od/prototypes/a/prototype.htm

BusinessDictionary.com. (2010). Retrieved from http://www.businessdictionary.com/

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International Technology Education Association, (2000). *Standards for technological literacy*. Reston, VA: ITEA.

Johnson, J.J. (n.d) *Form, fit, and function fundamentals.* Retrieved from *www.dmsms.org/file.jsp?storename=Form_Fit___Function.pdf*

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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

Term	Definition
Change Order	Documentation of a change to a design after the design has been finalized.
Fabricate	To make by art or skill and labor.

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

Altera. (2003). *Engineering change order (ECO) support in programmable logic design*. Retrieved from http://www.altera.ru/Disks/Altera%20Documentation%20Library/literature/wp/wp_ecopld.pdf

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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 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 CC: 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.

BM J: 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.

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

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 L: Many technological problems require a multidisciplinary approach.

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.

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

Term	Definition
Accuracy	The closeness of a measurement to the actual value of the quantity being measured.
Bias	Inclination or prejudice in favor of a particular person, thing, or viewpoint.
Calibrate	To check, adjust, or determine by comparison with a standard.
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.

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.
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.
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.
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.
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.
Repeatability	The property or quality of a test to give consistent results in repeated measurements.
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 every day 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.

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

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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

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

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

International Technology Education Association. (2000). *Standards for technological literacy*. Reston, VA: ITEA.

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.

National Council of Teachers of Mathematics (NCTM). (2000). *Principles and standards for school mathematics*. Reston, VA: NCTM.

National Research Council (NRC). (1996). *National science education standards*. Washington, D. C.: National Academy Press.

Project Connections. (2010). *Review checklists: Critical design review.* Retrieved from http://www.projectconnections.com/templates/detail/critical-design-review-checklist.html

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

Term	**Definition**
Expository	Serving to expound, set forth, or explain.
Juried Presentation	A showing or viewing of something that has been assessed by a group of judges or evaluators.
Peer Review	Evaluation of scientific, academic, or professional work by others working in the same field.
Project Portfolio	Documentation that portrays and highlights the development of a specific project.

Self Assessment	An assessment technique used to enhance learning and understanding through self-evaluation.
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.

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

Frye, E. (1997). *Engineering problem solving for mathematics, science, and technology education.* Hanover, NH: Dartmouth College, Dartmouth Project for Teaching Engineering Problem Solving.

International Technology Education Association, (2000). *Standards for technological literacy*. Reston, VA: ITEA.

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.

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The American heritage college dictionary. (4th ed.). (2007). Boston: Houghton Mifflin.