High School Introduction to Engineering Design Curriculum Essentials Document

Boulder Valley School District
Department of CTEC
May 2012
Introduction to Engineering Design Course

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

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

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

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

<table>
<thead>
<tr>
<th>Course Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>This is an introduction to different facets of design and will emphasize the following: evolution and history of design, the steps in a design process, the importance of proper sketching techniques, measurement and tools used in design, and the use of those tools and techniques to innovate or invent solutions to problems. Students will be introduced to a variety of skill building opportunities that will enhance their design skills and prepare them for the remaining units in this course.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Topics at a Glance</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Technical Sketching and Drawing</td>
</tr>
<tr>
<td>• Design Process</td>
</tr>
<tr>
<td>• Measurement and Statistics</td>
</tr>
<tr>
<td>• Puzzle Cube</td>
</tr>
<tr>
<td>• Geometric Shapes and Solutions</td>
</tr>
<tr>
<td>• Dimensions and Tolerances</td>
</tr>
<tr>
<td>• Advanced Modeling Skills</td>
</tr>
<tr>
<td>• Advanced Designs</td>
</tr>
<tr>
<td>• Reverse Engineering</td>
</tr>
<tr>
<td>• Structural Analysis</td>
</tr>
<tr>
<td>• Design Problems</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Assessments</th>
</tr>
</thead>
<tbody>
<tr>
<td>• There are many design processes that guide professionals in developing solutions to problems.</td>
</tr>
<tr>
<td>• A design process most used by engineers includes defining a problem, brainstorming, researching, identifying requirements, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype, testing, refining, making, and communicating results.</td>
</tr>
<tr>
<td>• Engineers create sketches to quickly record, communicate, and investigate ideas.</td>
</tr>
<tr>
<td>• Engineers apply dimensions to drawings to communicate size information.</td>
</tr>
<tr>
<td>• Statistical analysis of measurements can help verify the quality of a design or process.</td>
</tr>
<tr>
<td>• Engineers use Computer Aided Design modeling systems to quickly generate and annotate working drawings.</td>
</tr>
</tbody>
</table>
Prepared Graduates

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

1. CTE Essential Skills: Academic Foundations

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

Prepared Graduate Competencies in the CTE Essential Skills standard:

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

2. CTE Essential Skills: Communications Standards

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

Prepared Graduate Competencies in the CTE Essential Skills standard:

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

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

Prepared Graduate Competencies in the CTE Essential Skills standard:
- Employ critical thinking skills independently and in teams to solve problems and make decisions
- Employ critical thinking and interpersonal skills to resolve conflicts with staff and/or customers
- Conduct technical research to gather information necessary for decision-making

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

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

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

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

Prepared Graduate Competencies in the CTE Essential Skills standard:

- Employ leadership skills to accomplish organizational skills and objectives

6. CTE Essential Skills: Employability and Career Development

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

Prepared Graduate Competencies in the CTE Essential Skills standard:

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

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

- Relevant & rigorous learning
- Raising achievement among all students
- Strengthening Colorado’s workforce & economy

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

ALIGNMENT REQUIRED BY SB 08-212

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

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

STANDARDS REVIEW AND ALIGNMENT PROCESS

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

NATIONAL BENCHMARK REVIEW

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

- Based on this review Colorado CTE has moved from program-specific to Cluster & Pathway based standards and outcomes
- In addition, we arrived at fewer, higher, clearer and more transferrable standards, expectations and outcomes.

COLORADO CONTENT TEAMS REVIEW

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

ACADEMIC ALIGNMENT REVIEW

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

CURRENT STATUS

- One set of aligned Essential skills to drive Postsecondary and Workforce Readiness inclusion in all Career & Technical Education programs.
- 52 pathways with validated academic alignments
- 12 pathways with revised standards ready for alignment (currently there are no approved programs in these pathways)
- 21 pathways where no secondary programming currently exists. Standards and alignments will be developed as programs emerge.
- Available for review at: www.coloradostateplan.com/content_standards.htm
National Science Education Standards Grades 9-12

**NSES Content Standard K-12: 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
- Evolution and equilibrium
- Form and function

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

**NSES Content Standard B: Physical Science**
As a result of activities in grades 9-12, all students should develop an understanding of—
- Structure of atoms
- Structure and properties of matter
- Chemical reactions
- Motions and forces
- Conservation of energy and increase in disorder
- Interactions of energy and matter

**NSES Content Standard C: Life Science**
As a result of activities in grades 9-12, all students should develop an understanding of—
- The cell
- Molecular basis of heredity
- Biological evolution
- Interdependence of organisms
- Matter, energy, and organization in living systems
- Behavior of organisms

**NSES Content Standard D: Earth and Space Science**
As a result of activities in grades 9-12, all students should develop an understanding of—
- Energy in the earth system
- Geochemical cycles
- Origin and evolution of the earth system
- Origin and evolution of the universe
**NSES Content Standard E: Science and Technology**
As a result of activities in grades 9-12, all students should develop—
- Abilities of technological design
- Understandings about science and technology

**NSES Content Standard F: Science in Personal and Social Perspectives**
As a result of activities in grades 9-12, all students should develop understanding of—
- Personal and community health
- Population growth
- Natural resources
- Environmental quality
- Natural and human-induced hazards
- Science and technology in local, national, and global challenges

**NSES Content Standard G: History and Nature of Science**
As a result of activities in grades 9-12, all students should develop understanding of—
- Science as a human endeavor
- Nature of scientific knowledge
- Historical perspectives

Source: National Research Council (NRC) *National Science Education Standards.*
Unit 1 – Introduction to Design

Preface

This unit is an introduction to different facets of design and will emphasize the following: evolution and history of design, the steps in a design process, the importance of proper sketching techniques, measurement and tools used in design, and the use of those tools and techniques to innovate or invent solutions to problems. Students will be introduced to a variety of skill building opportunities that will enhance their design skills and prepare them for the remaining units in this course.

Concepts

1. There are many design processes that guide professionals in developing solutions to problems.
2. A design process most used by engineers includes defining a problem, brainstorming, researching, identifying requirements, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype, testing, refining, making, and communicating results.
3. Engineers create sketches to quickly record, communicate, and investigate ideas.
4. Engineers apply dimensions to drawings to communicate size information.
5. Statistical analysis of measurements can help verify the quality of a design or process.
6. Engineers use Computer Aided Design modeling systems to quickly generate and annotate working drawings.

Essential Questions

Lesson 1.1 Introduction to a Design Process

1. What is the design process and how is it used?
2. Why is brainstorming important when modifying or improving a product?
3. What is meant by constraints and criteria?
4. What are common constraints put on a product?
5. What comes to mind when you hear the words evolution of a product?
6. What kinds of situations might keep a designer from moving sequentially through a design process?
7. What is an engineer’s notebook and how is it used?
8. Why do engineers use graphics to record and communicate information?

Lesson 1.2 Introduction to Technical Sketching and Drawing

1. Why is sketching an important engineering skill?
2. What is the difference between sketching and drawing?
3. What does the term isometric sketch mean?
4. What does the term oblique sketch mean?
5. What is perspective sketching?
6. What advantages do pictorial drawings have over multiview drawings?
7. What are the three main views of a sketch or drawing that are required to depict an object?
8. Why should you not erase construction lines?
9. If you are given an object with an unknown function and told to create a sketch of it, how would you determine what the front view would look like?
10. What is orthographic projection?

Lesson 1.3 Measurement and Statistics
1. Why did our ancestors create measurement standards?
2. Who is responsible for establishing measurement standards that are used by engineers and manufacturers today?
3. What methods do engineers use to communicate an object’s dimensional information?
4. What problems could result from incorrectly converting measurements from one system to another?
5. What factors influence the precision of a measuring tool?
6. What information can a designer use from a statistical analysis of a product?

Lesson 1.4 Puzzle Cube
1. Why is a design process so important to follow when creating a solution to a problem?
2. What two-dimensional shapes are most often associated with three-dimensional forms?
3. What is the difference between a geometric constraint and a numeric constraint?
4. Why would you create a prototype of a product before the actual production takes place?

Lessons
Lesson 1.1 Introduction to a Design Process
Lesson 1.2 Introduction to Technical Sketching and Drawing
Lesson 1.3 Measurement and Statistics
Lesson 1.4 Puzzle Cube

Unit Evaluation
The Essential Questions and Conclusion questions at the end of each activity may be used along with the Assessment suggestions provided in each lesson to develop summative assessment tools, such as tests or end of unit projects.
Lesson 1.1 – Introduction to a Design Process

Preface

The word design is used throughout many disciplines, each with its own slightly different definition. Technical and non-technical people alike use the word in its generic form to identify something that is the product of a conscious human effort.

Design as a process is the cornerstone of all engineering professions. Professionals often use the phrase “the design process” when talking about a method by which problems are identified and solutions are generated. This sometimes suggests there is only one way to plan or problem-solve. In fact, there are a multitude of methods to design. Some are very vague, while others are quite detailed. But, they all start with a need, a problem, or a want, and follow through a series of steps or phases that result in the creation of something that serves as a solution to the need, problem, or want.

This lesson focuses on the tools that engineers use to solve problems. Students will study design processes and will use one of them to guide their actions. It is important to explain the use of the particular, identified design process in this course based on Standards for Technological Literacy Standard 8, Benchmark H. For purposes of this lesson and the course, 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
- communicating processes and results


This nationally recognized design process will be used throughout all Project Lead The Way® curricula.

In this lesson, students will be introduced to the idea that there are many design processes and no single design process is better or more useful than another. They will learn that the selected design process is the most accepted. Students will encounter each step in more detail as they gain knowledge and experience throughout the course. This lesson is designed to assess what students know at the beginning of the course. As students complete the Activities, Projects, and Problems in this lesson, the teacher will be able to determine the amount of instruction needed for the remaining lessons in this course.
Concepts
1. There are many design processes that guide professionals in developing solutions to problems.
2. A design process most used by engineers includes defining a problem, brainstorming, researching, identifying requirements, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype, testing, refining, making, and communicating results.
3. Design teams use brainstorming techniques to generate large numbers of ideas in short time periods.
4. Engineers conduct research to develop their knowledge base, stimulate creative ideas, and make informed decisions.
5. A designer uses an engineer’s notebook to chronologically document all aspects of a design project.

Standards and Benchmarks Addressed

Standards for Technological Literacy

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

**BM B:** Design is a creative process.

**BM C:** The design process is a purposeful method of planning practical solutions to problems.

**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 C:** The engineering design process involves defining a problem, generating ideas, selecting a solution, testing the solution(s), making the item, evaluating it, and presenting the results.

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

**BM E:** The process of experimentation, which is common in science, can also be used to solve technological problems.

**BM G:** Invention is a process of turning ideas and imagination into devices and systems.

**BM H:** Some technological problems are best solved through experimentation.

**BM I:** Research and development is a specific problem-solving approach that is used intensively in business and industry.

**Standard 17:** Students will develop an understanding of and be able to select and use information and communication technologies.
BM J: The design of a message is influenced by such factors as the intended audience, medium, purpose, and nature of the message.

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

- Systems, order, and organization

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

- Abilities of technological design

Principles and Standards for School Mathematics

Representation: Instructional programs from pre-kindergarten through grade 12 should enable all students to use representations to model and interpret physical, social, and mathematical phenomena.

Standards for English Language Arts

Standard 3: Students apply a wide range of strategies to comprehend, interpret, evaluate, and appreciate texts. They draw on their prior experience, their interactions with other readers and writers, their knowledge of word meaning and other texts, their word identification strategies, and their understanding of textual features (e.g. sound-letter correspondence, sentence structure, context, graphics).

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 nonprint texts, artifacts, and people) to communicate their discoveries in ways that suit their purpose and audience.
Performance Objectives

It is expected that students will:

- Apply engineering notebook standards and protocols when documenting their work during the school year.
- Identify and apply group brainstorming techniques and the rules associated with brainstorming.
- Research a product’s history, develop a PowerPoint presentation, list chronologically the major innovations to a product, and present findings to a group.
- Use online and published works to research aspects of design problems.
- Identify the design process steps used in given scenarios and be able to list the steps, if any are missing.

Assessment

Explanation

1. Students will explain how knowledge of brainstorming and sketching aid in the design of a product, such as a coffee cup, and depict their explanation in a bookmark.

2. Students will explain the significance of effective communication to a young student in grades six through eight.

3. Students will explain the process of the development of the first controlled, sustainable human-powered aircraft to a student that was absent.

Interpretation

4. Students will interpret and explain how the design process may be used in preparing for a sports competition or in common everyday events, such as writing a paper.

Application

5. Students will apply their knowledge of research, the design process, and documentation in the critique of a product that they use everyday, such as a cell phone or MP3 player.

Essential Questions

1. What is the design process and how is it used?
2. Why is brainstorming important when modifying or improving a product?
3. What is meant by constraints and criteria?
4. What are common constraints put on a product?
5. What comes to mind when you hear the words evolution of a product?
6. What kinds of situations might keep a designer from moving sequentially through a design process?
7. What is an engineer’s notebook and how is it used?
8. Why do engineers use graphics to record and communicate information?
Key Terms

Assessment  Brainstorming  Client
Constraint  Design  Design Brief
Design Process  Designer  Engineer
Engineer’s Notebook  Evolution  Innovation
Invention  Iterative  Problem Identification
Process  Product  Research
Sequential  Solution  Standard
Target Consumer  Time Line Chart

A list of Key Terms is provided in the Teacher Guidelines at the end of this lesson.

Day-by-Day Plans

Time: 11 days

NOTE: In preparation for teaching, it is strongly recommended that the teacher read the Teacher Notes for this lesson. This lesson is designed to assess what students know at the beginning of the course. As students complete the Activities, Projects, and Problems in this lesson, the teacher will be able to determine the amount of instruction needed for the remaining lessons in this course.

Day 1:

□ The teacher will present Concepts, Key Terms, and Essential Questions, in order to provide a lesson overview.
□ The teacher will present Engineers.ppt.
□ The teacher will distribute an engineer’s notebook to each student or have students create their own.
□ Note: The teacher will determine whether students will record their notes in a daily journal, portfolio, or their engineer’s notebook. For purposes of written directions in the day-by-day for each lesson in this course, it will be assumed students will record their notes in a journal. The journal may be a three-ring binder, spiral bound notebook, or an electronic document.
□ The teacher will distribute Sample Engineer’s Notebook Entries to each student and discuss what constitutes acceptable and unacceptable entries.
□ The teacher will present Engineer’s Notebook.ppt.
□ Note: The teacher may want to present the extended version of this PowerPoint. The extended version is located in the Instructional Resources at the end of this lesson.
□ Students will take notes in their journals while the teacher makes the presentation.
□ Students will be advised to keep work for the creation of portfolios. Portfolios will be discussed in Lesson 1.4.
Day 2 - 3:
- Students will participate in a teacher-led discussion on how society has changed because of a product or technology.
- The teacher will identify two or three major inventions that have made life easier, such as the automobile and telephone, to stimulate class discussion.
- The teacher will distribute and introduce Activity 1.1.1 Beverage Container.
- The teacher will present the Rules for Brainstorming.ppt.
- Students will begin work on Activity 1.1.1 Beverage Container.
- **Note:** The teacher may have other common objects to show that will offer students different experiences in learning about the parts of the design process in an impromptu way.
- The teacher may want to provide graph paper for the sketching located in the Teacher Guidelines located at the end of this lesson.
- The teacher will serve as a facilitator and keep students on task by offering cues and reiterating the problem statement.
- Students will present Activity 1.1.1 Beverage Container ideas to the class.
- The teacher will lead a discussion using the steps in the design process and possible constraints that would have to be addressed when redesigning the item. Refer to the Teacher Notes for a detailed explanation.

Day 4 - 6:
- The teacher will present the Evolution of Product Design.ppt.
- Students will take notes in their journals.
- The teacher will introduce and distribute Activity 1.1.2 Product Evolution and Activity 1.1.2 Product Evolution Rubric.
- **Optional:** The teacher may want to present Introduction to Research.ppt even though the design of this lesson is to assess students’ knowledge and ability without additional instruction or guidance.
- The teacher and students will discuss the expectations of the activity and how the rubric will be used to assess the activity.
- Students will begin work on Activity 1.1.2 Product Evolution using an approved product from their hobby or interest.

Day 7 - 8:
- Students will deliver their PowerPoint presentations to the class.
- **Note:** The teacher may want to invite an administrator, counselor, or member from the partnership team to view presentations.
- The teacher will assess the presentations using the Activity 1.1.2 Product Evolution Rubric.

Day 9 - 11:
- The teacher will distribute Example Design Process.
- The teacher will present the Design Process Overview.ppt.
- Students will take notes in their journals.
- The teacher will distribute Activity 1.1.3 Gossamer Condor.
- The teacher will show The Flight of the Gossamer Condor.
Note: The teacher may wish to use another video from his or her past experiences that covers the design process. However, the teacher will need to create a working document to accompany the video of choice.

Students will watch the film and complete Activity 1.1.3 Gossamer Condor.

The teacher will review Activity 1.1.3 Gossamer Condor Design and lead the class in a discussion on the iterative nature, the use of a design process, and the way it will be used throughout the remainder of the course.

The teacher will assess the students using Activity 1.1.3 Gossamer Condor Answer Key

Instructional Resources

PowerPoint Presentations
- Engineers
- Engineer’s Notebook
- Engineer’s Notebook long version
- Rules for Brainstorming
- Evolution of Product Design
- Introduction to Research
- Design Process Overview

Word Documents
- Activity 1.1.1 Beverage Container
- Activity 1.1.2 Product Evolution
- Activity 1.1.3 Gossamer Condor Design Brief

Answer Keys and Rubrics
- Activity 1.1.2 Product Evolution Rubric
- Activity 1.1.3 Gossamer Condor Design Brief Answer Key

Teacher Guidelines
- Lesson 1.1 Teacher Notes
- Sample Engineering Notebook Entries
- Example Design Process
- Lesson 1.1 Key Terms Only in Word
- Lesson 1.1 Key Terms and definitions in Excel
- Isometric graph paper
- Orthographic graph paper
Reference Sources


National Council of Teachers of English (NCTE) and International Reading Association (IRA) (1996). *Standards for English language arts*.


Lesson 1.2 – Introduction to Technical Sketching and Drawing

Preface

It is often said that a picture is worth a thousand words. This proverb is very true when communicating ideas to solving problems. To properly communicate technical information about objects that must be manufactured, fluency in the universal language of technical drawing is required. One of the first steps to learning this language is developing the ability to sketch.

Visualizing, communicating, exploring, and documenting ideas occur throughout the process of design. The process begins when a client and an engineer meet for the first time to define a problem; when research requires field measurements to be taken so that a scenario can be replicated; when an idea occurs during lunch and must be quickly recorded on a napkin before it is lost; when teams of people feed off each other’s ideas and brainstorm possible solutions; when an engineer works out the details of a design solution so that it can be prototyped and tested; and when a solution has been proven to work and must be documented for reproduction.

Technical sketching differs from technical drawing: technical sketches are made with a pencil, paper, and an idea, while technical drawing advances a sketch to follow specific technical drawing guidelines that employ the use of tools, such as isometric graph paper and the aid of a computer. Likewise, technical sketching differs from artistic sketching. Technical sketches follow the same standards that govern the development of technical drawings except the sketches are done freehand.

As they advance in their experiences and skills through the course, students will learn basic rules of technical sketching in this lesson and will learn the drawing standards that apply. The understanding of technical sketching is critical for designers when effectively conveying their ideas about a product. Sketching is the beginning stages of product development. Students will learn how to sketch isometric, oblique, perspective, and multiview sketches of various objects.

Concepts

1. Engineers create sketches to quickly record, communicate, and investigate ideas.
2. Pictorials and tonal shading techniques are used in combination to give sketched objects a realistic look.
3. Designers use isometric, oblique, perspective, and multiview sketching to maintain an object’s visual proportions.
4. A multiview projection is the most common method of communicating the shape and size of an object that is intended for manufacture.
Standards and Benchmarks Addressed

Standards for Technological Literacy

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

BM B: Expressing ideas to others verbally and through sketches and models is an important part of the design process.

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

BM E: The process of designing involves presenting some possible solutions in visual form and then selecting the best solution(s) from many.

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

BM C: People use symbols when they communicate by technology.

BM G: Letters, characters, icons, and signs are symbols that represent ideas, quantities, elements, and operations.

BM K: The use of symbols, measurements, and drawings promotes clear communication by providing a common language to express ideas.

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

National Science Education Standards

Unifying Concepts and Processes Standard K-12: As a result of activities in grades 9-12, all students should develop

- Evidence, models, and explanation

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

- Abilities of technological design

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; specify locations and describe spatial relationships using coordinate geometry and other representational systems; apply transformations and use symmetry to analyze mathematical situations; and 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; and apply appropriate techniques, tools, and formulas to determine measurements.

Connections: Instructional programs from pre-kindergarten through grade 12 should enable all students to 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; and 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 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 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:

☐ Identify, sketch, and explain the function of points, construction lines, object lines, and hidden lines.

☐ Plot points on grid paper to aid in the creation of sketches and drawings.

☐ Explain the concepts of technical sketching and drawing.

☐ Sketch an isometric view of simple geometric solids.

☐ Explain how an oblique view of simple geometric solids differs from an isometric view.

☐ Sketch one-point, two-point, and three-point perspectives of simple geometric solids.

☐ Describe the concept of proportion as it relates to freehand sketching.

☐ Sketch multiview drawings of simple geometric solids.

☐ Determine the front view for a given object.

Assessment

Explanation

1. Students will explain the difference between one-point, two-point, and three-point perspectives.

Application

2. Students will explain to a younger audience how sketching and shading techniques are used by engineers and in an art class.

3. Students will analyze and interpret ways in which political, cultural, social, and psychological concepts are explored in the world of art.
Essential Questions
1. Why is sketching an important engineering skill?
2. What is the difference between sketching and drawing?
3. What does the term *isometric sketch* mean?
4. What does the term *oblique sketch* mean?
5. What is perspective sketching?
6. What advantages do pictorial drawings have over multiview drawings?
7. What are the three main views of a sketch or drawing that are required to depict an object?
8. Why should you not erase construction lines?
9. If you are given an object with an unknown function and told to create a sketch of it, how would you determine what the front view would look like?
10. What is orthographic projection?

Key Terms

<table>
<thead>
<tr>
<th>Construction Line</th>
<th>Depth</th>
<th>Documentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edge</td>
<td>Ellipse</td>
<td>Freehand</td>
</tr>
<tr>
<td>Grid</td>
<td>Height</td>
<td>Hidden Line</td>
</tr>
<tr>
<td>Isometric Sketch</td>
<td>Line</td>
<td>Line Conventions</td>
</tr>
<tr>
<td>Line Weight</td>
<td>Manufacture</td>
<td>Measurement</td>
</tr>
<tr>
<td>Multiview Drawings</td>
<td>Object Line</td>
<td>Oblique Sketch</td>
</tr>
<tr>
<td>Orthographic Projection</td>
<td>Perspective Sketch</td>
<td>Pictorial Sketch</td>
</tr>
<tr>
<td>Plane</td>
<td>Point</td>
<td>Profile</td>
</tr>
<tr>
<td>Projection Line</td>
<td>Projection Plane</td>
<td>Proportion</td>
</tr>
<tr>
<td>Scale</td>
<td>Shading</td>
<td>Shape</td>
</tr>
<tr>
<td>Size</td>
<td>Sketch</td>
<td>Solid</td>
</tr>
<tr>
<td>Technical Working Drawing</td>
<td>Tone</td>
<td>Vanishing Point</td>
</tr>
<tr>
<td>Views</td>
<td>Visualize</td>
<td>Width</td>
</tr>
</tbody>
</table>

A list of Key Terms is provided in the Teacher Guidelines at the end of this lesson.
Day-by-Day Plans

Time: 11 days

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

Day 1:
- The teacher will present Concepts, Key Terms, and Essential Questions, and provide a lesson overview.
- The teacher will present slide one through seven of the Line Conventions.ppt.
- Students will take notes in their journals.

Day 2:
- The teacher will present the Isometric Pictorials.ppt.
- Students will take notes in their journals.
- The teacher will distribute Activity 1.2.1 Isometric Sketches.
- The teacher will provide Activity 1.2.1a Isometric Graph Paper handouts for or the Isometric Grid paper located in the Teacher Guidelines at the bottom of the lesson for the students to use.
- Students will begin work on Activity 1.2.1 Isometric Sketches.

Day 3:
- Students will complete Activity 1.2.1 Isometric Sketches.
- The teacher will assess student work using Activity 1.2.1 Isometric Sketches Answer Key.

Day 4:
- The teacher will present the Oblique Pictorials.ppt.
- Students will take notes in their journals.
- The teacher will distribute Activity 1.2.2 Oblique Sketches.
- Students will begin work on Activity 1.2.2 Oblique Sketches.

Day 5:
- Students will complete Activity 1.2.2 Oblique Sketches.
- The teacher will assess student work using Activity 1.2.2 Oblique Sketches Answer Key.

Day 6:
- The teacher will present the Perspective Sketches.ppt.
- Students will take notes in their journals.
- The teacher will distribute Activity 1.2.3 Perspective Sketches.
- Students will begin work on Activity 1.2.3 Perspective Sketches.
- Note: The purpose of the activity is to show students how to quickly sketch a perspective view.
Day 7:
- Students will complete Activity 1.2.3 Perspective Sketches.
- The teacher will assess student work using Activity 1.2.3 Perspective Sketches Answer Key.

Day 8-11:
- The teacher will present the Multiview Sketching.ppt.
- Students will take notes in their journals.
- The teacher will distribute Activity 1.2.4 Multiview Sketches.
- The teacher will provide instruction to the class on hidden lines and center lines and their use in technical sketches.
- The teacher may use parts of the Line Conventions.ppt used earlier in the lesson to provide instruction.
- Students will begin work on Activity 1.2.4 Multiview Sketches.
- Students will complete Activity 1.2.4 Multiview Sketches.
- The teacher will assess student work using Activity 1.2.4 Multiview Sketches Answer Key.
- Note: If the teacher needs more time for drill and practice on sketching techniques, additional time could be adjusted throughout the lesson.

Instructional Resources
PowerPoint Presentations
- Line Conventions
- Isometric Pictorials
- Oblique Pictorials
- Perspective Sketches
- Multiview Sketching

Word Documents
- Activity 1.2.1 Isometric Sketches
- Activity 1.2.2 Oblique Sketches
- Activity 1.2.3 Perspective Sketches
- Activity 1.2.4 Multiview Sketches

Answer Keys and Rubrics
- Activity 1.2.1 Isometric Sketches Answer Key
- Activity 1.2.2 Oblique Sketches Answer Key
- Activity 1.2.3 Perspective Sketches Answer Key
- Activity 1.2.4 Multiview Sketches Answer Key
Teacher Guidelines

Lesson 1.2 Teacher Notes
Lesson 1.2 Key Terms

Lesson 1.2 Key Terms and definitions in Excel
Isometric graph paper
Orthographic graph paper

Student Resources
Activity 1.2.1 Isometric Graph Paper

Reference Sources


National Council of Teachers of English (NCTE) and International Reading Association (IRA) (1996). *Standards for English language arts*.


Lesson 1.3 – Measurement and Statistics

Preface
The practice of measuring is older than recorded history. Every human civilization throughout history developed its own measuring tools and, along with them, its own measuring standards. It was through the establishment of measuring tools and standards that the Egyptians were able to build their giant pyramids, and the Romans were able to build their roads and aqueducts. Shared understanding and communication established through standardization played a key role in their successful outcome. Standardization is what allows many people to work individually on parts that come together to form a finished product or system. Without measurement standards, manufactured parts would not be interchangeable and mass production could not exist. Measurement is so important that the founding fathers of the United States included it in the Constitution, giving Congress the power to set uniform standards for weights and measures. Today, the American National Standards Institute serves as the unifying force system for the measurement used in the United States. This lesson provides an introduction to measurement through the study of linear distance and angles.

Since the beginning, scientists have realized the laws of nature are not bound to the borders between kingdoms or countries, and that uniform standards of measure form the foundation for changing the secrets of the universe into human knowledge. In the midst of the French Revolution, scientists developed a new system of measurement that was simple, logical, and well-suited to the needs of both scientists and engineers. Since its inception 220 years ago, the metric system has spread throughout the industrialized world, and is now the international standard for acquiring and communicating measurements.

In this lesson, students will learn about measurement and statistics. They will apply what they have learned through

- basic dimensioning techniques.
- reading English and metric scales.
- converting measurements between English and metric units.
- performing precision measurement using dial calipers.
- recording data
- performing basic statistical analysis.
- creating graphs of statistical information.

Concepts
1. Measurement systems were developed out of the need for standardization.
2. Engineers apply dimensions to drawings to communicate size information.
3. Manufactured parts are often created in different countries, where dimensional values are often converted from one standard unit to another.
4. The amount of variation that can be measured depends on the precision of the measuring tool.
5. Statistical analysis of measurements can help to verify the quality of a design or process.
6. Engineers use graphics to communicate patterns in recorded data.
Standards and Benchmarks Addressed

Standards for Technological Literacy

Standard 1: Students will develop an understanding of the characteristics and scope of technology.
BM B: All people use tools and techniques to help them do things.

Standard 2: Students will develop an understanding of the core concepts of technology.
BM K: Tools and machines extend human capabilities, such as holding, lifting, carrying, fastening, separating, and computing.

Standard 3: Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.
BM A: The study of technology uses many of the same ideas and skills as other subjects.
BM F: Knowledge gained from other fields of study has a direct effect on the development of technological products and systems.

Standard 7: Students will develop an understanding of the influence of technology on history.
BM E: The design and construction of structures for service or convenience have evolved from the development of techniques for measurement, controlling systems, and the understanding of spatial relationships.

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

Science and Technology Standard E: As a result of activities in grades 9-12, all students should develop
- Abilities of technological design
Principles and Standards for School Mathematics

Number 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; and 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; and 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.

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; and 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.

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:

- Research and design a CD cover or book jacket on the origins of the measurement systems.
- Measure and record linear distances using a scale to a precision of 1/16 inch and 1 mm.
- Measure and record linear distances using a dial caliper to a precision of 0.001 inch.
- Add and subtract U.S. standard and metric linear measurements.
- Convert linear distance measurements from inches to millimeters and vice versa.
- Apply linear dimensions to a multiview drawing.
- Calculate the mean, mode, median, and range of a data set.
- Create a histogram of recorded measurements showing data elements or class intervals, and frequency.

**Assessment**

**Explanation**
1. Students will explain the history of measurement to a younger student using their book jacket or CD cover as an example.

**Application**
2. Assess a student’s journal for evidence of effective communication of ideas such as,
   a. Do students’ sketches and drawings clearly communicate their ideas?
   b. Have students used a variety of methods to communicate their ideas?
   c. Have students integrated information from a variety of sources into their work?
3. Students will demonstrate and explain to another student how to measure objects using a scale or dial caliper.

**Interpretation**
4. Students will make journal entries reflecting on their learning and experiences. Example of prompts for the general entries: Write about what you learned in class today. How do you know when your sketches are ready to transfer into a drawing? What is something you learned today that you did not understand or know before?

**Self-Knowledge**
5. Students will be required to reflect on their work in their journals by recording their thoughts and ideas. They may use their self-assessments as a basis for improvement. Ideas and questions students may pose and answer in their journals are:
   □ Today, the hardest part for me to understand was...
   □ When I work in a group, I find that...
   □ When I work by myself, I find that...
   □ What did I accomplish today?
   □ Now that I have done this, what is next?

**Perspective**
6. Students will select an engineering blunder and prepare an essay that expresses two points of view about the role played by measurement.

**Essential Questions**
1. Why did our ancestors create measurement standards?
2. Who is responsible for establishing measurement standards that are used by engineers and manufacturers today?
3. What methods do engineers use to communicate an object’s dimensional information?
4. What problems could result from incorrectly converting measurements from one system to another?
5. What factors influence the precision of a measuring tool?
6. What information can a designer use from a statistical analysis of a product?

Key Terms

<table>
<thead>
<tr>
<th>American National Standards Institute (ANSI)</th>
<th>Accuracy</th>
<th>Caliper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class Interval</td>
<td>Convert</td>
<td>Data</td>
</tr>
<tr>
<td>Data Set</td>
<td>Dimension</td>
<td>Dimension Lines</td>
</tr>
<tr>
<td>English System</td>
<td>Extension Lines</td>
<td>Frequency</td>
</tr>
<tr>
<td>Graph</td>
<td>Histogram</td>
<td>International Organization for Standardization (ISO)</td>
</tr>
<tr>
<td>Mean</td>
<td>Measure</td>
<td>Median</td>
</tr>
<tr>
<td>Metric System</td>
<td>Mode</td>
<td>Normal Distribution</td>
</tr>
<tr>
<td>Numeric Constraint</td>
<td>Precision</td>
<td>Scale</td>
</tr>
<tr>
<td>Standard</td>
<td>Statistics</td>
<td>Two-Dimensional</td>
</tr>
<tr>
<td>Unit</td>
<td>Variation</td>
<td></td>
</tr>
</tbody>
</table>

A list of Key Terms is provided in the Teacher Guidelines at the end of this lesson.

Day-by-Day Plans

Time: 10 days

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

Day 1-2:

- The teacher will present Concepts, Key Terms, and Essential Questions to provide a lesson overview.
- The teacher will distribute and introduce Project 1.3.1 History of Measurement.
- Students will work on and complete Project 1.3.1 History of Measurement.
- The teacher will assess student work using Project 1.3.1 History of Measurement Rubric.
Day 3:
- The teacher will distribute **Activity 1.3.2 English and Metric Linear Measurements.**
- The teacher will distribute and explain the use of the **Activity 1.3.2a Decimal Conversion Chart.**
- The teacher will present **Scale Reading Basics.ppt.**
- Students will take notes in their journal and will refer to **Activity 1.3.2 English and Metric Linear Measurements** while the teacher presents **Scale Reading Basics.ppt.**
- Students will work on **Activity 1.3.2 English and Metric Linear Measurements** and complete the activity for homework.

Day 4-5:
- The teacher will assess the homework on **Activity 1.3.2 English and Metric Linear Measurements** using **Activity 1.3.2 English and Metric Linear Measurements Answer Key.**
- The teacher will distribute **Activity 1.3.3 fischertechniks® Block Measurement** or other activity – see Teacher Notes.
- The teacher will present **Dial Calipers.ppt.**
- Students will take notes in their journal and will refer to **Activity 1.3.3 fischertechniks® Block Measurement** while the teacher presents Dial Calipers.ppt.
- Students will complete **Activity 1.3.3 fischertechniks® Block Measurement.**

Day 6-7:
- The teacher will assess the students on **Activity 1.3.3** using **Activity 1.3.3 fischertechniks® Block Measurement Answer Key.**
- **Note:** Activity 1.3.3 fischertechniks® Block Measurement Answer Key may have different answers than those the students get due to variance in the blocks.
- **Optional:** The teacher will want to present slide 9-10 of the **Line Convention.ppt**
- The teacher will present **Dimension Practices .ppt.**
- Students will take notes in their journal.
- The teacher will distribute and explain **Activity 1.3.4 Linear Dimensions.**
- Students will work on the **Activity 1.3.4 Linear Dimensions.**
- The teacher will assess Activity 1.3.4 Linear Dimensions using **Activity 1.3.4 Linear Dimensions Answer Key.**

Day 8-10:
- **Optional:** The teacher will introduce students to the 3-D modeling software prior to the start of **Activity 1.3.5.**
- The teacher will present **Introduction to Basic Statistics.ppt.**
- Students will take notes in their journal.
- The teacher will distribute a dial caliper, 27 hardwood cubes, and **Activity 1.3.5 Applied Statistics** to each student.
Students will begin work on Activity 1.3.5 Applied Statistics.
Students will complete Activity 1.3.5 Applied Statistics.
The teacher will assess student work. Answers will vary due to variance in cubes.

**Instructional Resources**

- **PowerPoint Presentations**
  - Scale Reading Basics
  - Dial Calipers
  - Dimension Practices
  - Introduction to Basic Statistics

- **Word Documents**
  - Project 1.3.1 History of Measurement
  - Activity 1.3.2 English and Metric Linear Measurements
  - Activity 1.3.3 fischertechniks® Block Measurement
  - Activity 1.3.4 Linear Dimensions
  - Activity 1.3.5 Applied Statistics

- **Teacher Guidelines**
  - Lesson 1.3 Teacher Notes
  - Activity 1.3.2a Decimal Conversion Chart
  - Lesson 1.3 Key Terms
  - Lesson 1.3 Key Terms and definitions in Excel

- **Answer Keys and Rubrics**
  - Project 1.3.1 History of Measurement Rubric
  - Activity 1.3.2 English and Metric Linear Measurements Answer Key
  - Activity 1.3.3 fischertechniks® Block Measurement Answer Key
  - Activity 1.3.4 Linear Dimensions Answer Key
Reference Sources


National Council of Teachers of English (NCTE) and International Reading Association (IRA) (1996). *Standards for English language arts*.


Lesson 1.4 – Puzzle Cube

Preface

The process of design is inherently graphical. As ideas are developed, they are often jotted down on paper for later recollection and further development. As ideas are formalized, greater accuracy is required. At this point, sketches are converted to computer models and formal drawings, which include annotations describing the size and characteristics of the design features. Design engineers who have a strong understanding of shapes and other geometric relationships develop these formal drawings.

Today’s software that employs parametric design functionality requires an understanding of prior knowledge and concepts learned earlier in this unit. Students will transfer this prior knowledge to a project that will give a first hand experience at what a designer would go through given the problem statement from his or her boss.

In this lesson, students will learn how to create a product from conception to reality. They will do this by applying the design process steps first hand in the creation of their product. Students will live the life of a product designer and create a solution to a problem that exists for a company. They will also design a package for the puzzle cube.

Concepts

1. Three-dimensional forms are derived from two-dimensional shapes.
2. The results of the design process are commonly displayed as a physical model.
3. Engineers develop models to communicate and evaluate possible solutions.
4. Geometric and numeric constraints are used to define the shape and size of objects in Computer Aided Design (CAD) modeling systems.
5. Design engineers use CAD modeling systems to quickly generate and annotate working drawings.
6. Packaging not only protects a product, but contributes to that product’s commercial success.

Standards and Benchmarks Addressed

Standards for Technological Literacy

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

BM A: The study of technology uses many of the same ideas and skills as other subjects.

BM C: Various relationships exist between technology and other fields of study.

BM F: Knowledge gained from other fields of study has a direct effect on the development of technological products and systems.

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

BM A: The engineering design process includes identifying a
problem, looking for ideas, developing solutions, and sharing solutions with others.

**BM B:** Expressing ideas to others verbally and through sketches and models is an important part of the design process.

**BM D:** When designing an object, it is important to be creative and consider all ideas.

**BM F:** Design involves a set of steps, which can be performed in different sequences and repeated as needed.

**BM G:** Brainstorming is a group problem-solving design process in which each person in the group presents his or her ideas in an open forum.

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

**Standard 11**

Students will develop the abilities to apply the design process.

**BM H:** Apply a design process to solve problems in and beyond the laboratory-classroom.

**BM I:** Specify criteria and constraints for the design.

**BM J:** Make two-dimensional and three-dimensional representations of the designed solution.

**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 17**

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

**BM K:** The use of symbols, measurements, and drawings promotes clear communication by providing a common language to express ideas.

**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 Standard K-12:** As a result of activities in grades 9-12, all students should develop—

- Change, constancy, and measurement
- 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
Principles and Standards for School Mathematics

Number 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; and compute fluently and make reasonable estimates.

Algebra: Instructional programs from pre-kindergarten through grade 12 should enable all students to understand patterns, relations, and functions; represent and analyze mathematical situations and structures using algebraic symbols; use mathematical models to represent and understand quantitative relationships; and analyze change in various contexts.

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; and 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; and apply appropriate techniques, tools, and formulas to determine measurements.

Communication: Instructional programs from pre-kindergarten through grade 12 should enable all students to organize and consolidate their mathematical thinking through communication; and communicate their mathematical thinking coherently and clearly to peers, teachers, and others.

Connections: Instructional programs from pre-kindergarten through grade 12 should enable all students 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 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:*

- Brainstorm and sketch possible solutions to an existing design problem.
- Select an approach that meets or satisfies the constraints given in a design brief.
- Create simple extruded solid Computer Aided Design (CAD) models from dimensioned sketches.
- Generate dimensioned multiview drawings from simple CAD models.
- Measure and Fabricate parts for a functional prototype from the CAD multiview drawings.
- Assemble the product using the CAD modeling software.
- Test and evaluate the prototype and record results.
- Apply geometric and numeric constraints to CAD sketches.
- Identify the purpose of packaging in the design of consumer products.

**Assessment**

*Explanation*

1. Students will explain why design options of a project are determined by criteria and constraints.

*Application*

2. Students will design a product from a different form of material waste, such as plastic pipe, just as they did for the puzzle cube.

*Interpretation*

3. Students will illustrate their proposed project and use their illustration to explain how the project relates to everything they have learned thus far.
4. Students will explain the role of geometric shapes to the design of their puzzle cube.
5. Students will be assessed (Puzzle Cube Package Rubric) on their ability to create a package for their puzzle cubes.

**Essential Questions**

1. Why is a design process so important to follow when creating a solution to a problem?
2. What two-dimensional shapes are most often associated with three-dimensional forms?
3. What is the difference between a geometric constraint and a numeric constraint?
4. Why would you create a prototype of a product before the actual production takes place?

Key Terms

<table>
<thead>
<tr>
<th>Annotate</th>
<th>Assembly Drawing</th>
<th>Computer-Aided Design or Computer-Aided Drafting (CAD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Brief</td>
<td>Design Statement</td>
<td>Extrusion</td>
</tr>
<tr>
<td>Geometric Constraint</td>
<td>Logo</td>
<td>Manufacturer’s Joint</td>
</tr>
<tr>
<td>Marketing</td>
<td>Mock-up</td>
<td>Model</td>
</tr>
<tr>
<td>Numeric Constraint</td>
<td>Origin</td>
<td>Packaging</td>
</tr>
<tr>
<td>Plane</td>
<td>Prototype</td>
<td>Scale Model</td>
</tr>
<tr>
<td>Scoring</td>
<td>Solid Modeling</td>
<td>Three-Dimensional</td>
</tr>
</tbody>
</table>

Two-Dimensional

A list of Key Terms is provided in the Teacher Guidelines at the end of this lesson.

Day-by-Day Plans

Time: 17 days

**NOTE:** In preparation for teaching this lesson, it is strongly recommended that the teacher read the Teacher Notes. At the end of this lesson, present Portfolios.ppt and allow students time to begin work on portfolios.

Day 1:

- The teacher will present Concepts, Key Terms, and Essential Questions to provide a lesson overview.
- The teacher will distribute and introduce Project 1.4.1 Puzzle Design Challenge.
- The teacher will discuss constraints, requirements and questions about the project.
- The teacher will review the design process using Example Design Process distributed in Lesson 1.1.
- Students will keep this document available throughout this lesson.
Day 2:
- The teacher will distribute and introduce **Activity 1.4.2 Puzzle Part Combinations**.
- The teacher will distribute **Activity 1.4.2 Isometric Graph Paper** handout or the Isometric Grid paper located in the **Teacher Guidelines** at the bottom of the lesson for the students to use.
- **Note:** The teacher will review the **Sketched Puzzle Parts Example** for details.
- Students will begin work on Activity 1.4.2 Puzzle Part Combinations.

Day 3-15:
- The teacher will review the requirements for Project 1.4.1 Puzzle Design Challenge.
- Students will continue working on materials to be completed.
- The teacher will review **Example Sketched Puzzle Solution** for details on how students could hand in their decision solution.
- **Note:** The teacher will give an introduction to the 3-D Modeling software if he or she did not introduce it in Lesson 1.3.
- The teacher will keep students on task and demonstrate any details on the 3-D modeling software needed for completion of the project.
- The teacher will assess Project 1.4.1 Puzzle Design Challenge using **Project 1.4.1 Puzzle Design Rubric**.
- **Optional:** The teacher will have students challenge each other on their cube to see the time needed to assemble puzzles. This could be set up as a trial game to see which student’s puzzle cube is the most difficult to assemble and solve.

Day 16:
- The teacher will present **Marketing.ppt**.
- Students will take notes in their engineer’s notebook.
- The teacher will introduce and distribute **Activity 1.4.3 Puzzle Cube Package** and **Activity 1.4.3 Puzzle Cube Package Rubric**.
- Students will begin work on Activity 1.4.3 Puzzle Cube Package.

Day 17:
- Students will complete Activity 1.4.3 Puzzle Cube Package.
- The teacher will assist the students with their package designs.
**Instructional Resources**

- PowerPoint presentations
  - Marketing

**Word Documents**

- Project 1.4.1 Puzzle Design Challenge
- Activity 1.4.2 Puzzle Part Combinations
- Activity 1.4.3 Puzzle Cube Package

**Answer Keys and Rubrics**

- Project 1.4.1 Puzzle Design Rubric
- Activity 1.4.3 Puzzle Cube Package Rubric

**Teacher Guidelines**

**Lesson 1.4**

- Teacher Notes
- Activity 1.4.2 Isometric Graph Paper
- Sketched Puzzle Parts Example
- Example Sketched Puzzle Solution
- Lesson 1.4 Key Terms

**Lesson 1.4 Key Terms and definitions in Excel**

- Isometric graph paper
- Orthographic graph paper

**Reference Sources**


- National Council of Teachers of English (NCTE) and International Reading Association (IRA) (1996). *Standards for English language arts.*


Unit 2 – Design Solutions

Preface

This unit advances the students design skills in the area of geometric shapes and solids, dimensioning, 3D modeling software, and an advanced design. Students will learn how to calculate area and properties of solids. They will be introduced to working in teams and what it takes to come to a consensus. The unit will end with students using the design process to create a solution to a prescribed problem.

Concepts

1. Geometric shapes describe the two or three dimensional contours that characterize an object.
2. The properties of volume and surface area are common to all designed objects and provide useful information to the engineer.
3. Working drawings should contain only the dimensions that are necessary to build and inspect an object.
4. Solid modeling programs allow the designer to create quality designs for production in far less time than traditional design methods.
5. Engineers use CAD models, assemblies, and animations to check for design problems, verify the functional qualities of a design, and communicate information to other professionals and clients.
6. A design process most used by engineers includes defining a problem, brainstorming, researching, identifying requirements, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype, testing, refining, making, and communicating results.
7. Teamwork requires constant communication to achieve the goal at hand.
8. Fluid Power Concepts could be used to enhance design solutions.
**Essential Questions**

**Lesson 2.1 Geometric Shapes and Solids**

9. What are some examples of simple geometric shapes?
10. What two-dimensional shapes are most often associated with three-dimensional forms?
11. For what reasons might a designer need to know the volume and surface area of an object?
12. What is the difference between a geometric constraint and a numeric constraint?
13. What kind of additive and subtractive processes are used to manufacture actual physical objects?

**Lesson 2.2 Dimensions and Tolerances**

1. What is a working drawing?
2. What are dimensioning standards and how are they used?
3. What determines the location of the origin or datum from which all of the edges and features of an object are dimensioned?
4. What is a tolerance?
5. What effect can trailing zeroes in the dimension text have on the cost of a part?
6. Why is it necessary to use common units on a drawing for all dimensions?

**Lesson 2.3 Advanced Modeling**

1. What are the six degrees of freedom that an object has in space?
2. How do assembly constraints differ from geometric and numeric constraints?
3. What is the difference between an assembly and a subassembly?
4. For what reason might an engineer need to create an auxiliary view of an object?
5. For what reason might an engineer need to create a section view of an object?
6. What is a title block?
7. What information is typically on a title block?
8. What is an assembly drawing?
9. What purpose do balloons and a parts list serve in an assembly drawing?
10. What kind of information may be included in a parts list?
Lesson 2.4 Advanced Designs

1. What is a design brief?
2. Why is a design process so important to follow when creating a solution to a problem?
3. What is the purpose of design constraints?
4. What is a decision matrix and why is it used?
5. What does consensus mean, and how do teams use it to make decisions?
6. How are visual design principles and elements used to capture a consumer’s attention?
7. How is the design of a consumer product different then the design of a product used to help a manufacturing process?
8. What is fluid power?
9. What is the difference between hydraulic and pneumatic power systems?
10. How does the use of fluid power aid the use of electronics or other power systems?

Lessons
Lesson 2.1 Geometric Shapes and Solids
Lesson 2.2 Dimensions and Tolerances
Lesson 2.3 Advanced Modeling
Lesson 2.4 Advanced Designs

Unit Evaluation
The Essential Questions and Conclusion questions at the end of each activity may be used along with the Assessment suggestions provided in each lesson to develop summative assessment tools, such as tests or end of unit projects.
Lesson 2.1 – Geometric Shapes and Solids

Preface

Geometric shapes are found everywhere. Take a moment to analyze products or objects you use everyday. Several geometric shapes are what create or make up these products. Engineers who have a strong understanding of these shapes and other geometric relationships can help designers develop and create solutions to problems that exist. As these ideas are formalized, greater accuracy is required. Sketches are then converted to computer models and formal drawings, which include annotations describing the size and characteristics of the design features. Engineers who have a strong understanding of shapes and other geometric relationships develop these formal drawings.

Designers have used Computer Aided Design (CAD) programs for decades to refine ideas and generate images that manufacturers and other professionals can use to make profitable solutions to problems. The development of three-dimensional CAD solid modeling programs has resulted in significant increases in the quality of complex designs while drastically reducing the amount of time needed to produce those designs. Engineers have stated that the development of three-dimensional CAD solid modeling programs made engineering fun. Coming up with an idea for a solution to a problem is an exhilarating experience.

Today's software that employs parametric design functionality requires an understanding of geometric relationships, such as perpendicular, parallel, and tangent. Students will transfer their knowledge of geometric relationships to parametric modeling.

In this lesson, students will apply the skills learned in Unit 1. They will learn how to calculate the area of two-dimensional shapes. Students will learn about material density, and how to calculate the surface area, volume, and weight of three-dimensional solids. Students will also further their knowledge and use of the CAD modeling software used in this course.
Concepts

1. Geometric shapes describe the two or three dimensional contours that characterize an object.
2. The properties of volume and surface area are common to all designed objects and provide useful information to the engineer.
3. CAD systems are used to increase productivity and reduce design costs.
4. Geometric and numeric constraints are used to define the shape and size of objects in CAD modeling systems.
5. Solid CAD models are the result of both additive and subtractive processes.

Standards and Benchmarks Addressed

Standards for Technological Literacy

Standard 1: Students will develop an understanding of the characteristics and scope of technology.
BM D: Tools, materials, and skills are used to make things and carry out tasks.

Standard 2: Students will develop an understanding of the core concepts of technology.
BM I: Tools are used to design, make, use, and assess technology.
BM J: Materials have many different properties.
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.

Standard 3: Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.
BM C: Various relationships exist between technology and other fields of study.
BM F: Knowledge gained from other fields of study has a direct effect on the development of technological products and systems.

Standard 9: Students will develop an understanding of engineering design.
BM B: Expressing ideas to others verbally and through sketches and models is an important part of the design process.
BM E: Models are used to communicate and test design ideas and processes.

Standard 11: Students will develop the abilities to apply the design process.
BM J: Make two-dimensional and three-dimensional representations of the designed solution.
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.

Standard 12: Students will develop the abilities to use and maintain technological products and systems.
BM P: Use computers and calculators to access, retrieve, organize 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 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 Standard K-12: As a result of activities in grades 9-12, all students should develop—
- 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
- Understandings 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

Principles and Standards for School Mathematics

Number 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; and computer fluently and make reasonable estimates.

Algebra: Instructional programs from pre-kindergarten through grade 12 should enable all students to understand patterns, relations, and functions; represent and analyze mathematical situations and structures using algebraic symbols; use mathematical models to represent and understand quantitative relationships; analyze change in various contexts.
**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.

**Communication:** Instructional programs from pre-kindergarten through grade 12 should enable all students to organize and consolidate their mathematical thinking through communication.

**Connections:** Instructional programs from pre-kindergarten through grade 12 should enable all students to 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 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:*

- Identify common geometric shapes and forms by name.
- Calculate the area of simple geometric shapes.
- Calculate the surface area and volume of simple geometric forms.
- Identify and explain the various geometric relationships that exist between the elements of two-dimensional shapes and three-dimensional forms.
Identify and define the axes, planes, and sign conventions associated with the Cartesian coordinate system.

Apply geometric and numeric constraints to CAD sketches.

Utilize sketch-based, work reference, and placed features to develop solid CAD models from dimensioned drawings.

Explain how a given object’s geometry is the result of sequential additive and subtractive processes.

**Assessment**

**Explanation**

1. Students will explain the advantages of using a 3-D CAD modeling program when creating drawings for production.

**Application**

2. Students will create a three-dimensional computer model of a piece of furniture in the classroom.

**Interpretation**

3. Students will explain to a younger student why he or she should learn how to calculate the area of a shape.

4. Students will document and show the importance of using geometric principles to aid in the design of an object.

**Self-knowledge**

5. In a journal entry or lesson test, students will explain how calculating properties of a geometric solid works and why these criteria or constraints are needed when designing.

**Essential Questions**

1. What are some examples of simple geometric shapes?

2. What two-dimensional shapes are most often associated with three-dimensional forms?

3. For what reasons might a designer need to know the volume and surface area of an object?

4. What is the difference between a geometric constraint and a numeric constraint?

5. What kind of additive and subtractive processes are used to manufacture actual physical objects?
Key Terms

<table>
<thead>
<tr>
<th>Acute Triangle</th>
<th>Angle</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axis</td>
<td>Computer-Aided Design or Computer-Aided Drafting (CAD)</td>
<td>Cartesian Coordinate System</td>
</tr>
<tr>
<td>Chamfer</td>
<td>Circle</td>
<td>Circumscribe</td>
</tr>
<tr>
<td>Counterbore</td>
<td>Countersink</td>
<td>Cylinder</td>
</tr>
<tr>
<td>Diameter</td>
<td>Ellipse</td>
<td>Extrusion</td>
</tr>
<tr>
<td>Geometric Constraint</td>
<td>Inscribe</td>
<td>Mass</td>
</tr>
<tr>
<td>Numeric Constraint</td>
<td>Obtuse Triangle</td>
<td>Origin</td>
</tr>
<tr>
<td>Parallelogram</td>
<td>Pattern</td>
<td>Pi</td>
</tr>
<tr>
<td>Plane</td>
<td>Polygon</td>
<td>Prism</td>
</tr>
<tr>
<td>Quadrilateral</td>
<td>Radius</td>
<td>Rectangle</td>
</tr>
<tr>
<td>Regular Polygon</td>
<td>Revolution</td>
<td>Right Triangle</td>
</tr>
<tr>
<td>Rotation</td>
<td>Round</td>
<td>Solid</td>
</tr>
<tr>
<td>Solid Modeling</td>
<td>Space</td>
<td>Square</td>
</tr>
<tr>
<td>Surface Area</td>
<td>Tap</td>
<td>Taper</td>
</tr>
<tr>
<td>Three-Dimensional</td>
<td>Triangle</td>
<td>Two-Dimensional</td>
</tr>
<tr>
<td>Vertex</td>
<td>Volume</td>
<td>Working Drawings</td>
</tr>
</tbody>
</table>

A list of Key Terms is provided in the Teacher Guidelines at the end of this lesson.

Day-by-Day Plans

Time: 10 days

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

NOTE: The files needed for this lesson can be found in the Inventor files folder.
Day 1-2:

- The teacher will present **Concepts, Key Terms, and Essential Questions**, and provide a lesson overview.
- **Note:** The teacher will need to create a customized title block for the classroom before teaching this lesson. A tutorial is located in the **Teacher Notes** for this lesson.
- The teacher will present **Geometric Shapes and Area.ppt**.
- Students will take notes in their journals.
- The teacher will distribute **Project 2.1.1 Shape and Measurement Madness**.
- Students will work on Project 2.1.1 Shape and Measurement Madness and complete the project for homework.
- The teacher will assess students’ work based on completion.

Day 3:

- The teacher will distribute **Activity 2.1.2 Calculating Properties of Shapes**.
- Students will work on Activity 2.1.2 Calculating Properties of Shapes and complete the activity for homework.
- The teacher will assess student work using **Activity 2.1.2 Calculating Properties of Shapes Answer Key**

Day 4-5:

- The teacher will distribute **Activity 2.1.3 Making Sketches in CAD**.
- The teacher will demonstrate how to use the sketch tools within a CAD solid modeling program needed to complete the activity.
- **Note:** The files needed for this project can be found in the **Inventor files** folder. The teacher can access how to assemble and apply motion to the train from the tutorial on the Virtual Academy.
- Students will begin work on Activity 2.1.3 Making Sketches in CAD.
- The teacher will assist students when needed.
- Students will complete Activity 2.1.3 Making Sketches in CAD.
- The teacher will assess students’ work based on completion.

Day 6:

- The teacher will present **Properties of Geometric Solids.ppt**.
- Students will take notes in their journals.
- The teacher will distribute **Activity 2.1.4 Calculating Properties of Solids**.
- Students will begin work on Activity 2.1.4 Calculating Properties of Solids.
- Students will complete Activity 2.1.4 Calculating Properties of Solids for homework.
- The teacher will assess student work using **Activity 2.1.4 Calculating Properties of Solids Answer Key**
Day 7-8:
- The teacher will distribute **Activity 2.1.5 CAD Model Features**.
- The teacher will discuss the Cartesian coordinate system along with the axes and planes associated with this system.
- The teacher will demonstrate how to use the feature tools within a CAD solid modeling program needed to complete the activity.
- **Note:** The files needed for this project can be found in the **Inventor files** folder. The teacher can access how to assemble and apply motion to the train from the tutorial on the Virtual Academy.
- Students will begin work on Activity 2.1.5 CAD Model Features.
- The teacher will assist students when needed.
- Students will complete Activity 2.1.5 CAD Model Features.
- The teacher will assess students’ work based on completion.

Day 9-10:
- The teacher will present **Additive and Subtractive Solid Modeling.ppt**.
- Students will take notes in their journals.
- The teacher will distribute **Project 2.1.6 Modeling Creation**.
- Students will begin work on Project 2.1.6 Modeling Creation.
- The teacher will assist students when needed.
- Students will complete Project 2.1.6 Modeling Creation.
- The teacher will assess students’ work based on completion.

**Instructional Resources**

**PowerPoint Presentations**
- Geometric Shapes and Area
- Properties of Geometric Solids
- Additive and Subtractive Solid Modeling

**Word Documents**
- Project 2.1.1 Shape and Measurement Madness
- Activity 2.1.2 Calculating Properties of Shapes
- Activity 2.1.3 Making Sketches in CAD
- Activity 2.1.4 Calculating Properties of Solids
- Activity 2.1.5 CAD Model Features
- Project 2.1.6 Modeling Creation

**Answer Keys and Rubrics**
- Activity 2.1.2 Calculating Properties of Shapes Answer Key
- Activity 2.1.4 Calculating Properties of Solids Answer Key
Teacher Guidelines

Lesson 2.1 Teacher Notes
Lesson 2.1 Key Terms

Lesson 2.1 Key Terms and definitions in Excel

Inventor Files
IED Considerations

Graphic Files

PLTW

Reference Sources


National Council of Teachers of English (NCTE) and International Reading Association (IRA) (1996). *Standards for English language arts*.


Lesson 2.2 – Dimensions and Tolerances

Preface

Effective communication of ideas and information has been a goal of humans since the beginning of time. There is evidence that even cavemen used symbols and drawings to convey and preserve information or ideas. These cave drawings have survived for centuries, but the message and intent of the drawings are unclear when people try to interpret them today. Varied interpretations of the same drawing have been made, ranging from an artistic attempt to a record of every day life.

During the Industrial Revolution, early documentation of manufactured parts consisted of varying pictorial drawings with only a few dimensions. This method was adequate when a small group or an individual made all of the parts for the entire product. Verbal communication or personal knowledge was used to fill in the blanks. Manufacturing began to expand as companies started to specialize in different areas. Now, parts of machines are being created by different people in different companies, in different states, and eventually in different areas of the world. These individuals working in isolation do not understand how the parts that were being used will function in the overall project. The result is that many of the finished parts do not function properly. The solution was the development of standards that govern how the design of parts are dimensioned and tolerated in order to communicate effectively. These standards were developed from common, acceptable practices and continue to evolve to this day.

The drafting, dimensioning, and tolerancing standards are a design language that allow designers to clearly and accurately communicate their ideas about form and function to people all over the world, regardless of what language they speak. It is important that everyone involved with the design process understands the proper documentation of technical drawings to insure that the design will achieve its full potential. Mistakes to technical drawings could be costly for a company and result in a loss of profit which could cost people jobs. Drafting standards are a language all their own. It is a language that every designer must understand and become fluent in using.
Concepts

1. Working drawings should contain only the dimensions that are necessary to build and inspect an object.
2. Object features require specialized dimensions and symbols to communicate technical information, such as size.
3. There is always a degree of variation between the actual manufactured object and its dimensioned drawing.
4. Engineers specify tolerances to indicate the amount of dimensional variation that may occur without adversely affecting an object’s function.
5. Tolerances for mating part features are determined by the type of fit.

Standards and Benchmarks Addressed

Standards for Technological Literacy

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 G: Use common symbols, such as numbers and words, to communicate key ideas.
BM L: Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

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 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; and 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.
**Connections:** Instructional programs from pre-kindergarten through grade 12 should enable all students to recognize and use connections among mathematical ideas; 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 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:*

- Explain the differences between size and location dimensions.
- Differentiate between datum dimensioning and chain dimensioning.
- Identify and dimension fillets, rounds, diameters, chamfers, holes, slots, and screw threads in orthographic projection drawings.
- Explain the rules that are associated with the application of dimensions to multiview drawings.
- Identify, sketch, and explain the difference between general tolerances, limit dimensions, unilateral, and bilateral tolerances.
- Differentiate between clearance and interference fits.

**Assessment**

*Application*

1. Students will take a completed working drawing of an object or product and will write a description of the object based on the information provided. They will determine if the dimensioning is correct and what areas must be modified to show how the object should look. They will finish by completing a sketch of the object.

2. Students are given an isometric drawing of an object and asked to determine the hidden sections based on the dimensions provided with the dimensions for the hidden lines shown with variables, such as X or Y. This application is to build awareness of hidden lines and the value of accurate dimensioning.
Perspective

3. Students will answer the question, “Of what value is the use of dimensioning an object or product?” How important is the use of dimensioning and how does it aid in the design of a product?

Essential Questions

1. What is a working drawing?
2. What are dimensioning standards and how are they used?
3. What determines the location of the origin or datum from which all of the edges and features of an object are dimensioned?
4. What is a tolerance?
5. What effect can trailing zeroes in the dimension text have on the cost of a part?
6. Why is it necessary to use common units on a drawing for all dimensions?

Key Terms

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aligned Dimension</td>
<td>American National Standards Institute (ANSI)</td>
</tr>
<tr>
<td>Arrowheads</td>
<td>American Society of Mechanical Engineers (ASME)</td>
</tr>
<tr>
<td>Baseline Dimensioning</td>
<td>Datum</td>
</tr>
<tr>
<td>Chain Dimensioning</td>
<td>Datum Dimension</td>
</tr>
<tr>
<td>Dimension</td>
<td>Dimension Lines</td>
</tr>
<tr>
<td>Dual Dimensions</td>
<td>Datum Dimension</td>
</tr>
<tr>
<td>Extension Lines</td>
<td>General Notes</td>
</tr>
<tr>
<td>Least Material Condition</td>
<td>Leaders</td>
</tr>
<tr>
<td>(LMC)</td>
<td>Limits of Dimension</td>
</tr>
<tr>
<td>Location Dimension</td>
<td>Local Notes</td>
</tr>
<tr>
<td>Maximum Material Condition (MMC)</td>
<td>Nominal Size</td>
</tr>
<tr>
<td>Reference Dimension</td>
<td>Size Dimensions</td>
</tr>
<tr>
<td>Unidirectional Dimension</td>
<td>Tolerance</td>
</tr>
<tr>
<td>Unilateral Tolerance</td>
<td>Working Drawings</td>
</tr>
</tbody>
</table>

A list of Key Terms is provided in the Teacher Guidelines at the end of this lesson.

Day-by-Day Plans

Total Time: 9 days

NOTE: In preparation for teaching this lesson, it is strongly recommended that the teacher read the Teacher Notes.
Day 1:
- The teacher will present the Concepts, Key Terms and Essential Questions, and provide students with a lesson overview.
- The teacher will present Dimension Guidelines.ppt.
- Students will take notes in their journals.
- The teacher will introduce and distribute Activity 2.2.1 What Is Wrong with this Picture?
- Students will work in teams of two on Activity 2.2.1 What Is Wrong with This Picture?

Day 2-3:
- Students will complete Activity 2.2.1 What Is Wrong with this Picture.
- The teacher will assist the students and assess their work using Activity 2.2.1 What Is Wrong with this Picture Answer Key.
- The teacher will moderate a class discussion on the results of Activity 2.2.1 What Is Wrong with this Picture?
- Students will participate in a class discussion to identify the problems associated with the three dimensioned drawings in Activity 2.2.1 What Is Wrong with this Picture?
- Note: The teacher will need to demonstrate how to dimension one of the above drawings in the 3-D CAD Modeling Software before moving to the next activity.

Day 4-6:
- The teacher will present Dimensioning Standards.ppt.
- Students will take notes in their journals.
- Optional: The teacher may want to distribute Activity 2.2.2a General Rules for Dimensioning.
- The teacher will introduce and distribute Activity 2.2.2 Model Dimensioning.
- Students will begin work on Activity 2.2.2 Model Dimensioning.
- The teacher will assist the students when needed.
- The teacher will assess student work using Activity 2.2.2 Model Dimensioning Answer Key.

Day 7:
- The teacher will present Tolerances.ppt.
- Students will take notes in their journals.
- The teacher will introduce and distribute Activity 2.2.3 Tolerances.
- Students will begin work on Activity 2.2.3 Tolerances.

Days 8-9:
- Students will finish work on Activity 2.2.3 Tolerances.
- The teacher will assist the students and assess their work.
Instructional Resources

PowerPoint Presentations
- Dimension Guidelines
- Dimensioning Standards
- Tolerances

Word Documents

**Activity 2.2.1 What Is Wrong with this Picture?**
Activity 2.2.2 Model Dimensioning
Activity 2.2.2a General Rules for Dimensioning
Activity 2.2.3 Tolerances

Answer Keys and Rubrics

**Activity 2.2.1 What Is Wrong with this Picture Answer Key**
Activity 2.2.2 Model Dimensioning Answer Key

Teacher Guidelines

- Lesson 2.2 Teacher Notes
- Lesson 2.2 Key Terms
- **Lesson 2.2 Key Terms and definitions in Excel**

Reference Sources


National Council of Teachers of English (NCTE) and International Reading Association (IRA) (1996). *Standards for English language arts*.


Lesson 2.3 – Advanced Modeling Skills

Preface

Parameters-based computer modeling programs utilize the powerful mathematical capabilities of computers to store, maintain, modify, and update vast quantities of information. CAD solid modeling programs serve as a bridge between design intent and the resulting geometry by giving the engineer the opportunity to establish design parameters. Parameters establish the relationships between the geometric elements of a design and allow the computer to make significant modifications to multiple areas of a design simultaneously. This is what separates a solid modeling program from simpler CAD programs. Coupled with the ability to share design information through the internet with teammates and customers across the world, parameter-based computer modeling has proven itself to be a significant design tool.

Most devices are comprised of several components that work together. CAD solid modeling programs allow designers to simulate the interactions between the components of a design to forecast how the design will behave when it is actually manufactured. Students will use the computer to determine if interferences exist between assembled components. Once students have experienced assembling models, they will animate the models by driving their assembly constraints to verify the models’ functional characteristics. Students will also learn how to use algebraic equations to drive multiple constraints simultaneously.

It is important that the parallels between CAD operations and manufacturing operations be identified as students learn how objects are created in a virtual environment. After all, designing a virtual object that cannot be built is a major problem.

This lesson will cover many of the 3D functions used to develop individual and assembly CAD solid models. Students will use these modeling skills to develop their design solutions to various projects and problems throughout the rest of the course. The goal of this lesson is to provide an opportunity for students to acquire the knowledge and experience to effectively utilize CAD as a design tool in an engineering design process.
Concepts

1. Solid modeling programs allow the designer to create quality designs for production in far less time than traditional design methods.

2. Engineers use CAD models, assemblies, and animations to check for design problems, verify the functional qualities of a design, and communicate information to other professionals and clients.

3. Auxiliary views allow the engineer to communicate information about an object’s inclined surfaces that appear foreshortened in basic multiview drawings.

4. Designers use sectional views to communicate an object’s interior features that may be difficult to visualize from the outside.

5. As individual objects are assembled together, their degrees of freedom are systematically removed.

6. Engineers create mathematical formulas to establish geometric and functional relationships within their designs.

7. A title block provides the engineer and manufacturer with important information about an object and its creator.

8. A parts list and balloons are used to identify individual components in an assembly drawing.

Standards and Benchmarks Addressed

Standards for Technological Literacy

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

BM D: Tools, materials, and skills are used to make things and carry out tasks.

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.

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

BM F: Knowledge gained from other fields of study has a direct effect on the development of technological products and systems.

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

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

BM B: Expressing ideas to others verbally and through sketches and models is an important part of the design process.

BM H: Modeling, testing, evaluating, and modifying are used to transform ideas into practical solutions.
**Standard 11:** Students will develop abilities to apply the design process.
**BM J:** Make two-dimensional and three-dimensional representations of the designed solution.

**Standard 12:** Students will develop the abilities to use and maintain technological products and systems.
**BM D:** Follow step-by-step directions to assemble a product.

**Standard 17:** Students will develop an understanding of and be able to select and use information and communication technologies.
**BM K:** The use of symbols, measurements, and drawings promotes clear communication by providing a common language to express ideas.

**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 F:** Manufacturing systems use mechanical processes that change the form of materials through the processes of separating, forming, combining, and conditioning them.

**National Science Education Standards**

**Unifying Concepts and Processes Standard K-12:** 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
- Understandings about scientific inquiry
Principles and Standards for School Mathematics

Number 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; and compute fluently and make reasonable estimates.

Algebra: Instructional programs from pre-kindergarten through grade 12 should enable all students to represent and analyze mathematical situations and structures using algebraic symbols; use mathematical models to represent and understand quantitative relationships.

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; and 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; and apply appropriate techniques, tools, and formulas to determine measurements.

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; and analyze and evaluate the mathematical thinking and strategies of others.

Presentation: Instructional programs from pre-kindergarten through grade 12 should enable all students to create and use representations to organize, record, and communicate mathematical ideas.

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.
Performance Objectives

*It is expected that students will:*

- Sketch and model an auxiliary view of a given object to communicate the true size and shape of its inclined surface.
- Describe the purpose and demonstrate the application of section lines and cutting plane lines in a section view drawing.
- Sketch a full and half section view of a given object to communicate its interior features.
- Identify algebraic relationships between the dimensional values of a given object.
- Apply assembly constraints to individual CAD models to create mechanical systems.
- Perform part manipulation during the creation of an assembly model.
- Explain how assembly constraints are used to systematically remove the degrees of freedom for a set of components in a given assembly.
- Create an exploded model of a given assembly.
- Determine ratios and apply algebraic formulas to animate multiple parts within an assembly model.
- Create and describe the purpose of the following items: exploded isometric assembly view, balloons, and parts list.

Assessment

*Explanation*

1. Students will explain the difference between geometric, parametric, and assembly constraints.
2. Students will explain the degrees of freedom an object has before any constraints are applied to a student who was absent.

*Interpretation*

3. Students will analyze and evaluate another classmate’s dimensioned multiview drawings and pictorials developed in a 3D CAD modeling program.
4. Students will derive algebraic equations from a given part’s dimensions that will be used to maintain that part’s geometric proportions.

*Application*

5. Students will demonstrate and explain how to fully constrain objects to the class using the CAD modeling program.

*Perspective*

6. Students will select a product available in the classroom, write detailed instructions on how the product would be made using a CAD modeling software, and discuss an alternate way of creating the same part.
Essential Questions

1. What are the six degrees of freedom that an object has in space?
2. How do assembly constraints differ from geometric and numeric constraints?
3. What is the difference between an assembly and a subassembly?
4. For what reason might an engineer need to create an auxiliary view of an object?
5. For what reason might an engineer need to create a section view of an object?
6. What is a title block?
7. What information is typically on a title block?
8. What is an assembly drawing?
9. What purpose do balloons and a parts list serve in an assembly drawing?
10. What kind of information may be included in a parts list?

Key Terms

<table>
<thead>
<tr>
<th>Assembly</th>
<th>Assembly Drawing</th>
<th>Auxiliary View</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balloons</td>
<td>Blind Hole</td>
<td>Break Line</td>
</tr>
<tr>
<td>Broken-Out Section</td>
<td>Chamfer</td>
<td>Clearance Fit</td>
</tr>
<tr>
<td>Component</td>
<td>Constraint</td>
<td>Counterbore</td>
</tr>
<tr>
<td>Countersink</td>
<td>Cutting Plane Line</td>
<td>Degree of Freedom</td>
</tr>
<tr>
<td>Detail Drawing</td>
<td>Documentation</td>
<td>Exploded Assembly</td>
</tr>
<tr>
<td>Fillet</td>
<td>Foreshorten</td>
<td>Formula</td>
</tr>
<tr>
<td>Full Section</td>
<td>Half Section</td>
<td>Interference</td>
</tr>
<tr>
<td>Key</td>
<td>Keyseat</td>
<td>Keyway</td>
</tr>
<tr>
<td>Parameter</td>
<td>Parametric modeling</td>
<td>Parts List</td>
</tr>
<tr>
<td>Phantom Line</td>
<td>Ratio</td>
<td>Rib</td>
</tr>
<tr>
<td>Rotation</td>
<td>Round</td>
<td>Scale</td>
</tr>
<tr>
<td>Section Lines</td>
<td>Sectional View</td>
<td>Spotface</td>
</tr>
<tr>
<td>Subassembly</td>
<td>Tap</td>
<td>Taper</td>
</tr>
<tr>
<td>Title Block</td>
<td>Translation</td>
<td>Working drawings</td>
</tr>
</tbody>
</table>

A list of Key Terms is provided in the Teacher Guidelines at the end of this lesson.
Day-by-Day Activities

Time: 19 days

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

Note: The files needed for this lesson can be found in the Inventor files folder.

Day 1-2:

- The teacher will present Concepts, Key Terms, and Essential Questions, and provide a lesson overview.
- The teacher will present Work Points, Work Axes, and Work Planes.ppt.
- Students will take notes in their journals.
- The teacher will introduce and distribute Project 2.3.1 Arbor Press or Project 2.3.1a Miniature Train depending on available time and teacher preference.
- Note: The files needed for this project can be found in the Inventor files folder. The teacher can access how to assemble and apply motion to the train from the tutorial on the Virtual Academy.
- Optional: The teacher may want to divide the students with half of them working on Project 2.3.1 Arbor Press and the other half on Project 2.3.1a Miniature Train. The students could then discuss differences and similarities with each project.
- Students will begin work on Project 2.3.1 Arbor Press or Project 2.3.1a Miniature Train.

Day 3-4:

- The teacher will introduce and distribute Activity 2.3.2 Parametric Constraints.
- The teacher will present Parametric Modeling.ppt.
- Students will take notes in their journals.
- Students will begin work on Activity 2.3.2 Parametric Constraints.
- The teacher will assist the students with Activity 2.3.2 Parametric Constraints.
- Students will complete Activity 2.3.2 Parametric Constraints.
- The teacher will assess student work using Activity 2.3.2 Parametric Constraints Answer Key.
- Students will continue working on Project 2.3.1 Arbor Press or Project 2.3.1a Miniature Train.
Day 5-6:
- The teacher will present **Auxiliary Views.ppt**.
- Students will take notes in their journals.
- The teacher will introduce and distribute **Activity 2.3.3 Auxiliary Views**.
- Students will begin work on Activity 2.3.3 Auxiliary Views.
- The teacher will assist the students with Activity 2.3.3 Auxiliary Views.
- Students will finish work on Activity 2.3.3 Auxiliary Views.
- The teacher will assess student work using **Activity 2.3.3 Auxiliary Views Answer Key**.
- Students will continue working on Project 2.3.1 Arbor Press or Project 2.3.1a Miniature Train.

Day 7-8
- The teacher will present **Sectional Views.ppt**.
- Students will take notes in their journals.
- The teacher will introduce and distribute **Activity 2.3.4 Sectional Views**.
- Students will begin work on Activity 2.3.4 Sectional Views.
- The teacher will assist the students with Activity 2.3.4 Sectional Views.
- Students will finish work on Activity 2.3.4 Sectional Views.
- The teacher will assess student work using **Activity 2.3.4 Sectional Views Answer Key**.
- Students will continue working on Project 2.3.1 Arbor Press or Project 2.3.1a Miniature Train.

Day 9-10
- The teacher will present **Basic Assembly Constraints and Concepts.ppt**
- Students will take notes in their journals.
- The teacher will introduce and demonstrate the exercises in **Activity 2.3.5 Assembly Models**.
- Students will begin work on Activity 2.3.5 Assembly Models.
- The teacher will assist the students with Activity 2.3.5 Assembly Models.
- Students will complete Activity 2.3.5 Assembly Models.
Day 11-12
- **Optional:** The teacher will present *Exploded CAD Assembly Models.ppt.* The teacher may want to demonstrate this to students instead of showing the presentation.
- Students will take notes in their journals.
- The teacher will demonstrate how to explode an assembly using the Arbor Press or the miniature train project.
- Students will explode their Arbor Press or Miniature Train assembly.
- The teacher will assist the students when needed.

Day 13-14
- **Optional:** The teacher will present *Animating Assembly Models and Exporting Video.ppt.* The teacher may want to demonstrate this to students instead of showing the presentation.
- Students will take notes in their journals.
- The teacher will demonstrate how to animate an assembly using the Arbor Press or the Miniature Train project.
- Students will animate their Arbor Press or Miniature Train assembly.
- The teacher will assist the students when needed.

Day 15-19
- The teacher will introduce and distribute *Activity 2.3.6 Arbor Press Drawings* and *Activity 2.3.6 Detail Drawing Rubric.*
- The teacher will let students know they can use the same activity set up for the Miniature Train.
- The teacher will demonstrate creating a dimensioned multiview drawing from one of the Arbor Press part models or Miniature Train part. The demonstration will include the creation of section and auxiliary views, centerlines, dimensions, and tolerances.
- Students will take notes in their journals.
- Students will begin work on Activity 2.3.6 Arbor Press Drawings.
- The teacher will use the Activity 2.3.6 Detail Drawing Rubric to assess the students’ drawings.
- The teacher can use the same rubric set up for the Miniature train set-up.
- **Optional:** The teacher will present *Assembly Drawings, Balloons, and Parts Lists.ppt.* The teacher may want to demonstrate this to students instead of showing the presentation.
- Students will take notes in their journals.
- The teacher will demonstrate the application of balloons and a parts list to an exploded isometric pictorial assembly drawing of the Arbor Press, and the creation of a sectioned assembly view.
- Students will complete Activity 2.3.6 Arbor Press Drawings or Miniature Train.
Instructional Resources

PowerPoint presentations
- Work Points, Work Axes, and Work Planes
- Parametric Modeling
- Auxiliary Views
- Sectional Views
- Basic Assembly Constraints and Concepts
- Exploded CAD Assembly Models
- Animating Assembly Models and Exporting Video
- Assembly Drawings, Balloons, and Parts List

Word Documents
- Project 2.3.1 Arbor Press
- Project 2.3.1a Miniature Train
- Activity 2.3.2 Parametric Constraints
- Activity 2.3.3 Auxiliary Views
- Activity 2.3.4 Sectional Views
- Activity 2.3.5 Assembly Models
- Activity 2.3.6 Arbor Press Drawings

Answer Keys and Rubrics
- Activity 2.3.2 Parametric Constraints Answer Key
- Activity 2.3.3 Auxiliary Views Answer Key
- Activity 2.3.4 Sectional Views Answer Key
- Activity 2.3.6 Detail Drawing Rubric

Teacher Guidelines
- Lesson 2.3 Teacher Notes
- Lesson 2.3 Key Terms
- Lesson 2.3 Key Terms and definitions in Excel
- Inventor Files
- IED Considerations
Reference Sources


Note: Additional resources pertaining to CAD solid modeling are available on the Project Lead The Way, Inc. Virtual Academy.
Lesson 2.4 – Advanced Designs

Preface

As time and technology have advanced, the process of designing products has become quicker, more precise, and efficient, which enables changes to be made when needed. The process from getting a concept to a marketable solution is also being completed with higher quality and in far less time.

The design of solutions to problems is sometimes completed in teams. These teams work together, constantly communicating with each other, to create the desired product needed. The team may receive a problem and then are expected to create a solution with very few constraints. This allows teams to think outside the box and use their imagination. The process of deriving solutions to these problems will vary from team to team. Designs are usually presented to supervisors or board members and a single solution is then chosen.

In this lesson, students will work in teams of two. They will choose a problem from a list of design briefs and create a solution to the problem. Each team will apply the design process steps in the development of their solution. Students will work as a product design team and together, create a solution to their chosen problem. Challenges they will encounter are written up in such a way that they will experience a design work environment, such as a design challenge for redesigning a fluid power system, or a challenge for designing a executive desk set, as well as others. Students will then make plans to market their solution to their company.

Concepts

1. Design solutions are created while working in teams and sometimes as an individual.
2. Engineers use design briefs to explain the problem, identify solution expectations, and establish project constraints.
3. Teamwork requires constant communication to achieve the goal at hand.
4. Engineers conduct research to develop their knowledge base, stimulate creative ideas, and make informed decisions.
5. Engineers use a design process to create solutions to existing problems.
6. Engineers use computer-aided design (CAD) modeling systems to quickly generate and annotate working drawings.
7. Fluid Power Concepts could be used to enhance design solutions.
8. The use of fluid power, hydraulics and pneumatics is used as an enhancement to solving problems with electrical control systems.
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.

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

**BM A:** The study of technology uses many of the same ideas and skills as other subjects.

**BM C:** Various relationships exist between technology and other fields of study.

**BM F:** Knowledge gained from other fields of study has a direct effect on the development of technological products and systems.

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

**BM A:** Products are made to meet individual needs and wants.

**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 A:** The engineering design process includes identifying a problem, looking for ideas, developing solutions, and sharing solutions with others.

**BM B:** Expressing ideas to others verbally and through sketches and models is an important part of the design process.

**BM D:** When designing an object, it is important to be creative and consider all ideas.

**BM F:** Design involves a set of steps, which can be performed in different sequences and repeated as needed.

**BM G:** Brainstorming is a group problem-solving design process in which each person in the group presents his or her ideas in an open forum.

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

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

**BM E:** The process of designing involves presenting some possible solutions in visual form and then selecting the best solution(s) from many.
BM I: Specify criteria and constraints for the design.
BM J: Make two-dimensional and three-dimensional representations of the designed solution.
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 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 Standard K-12:** As a result of activities in grades 9-12, all students should develop—
- Change, constancy, and measurement
- 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

**Principles and Standards for School Mathematics**

Number 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; and compute fluently and make reasonable estimates.

Algebra: Instructional programs from pre-kindergarten through grade 12 should enable all students to understand patterns, relations, and functions; represent and analyze mathematical situations and structures using algebraic symbols; use mathematical models to represent and understand quantitative relationships; and analyze change in various contexts.

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; and 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; and apply appropriate techniques, tools, and formulas to determine measurements.

**Problem Solving** Instructional programs from pre-kindergarten through grade 12 should enable all students to solve problems that arise in mathematics and in other contexts; apply and adapt a variety of appropriate strategies to solve problems.

**Communication:** Instructional programs from pre-kindergarten through grade 12 should enable all students to organize and consolidate their mathematical thinking through communication; and communicate their mathematical thinking coherently and clearly to peers, teachers, and others.

**Connections:** Instructional programs from pre-kindergarten through grade 12 should enable all students 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 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:*

- Brainstorm and sketch possible solutions to an existing design problem.
- Create a decision making matrix.
- Select an approach that meets or satisfies the constraints given in a design brief.
- Create solid computer-aided design (CAD) models of each part from dimensioned sketches using a variety of methods.
- Apply geometric numeric and parametric constraints to form CAD modeled parts.
- Generate dimensioned multiview drawings from simple CAD modeled parts.
- Assemble the product using the CAD modeling software.
- Explain what constraints are and why they are included in a design brief.
Create a three-fold brochure marketing the designed solution for the chosen problem, such as a consumer product, a dispensing system, a new form of control system, or extend a product design to meet a new requirement.

Explain the concept of fluid power, and the difference between hydraulic and pneumatic power systems

**Assessment**

**Explanation**

1. Students will explain why design options of a project are determined by criteria and constraints.

**Application**

2. Students will design an alternate solution to the same design brief completed in the lesson and adjust their solution to include a different material.

**Interpretation**

3. Students will illustrate their proposed solution and use their illustration to explain how it relates to what they have learned about engineering design.

4. Students will explain the advantages and disadvantages of working in teams answering questions, such as:
   a. When I work with a team I find that I ...
   b. The hardest thing for me to do when working with a team is ...
   c. The easiest part of working on a team is ...
Essential Questions

1. What is a design brief?
2. Why is a design process so important to follow when creating a solution to a problem?
3. What is the purpose of design constraints?
4. What is a decision matrix and why is it used?
5. What does consensus mean, and how do teams use it to make decisions?
6. How are visual design principles and elements used to capture a consumer’s attention?
7. How is the design of a consumer product different then the design of a product used to help a manufacturing process?
8. What is fluid power?
9. What is the difference between hydraulic and pneumatic power systems?
10. How does the use of fluid power aid the use of electronics or other power systems?

Key Terms

Accuracy  Assembly  Assembly Drawing
Component  Consensus  Constraint
Decision Matrix  Design Brief  Design Process
Design Statement  Designer  Fluid Power
Hydraulics  Marketing  Multiview Drawing
Pneumatics  Problem Statement  Purpose
Solid Modeling  Target Consumer  Team

A list of Key Terms is provided in the Teacher Guidelines at the end of this lesson.

Day-by-Day Plans

Time: 12 days

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

Day 1-2:

☐ The teacher will present Concepts, Key Terms, and Essential Questions to provide a lesson overview.
☐ The teacher will distribute and introduce Project 2.4.1 Design Challenge and Project 2.4.1 Design Challenge Rubric.
☐ The teacher will divide the class into groups of two.
△ The teacher will discuss constraints, requirements and design briefs for each project.
△ The teacher will present Teamwork.ppt and the Fluid Power.ppt.
△ Students will take notes in their journals.
△ The teacher will review the design process using Example Design Process distributed in Lesson 1.1.
△ Students will keep Example Design Process document available throughout this lesson.
△ The teacher will distribute the graph paper located in the Teacher Guidelines at the end of this lesson.
△ Students will begin work on Project 2.4.1 Design Challenge.

**Day3-12:**

△ The teacher will distribute Decision Matrix Template
△ The teacher will present the Decision Making Matrix.ppt.
△ Students will take notes in their journals.
△ Students will continue working on materials to be completed for Project 2.4.1 Design Challenge.
△ The teacher will keep students on task and answer any questions during the process.
△ Students will complete Project 2.4.1 Design Challenges.
△ Students will present their design solution using their three-fold brochure and an oral report to the class.
△ The teacher will assess students using Project 2.4.1 Design Challenges Rubric.
△ **Optional:** The teacher may want to have students take the Midterm Exam located in the Instructional Resources area below.

**Instructional Resources**

PowerPoint Presentations
- Teamwork
- Fluid Power
- Decision Making Matrix

Word Documents
- **Project 2.4.1 Design Challenge**
- Midterm Exam
- Midterm Exam Recording Sheet

Answer Keys and Rubrics
- Project 2.4.1 Design Challenge Rubric
- Midterm Exam Answer Key
Teacher Guidelines

Lesson 2.4 Teacher Notes
Lesson 2.4 Key Terms

**Lesson 2.4 Key Terms and definitions in Excel**

Decision Matrix Template in Word
Decision Matrix Template in Excel
Isometric graph paper
Isometric graph paper
Orthographic graph paper

Reference Sources


National Council of Teachers of English (NCTE) and International Reading Association (IRA) (1996). *Standards for English language arts*.


Lesson 2.4 – Advanced Designs

Preface

As time and technology have advanced, the process of designing products has become quicker, more precise, and efficient, which enables changes to be made when needed. The process from getting a concept to a marketable solution is also being completed with higher quality and in far less time.

The design of solutions to problems is sometimes completed in teams. These teams work together, constantly communicating with each other, to create the desired product needed. The team may receive a problem and then are expected to create a solution with very few constraints. This allows teams to think outside the box and use their imagination. The process of deriving solutions to these problems will vary from team to team. Designs are usually presented to supervisors or board members and a single solution is then chosen.

In this lesson, students will work in teams of two. They will choose a problem from a list of design briefs and create a solution to the problem. Each team will apply the design process steps in the development of their solution. Students will work as a product design team and together, create a solution to their chosen problem. Challenges they will encounter are written up in such a way that they will experience a design work environment, such as a design challenge for redesigning a fluid power system, or a challenge for designing an executive desk set, as well as others. Students will then make plans to market their solution to their company.

Concepts

1. Design solutions are created while working in teams and sometimes as an individual.
2. Engineers use design briefs to explain the problem, identify solution expectations, and establish project constraints.
3. Teamwork requires constant communication to achieve the goal at hand.
4. Engineers conduct research to develop their knowledge base, stimulate creative ideas, and make informed decisions.
5. Engineers use a design process to create solutions to existing problems.
6. Engineers use computer-aided design (CAD) modeling systems to quickly generate and annotate working drawings.
7. Fluid Power Concepts could be used to enhance design solutions.
8. The use of fluid power, hydraulics and pneumatics is used as an enhancement to solving problems with electrical control systems.
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.

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

**BM A:** The study of technology uses many of the same ideas and skills as other subjects.

**BM C:** Various relationships exist between technology and other fields of study.

**BM F:** Knowledge gained from other fields of study has a direct effect on the development of technological products and systems.

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

**BM A:** Products are made to meet individual needs and wants.

**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 A:** The engineering design process includes identifying a problem, looking for ideas, developing solutions, and sharing solutions with others.

**BM B:** Expressing ideas to others verbally and through sketches and models is an important part of the design process.

**BM D:** When designing an object, it is important to be creative and consider all ideas.

**BM F:** Design involves a set of steps, which can be performed in different sequences and repeated as needed.

**BM G:** Brainstorming is a group problem-solving design process in which each person in the group presents his or her ideas in an open forum.

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

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

**BM E:** The process of designing involves presenting some possible solutions in visual form and then selecting the best solution(s) from many.
BM I: Specify criteria and constraints for the design.
BM J: Make two-dimensional and three-dimensional representations of the designed solution.
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 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 Standard K-12: As a result of activities in grades 9-12, all students should develop—
- Change, constancy, and measurement
- 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

Principles and Standards for School Mathematics

Number 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; and compute fluently and make reasonable estimates.

Algebra: Instructional programs from pre-kindergarten through grade 12 should enable all students to understand patterns, relations, and functions; represent and analyze mathematical situations and structures using algebraic symbols; use mathematical models to represent and understand quantitative relationships; and analyze change in various contexts.

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; and 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; and apply appropriate techniques, tools, and formulas to determine measurements.

Problem Solving: Instructional programs from pre-kindergarten through grade 12 should enable all students to solve problems that arise in mathematics and in other contexts; apply and adapt a variety of appropriate strategies to solve problems.

Communication: Instructional programs from pre-kindergarten through grade 12 should enable all students to organize and consolidate their mathematical thinking through communication; and communicate their mathematical thinking coherently and clearly to peers, teachers, and others.

Connections: Instructional programs from pre-kindergarten through grade 12 should enable all students 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 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:

- Brainstorm and sketch possible solutions to an existing design problem.
- Create a decision making matrix.
- Select an approach that meets or satisfies the constraints given in a design brief.
- Create solid computer-aided design (CAD) models of each part from dimensioned sketches using a variety of methods.
- Apply geometric numeric and parametric constraints to form CAD modeled parts.
- Generate dimensioned multiview drawings from simple CAD modeled parts.
- Assemble the product using the CAD modeling software.
- Explain what constraints are and why they are included in a design brief.
Create a three-fold brochure marketing the designed solution for the chosen problem, such as a consumer product, a dispensing system, a new form of control system, or extend a product design to meet a new requirement.

Explain the concept of fluid power, and the difference between hydraulic and pneumatic power systems

**Assessment**

**Explanation**

1. Students will explain why design options of a project are determined by criteria and constraints.

**Application**

2. Students will design an alternate solution to the same design brief completed in the lesson and adjust their solution to include a different material.

**Interpretation**

3. Students will illustrate their proposed solution and use their illustration to explain how it relates to what they have learned about engineering design.

4. Students will explain the advantages and disadvantages of working in teams answering questions, such as:
   a. When I work with a team I find that I ...
   b. The hardest thing for me to do when working with a team is ...
   c. The easiest part of working on a team is ...
**Essential Questions**

1. What is a design brief?
2. Why is a design process so important to follow when creating a solution to a problem?
3. What is the purpose of design constraints?
4. What is a decision matrix and why is it used?
5. What does consensus mean, and how do teams use it to make decisions?
6. How are visual design principles and elements used to capture a consumer’s attention?
7. How is the design of a consumer product different than the design of a product used to help a manufacturing process?
8. What is fluid power?
9. What is the difference between hydraulic and pneumatic power systems?
10. How does the use of fluid power aid the use of electronics or other power systems?

**Key Terms**

<table>
<thead>
<tr>
<th>Accuracy</th>
<th>Assembly</th>
<th>Assembly Drawing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component</td>
<td>Consensus</td>
<td>Constraint</td>
</tr>
<tr>
<td>Decision Matrix</td>
<td>Design Brief</td>
<td>Design Process</td>
</tr>
<tr>
<td>Design Statement</td>
<td>Designer</td>
<td>Fluid Power</td>
</tr>
<tr>
<td>Hydraulics</td>
<td>Marketing</td>
<td>Multiview Drawing</td>
</tr>
<tr>
<td>Pneumatics</td>
<td>Problem Statement</td>
<td>Purpose</td>
</tr>
<tr>
<td>Solid Modeling</td>
<td>Target Consumer</td>
<td>Team</td>
</tr>
</tbody>
</table>

A list of Key Terms is provided in the Teacher Guidelines at the end of this lesson.

**Day-by-Day Plans**

*Time: 12 days*

**NOTE:** In preparation for teaching this lesson, it is strongly recommended that the teacher read the Teacher Notes.
Day 1-2:
- The teacher will present **Concepts, Key Terms, and Essential Questions** to provide a lesson overview.
- The teacher will distribute and introduce **Project 2.4.1 Design Challenge** and **Project 2.4.1 Design Challenge Rubric**.
- The teacher will divide the class into groups of two.
- The teacher will discuss constraints, requirements and design briefs for each project.
- The teacher will present **Teamwork.ppt** and the **Fluid Power.ppt**.
- Students will take notes in their journals.
- The teacher will review the design process using **Example Design Process** distributed in Lesson 1.1.
- Students will keep Example Design Process document available throughout this lesson.
- The teacher will distribute the graph paper located in the **Teacher Guidelines** at the end of this lesson.
- Students will begin work on Project 2.4.1 Design Challenge.

Day 3-12:
- The teacher will distribute **Decision Matrix Template**
- The teacher will present the **Decision Making Matrix.ppt**.
- Students will take notes in their journals.
- Students will continue working on materials to be completed for Project 2.4.1 Design Challenge.
- The teacher will keep students on task and answer any questions during the process.
- Students will complete Project 2.4.1 Design Challenges.
- Students will present their design solution using their three-fold brochure and an oral report to the class.
- The teacher will assess students using Project 2.4.1 Design Challenges Rubric.
- **Optional:** The teacher may want to have students take the **Midterm Exam** located in the Instructional Resources area below.

**Instructional Resources**

**PowerPoint Presentations**
- **Teamwork**
- **Fluid Power**
- **Decision Making Matrix**
Word Documents

**Project 2.4.1 Design Challenge**
Midterm Exam
Midterm Exam Recording Sheet

Answer Keys and Rubrics

**Project 2.4.1 Design Challenge Rubric**
Midterm Exam Answer Key

Teacher Guidelines

**Lesson 2.4 Teacher Notes**
**Lesson 2.4 Key Terms**

**Lesson 2.4 Key Terms and definitions in Excel**
Decision Matrix Template in Word
Decision Matrix Template in Excel
Isometric graph paper
Isometric graph paper
Orthographic graph paper

Reference Sources


National Council of Teachers of English (NCTE) and International Reading Association (IRA) (1996). *Standards for English language arts*.


Lesson 2.4 – Advanced Designs

Preface

As time and technology have advanced, the process of designing products has become quicker, more precise, and efficient, which enables changes to be made when needed. The process from getting a concept to a marketable solution is also being completed with higher quality and in far less time.

The design of solutions to problems is sometimes completed in teams. These teams work together, constantly communicating with each other, to create the desired product needed. The team may receive a problem and then are expected to create a solution with very few constraints. This allows teams to think outside the box and use their imagination. The process of deriving solutions to these problems will vary from team to team. Designs are usually presented to supervisors or board members and a single solution is then chosen.

In this lesson, students will work in teams of two. They will choose a problem from a list of design briefs and create a solution to the problem. Each team will apply the design process steps in the development of their solution. Students will work as a product design team and together, create a solution to their chosen problem. Challenges they will encounter are written up in such a way that they will experience a design work environment, such as a design challenge for redesigning a fluid power system, or a challenge for designing a executive desk set, as well as others. Students will then make plans to market their solution to their company.

Concepts

1. Design solutions are created while working in teams and sometimes as an individual.
2. Engineers use design briefs to explain the problem, identify solution expectations, and establish project constraints.
3. Teamwork requires constant communication to achieve the goal at hand.
4. Engineers conduct research to develop their knowledge base, stimulate creative ideas, and make informed decisions.
5. Engineers use a design process to create solutions to existing problems.
6. Engineers use computer-aided design (CAD) modeling systems to quickly generate and annotate working drawings.
7. Fluid Power Concepts could be used to enhance design solutions.
8. The use of fluid power, hydraulics and pneumatics is used as an enhancement to solving problems with electrical control systems.
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.

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

**BM A:** The study of technology uses many of the same ideas and skills as other subjects.

**BM C:** Various relationships exist between technology and other fields of study.

**BM F:** Knowledge gained from other fields of study has a direct effect on the development of technological products and systems.

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

**BM A:** Products are made to meet individual needs and wants.

**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 A:** The engineering design process includes identifying a problem, looking for ideas, developing solutions, and sharing solutions with others.

**BM B:** Expressing ideas to others verbally and through sketches and models is an important part of the design process.

**BM D:** When designing an object, it is important to be creative and consider all ideas.

**BM F:** Design involves a set of steps, which can be performed in different sequences and repeated as needed.

**BM G:** Brainstorming is a group problem-solving design process in which each person in the group presents his or her ideas in an open forum.

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

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

**BM E:** The process of designing involves presenting some possible solutions in visual form and then selecting the best solution(s) from many.
BM I: Specify criteria and constraints for the design.
BM J: Make two-dimensional and three-dimensional representations of the designed solution.
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 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 Standard K-12:** As a result of activities in grades 9-12, all students should develop—

- **Change, constancy, and measurement**
- **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**

**Principles and Standards for School Mathematics**

**Number 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; and compute fluently and make reasonable estimates.

**Algebra:** Instructional programs from pre-kindergarten through grade 12 should enable all students to understand patterns, relations, and functions; represent and analyze mathematical situations and structures using algebraic symbols; use mathematical models to represent and understand quantitative relationships; and **analyze change** in various contexts.

**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; and 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; and apply appropriate techniques, tools, and formulas to determine measurements.

Problem Solving: Instructional programs from pre-kindergarten through grade 12 should enable all students to solve problems that arise in mathematics and in other contexts; apply and adapt a variety of appropriate strategies to solve problems.

Communication: Instructional programs from pre-kindergarten through grade 12 should enable all students to organize and consolidate their mathematical thinking through communication; and communicate their mathematical thinking coherently and clearly to peers, teachers, and others.

Connections: Instructional programs from pre-kindergarten through grade 12 should enable all students to 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 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:

- Brainstorm and sketch possible solutions to an existing design problem.
- Create a decision making matrix.
- Select an approach that meets or satisfies the constraints given in a design brief.
- Create solid computer-aided design (CAD) models of each part from dimensioned sketches using a variety of methods.
- Apply geometric numeric and parametric constraints to form CAD modeled parts.
- Generate dimensioned multiview drawings from simple CAD modeled parts.
- Assemble the product using the CAD modeling software.
- Explain what constraints are and why they are included in a design brief.
Create a three-fold brochure marketing the designed solution for the chosen problem, such as a consumer product, a dispensing system, a new form of control system, or extend a product design to meet a new requirement.

Explain the concept of fluid power, and the difference between hydraulic and pneumatic power systems

**Assessment**

*Explanation*

1. Students will explain why design options of a project are determined by criteria and constraints.

*Application*

2. Students will design an alternate solution to the same design brief completed in the lesson and adjust their solution to include a different material.

*Interpretation*

3. Students will illustrate their proposed solution and use their illustration to explain how it relates to what they have learned about engineering design.

4. Students will explain the advantages and disadvantages of working in teams answering questions, such as:
   a. When I work with I team I find that I ...
   b. The hardest thing for me to do when working with a team is ...
   c. The easiest part of working on a team is ...
Essential Questions

1. What is a design brief?
2. Why is a design process so important to follow when creating a solution to a problem?
3. What is the purpose of design constraints?
4. What is a decision matrix and why is it used?
5. What does consensus mean, and how do teams use it to make decisions?
6. How are visual design principles and elements used to capture a consumer’s attention?
7. How is the design of a consumer product different then the design of a product used to help a manufacturing process?
8. What is fluid power?
9. What is the difference between hydraulic and pneumatic power systems?
10. How does the use of fluid power aid the use of electronics or other power systems?

Key Terms

Accuracy  Assembly  Assembly Drawing
Component  Consensus  Constraint
Decision Matrix  Design Brief  Design Process
Design Statement  Designer  Fluid Power
Hydraulics  Marketing  Multiview Drawing
Pneumatics  Problem Statement  Purpose
Solid Modeling  Target Consumer  Team

A list of Key Terms is provided in the Teacher Guidelines at the end of this lesson.

Day-by-Day Plans

Time: 12 days

NOTE: In preparation for teaching this lesson, it is strongly recommended that the teacher read the Teacher Notes.
Day 1-2:
- The teacher will present **Concepts, Key Terms**, and **Essential Questions** to provide a lesson overview.
- The teacher will distribute and introduce **Project 2.4.1 Design Challenge** and **Project 2.4.1 Design Challenge Rubric**.
- The teacher will divide the class into groups of two.
- The teacher will discuss constraints, requirements and design briefs for each project.
- The teacher will present **Teamwork.ppt** and the **Fluid Power.ppt**.
- Students will take notes in their journals.
- The teacher will review the design process using **Example Design Process** distributed in Lesson 1.1.
- Students will keep Example Design Process document available throughout this lesson.
- The teacher will distribute the graph paper located in the **Teacher Guidelines** at the end of this lesson.
- Students will begin work on Project 2.4.1 Design Challenge.

Day 3-12:
- The teacher will distribute **Decision Matrix Template**
- The teacher will present the **Decision Making Matrix.ppt**.
- Students will take notes in their journals.
- Students will continue working on materials to be completed for Project 2.4.1 Design Challenge.
- The teacher will keep students on task and answer any questions during the process.
- Students will complete Project 2.4.1 Design Challenges.
- Students will present their design solution using their three-fold brochure and an oral report to the class.
- The teacher will assess students using Project 2.4.1 Design Challenges Rubric.
- **Optional**: The teacher may want to have students take the **Midterm Exam** located in the Instructional Resources area below.

### Instructional Resources

**PowerPoint Presentations**
- **Teamwork**
- **Fluid Power**
- **Decision Making Matrix**
Word Documents

**Project 2.4.1 Design Challenge**
Midterm Exam
Midterm Exam Recording Sheet

Answer Keys and Rubrics

**Project 2.4.1 Design Challenge Rubric**
Midterm Exam Answer Key

Teacher Guidelines

**Lesson 2.4 Teacher Notes**
**Lesson 2.4 Key Terms**
**Lesson 2.4 Key Terms and definitions in Excel**
Decision Matrix Template in Word
Decision Matrix Template in Excel
Isometric graph paper
Isometric graph paper
Orthographic graph paper

Reference Sources


National Council of Teachers of English (NCTE) and International Reading Association (IRA) (1996). *Standards for English language arts.*


Lesson 2.4 – Advanced Designs

Preface

As time and technology have advanced, the process of designing products has become quicker, more precise, and efficient, which enables changes to be made when needed. The process from getting a concept to a marketable solution is also being completed with higher quality and in far less time.

The design of solutions to problems is sometimes completed in teams. These teams work together, constantly communicating with each other, to create the desired product needed. The team may receive a problem and then are expected to create a solution with very few constraints. This allows teams to think outside the box and use their imagination. The process of deriving solutions to these problems will vary from team to team. Designs are usually presented to supervisors or board members and a single solution is then chosen.

In this lesson, students will work in teams of two. They will choose a problem from a list of design briefs and create a solution to the problem. Each team will apply the design process steps in the development of their solution. Students will work as a product design team and together, create a solution to their chosen problem. Challenges they will encounter are written up in such a way that they will experience a design work environment, such as a design challenge for redesigning a fluid power system, or a challenge for designing a executive desk set, as well as others. Students will then make plans to market their solution to their company.

Concepts

1. Design solutions are created while working in teams and sometimes as an individual.
2. Engineers use design briefs to explain the problem, identify solution expectations, and establish project constraints.
3. Teamwork requires constant communication to achieve the goal at hand.
4. Engineers conduct research to develop their knowledge base, stimulate creative ideas, and make informed decisions.
5. Engineers use a design process to create solutions to existing problems.
6. Engineers use computer-aided design (CAD) modeling systems to quickly generate and annotate working drawings.
7. Fluid Power Concepts could be used to enhance design solutions.
8. The use of fluid power, hydraulics and pneumatics is used as an enhancement to solving problems with electrical control systems.
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.

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

**BM A:** The study of technology uses many of the same ideas and skills as other subjects.

**BM C:** Various relationships exist between technology and other fields of study.

**BM F:** Knowledge gained from other fields of study has a direct effect on the development of technological products and systems.

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

**BM A:** Products are made to meet individual needs and wants.

**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 A:** The engineering design process includes identifying a problem, looking for ideas, developing solutions, and sharing solutions with others.

**BM B:** Expressing ideas to others verbally and through sketches and models is an important part of the design process.

**BM D:** When designing an object, it is important to be creative and consider all ideas.

**BM F:** Design involves a set of steps, which can be performed in different sequences and repeated as needed.

**BM G:** Brainstorming is a group problem-solving design process in which each person in the group presents his or her ideas in an open forum.

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

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

**BM E:** The process of designing involves presenting some possible solutions in visual form and then selecting the best solution(s) from many.
**BM I:** Specify criteria and constraints for the design.

**BM J:** Make two-dimensional and three-dimensional representations of the designed solution.

**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 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 Standard K-12:** As a result of activities in grades 9-12, all students should develop—

- **Change, constancy, and measurement**
- **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**

**Principles and Standards for School Mathematics**

**Number 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; and compute fluently and make reasonable estimates.

**Algebra:** Instructional programs from pre-kindergarten through grade 12 should enable all students to understand patterns, relations, and functions; represent and analyze mathematical situations and structures using algebraic symbols; use mathematical models to represent and understand quantitative relationships; and analyze change in various contexts.

**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; and 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; and apply appropriate techniques, tools, and formulas to determine measurements.

Problem Solving: Instructional programs from pre-kindergarten through grade 12 should enable all students to solve problems that arise in mathematics and in other contexts; apply and adapt a variety of appropriate strategies to solve problems.

Communication: Instructional programs from pre-kindergarten through grade 12 should enable all students to organize and consolidate their mathematical thinking through communication; and communicate their mathematical thinking coherently and clearly to peers, teachers, and others.

Connections: Instructional programs from pre-kindergarten through grade 12 should enable all students 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 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:

- Brainstorm and sketch possible solutions to an existing design problem.
- Create a decision making matrix.
- Select an approach that meets or satisfies the constraints given in a design brief.
- Create solid computer-aided design (CAD) models of each part from dimensioned sketches using a variety of methods.
- Apply geometric numeric and parametric constraints to form CAD modeled parts.
- Generate dimensioned multiview drawings from simple CAD modeled parts.
- Assemble the product using the CAD modeling software.
- Explain what constraints are and why they are included in a design brief.
Create a three-fold brochure marketing the designed solution for the chosen problem, such as a consumer product, a dispensing system, a new form of control system, or extend a product design to meet a new requirement.

Explain the concept of fluid power, and the difference between hydraulic and pneumatic power systems

**Assessment**

*Explanation*

1. Students will explain why design options of a project are determined by criteria and constraints.

*Application*

2. Students will design an alternate solution to the same design brief completed in the lesson and adjust their solution to include a different material.

*Interpretation*

3. Students will illustrate their proposed solution and use their illustration to explain how it relates to what they have learned about engineering design.

4. Students will explain the advantages and disadvantages of working in teams answering questions, such as:
   a. When I work with a team I find that I ...
   b. The hardest thing for me to do when working with a team is ...
   c. The easiest part of working on a team is ...
Essential Questions

1. What is a design brief?
2. Why is a design process so important to follow when creating a solution to a problem?
3. What is the purpose of design constraints?
4. What is a decision matrix and why is it used?
5. What does consensus mean, and how do teams use it to make decisions?
6. How are visual design principles and elements used to capture a consumer’s attention?
7. How is the design of a consumer product different then the design of a product used to help a manufacturing process?
8. What is fluid power?
9. What is the difference between hydraulic and pneumatic power systems?
10. How does the use of fluid power aid the use of electronics or other power systems?

Key Terms

Accuracy Assembly Assembly Drawing
Component Consensus Constraint
Decision Matrix Design Brief Design Process
Design Statement Designer Fluid Power
Hydraulics Marketing Multiview Drawing
Pneumatics Problem Statement Purpose
Solid Modeling Target Consumer Team

A list of Key Terms is provided in the Teacher Guidelines at the end of this lesson.

Day-by-Day Plans

Time: 12 days

NOTE: In preparation for teaching this lesson, it is strongly recommended that the teacher read the Teacher Notes.
Day 1-2:

- The teacher will present Concepts, Key Terms, and Essential Questions to provide a lesson overview.
- The teacher will distribute and introduce Project 2.4.1 Design Challenge and Project 2.4.1 Design Challenge Rubric.
- The teacher will divide the class into groups of two.
- The teacher will discuss constraints, requirements and design briefs for each project.
- The teacher will present Teamwork.ppt and the Fluid Power.ppt.
- Students will take notes in their journals.
- The teacher will review the design process using Example Design Process distributed in Lesson 1.1.
- Students will keep Example Design Process document available throughout this lesson.
- The teacher will distribute the graph paper located in the Teacher Guidelines at the end of this lesson.
- Students will begin work on Project 2.4.1 Design Challenge.

Day 3-12:

- The teacher will distribute Decision Matrix Template
- The teacher will present the Decision Making Matrix.ppt.
- Students will take notes in their journals.
- Students will continue working on materials to be completed for Project 2.4.1 Design Challenge.
- The teacher will keep students on task and answer any questions during the process.
- Students will complete Project 2.4.1 Design Challenges.
- Students will present their design solution using their three-fold brochure and an oral report to the class.
- The teacher will assess students using Project 2.4.1 Design Challenges Rubric.
- Optional: The teacher may want to have students take the Midterm Exam located in the Instructional Resources area below.

Instructional Resources

PowerPoint Presentations

Teamwork
Fluid Power
Decision Making Matrix
Word Documents

Project 2.4.1 Design Challenge
Midterm Exam
Midterm Exam Recording Sheet

Answer Keys and Rubrics

Project 2.4.1 Design Challenge Rubric
Midterm Exam Answer Key

Teacher Guidelines

Lesson 2.4 Teacher Notes
Lesson 2.4 Key Terms
Lesson 2.4 Key Terms and definitions in Excel
Decision Matrix Template in Word
Decision Matrix Template in Excel
Isometric graph paper
Isometric graph paper
Orthographic graph paper

Reference Sources


Lesson 3.3 – Structural Analysis

Preface

Ever wonder how products work, or how some items improve over time? Take luggage, for example. While the main purpose of luggage is to provide a way to safely transport your travel items, the suitcase has evolved greatly over time. It is common today to see lightweight, durable luggage on wheels, with telescoping handles, and a wide variety of storage and travel options, all while fitting nicely in an airplane overhead compartment. Product teardown is an important step in the redesign process. It provides an in-depth look at product characteristics. Teardown is the taking apart or disassembly of a product to help a person understand, study and analyze the product’s properties and function. The study of a product should result in a better understanding of its strengths, weakness and the manufacturing process used. Often product teardown gives a manufacturer a look at a competitor’s product to determine information such as material, application, manufacturing process, new technology, costs, and trends. This process is often the first step in the evolution of a product. One of the main reasons to perform a product teardown is to understand how things work.

The analysis of product parts in the design phase can help a company bring a better product to market in less time. One aspect of the analysis cycle would be determining a part’s weight, surface area and volume. These mass properties will help a manufacturer to determine quantities of production and finishing materials needed, as well as to assess product packaging and shipping costs.

Teachers, students and design engineers need to keep in mind that any analysis, whether detailed or fundamental, is a mathematical approximation that must be understood, interpreted, and tested in the final product design. Proper use of analysis tools has the potential to greatly reduce, but not eliminate, the physical prototype. The results of this experimentation will lead to a wider variety of design options and improved products. In this lesson, students will build several solid models of a product and determine the mass properties of a product.

Understanding the joinery, fasteners, and adhesives used in material processing is a key to identifying how products have been assembled and why. The study of various joints, fasteners, and adhesives will allow greater insight into the manufacturing process used to produce products. This knowledge will aid in the product teardown process and allow students to effectively reverse engineer a product.

Concepts

1. Objects are held together by means of joinery, fasteners, or adhesives.
2. Precision measurement tools and techniques are used to accurately record an object’s geometry.
3. Operational conditions, material properties, and manufacturing methods help engineers determine the material makeup of a design.
4. Engineers use reference sources and computer-aided design (CAD) systems to calculate the mass properties of designed objects.
5. There are many mass properties of a product; some of these are volume, surface area, density, and mass.
Standards and Benchmarks Addressed

Standards for Technological Literacy

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 H: Modeling, testing, evaluating, and modifying are used to transform ideas into practical solutions.

National Science Education Standards

Unifying Concepts and Processes Standard K-12: 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
- Evolution and equilibrium
- 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
- Understandings 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 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.
Algebra: Instructional programs from pre-kindergarten through grade 12 should enable all students to—
- represent and analyze mathematical situations and structures using algebraic symbols;
- use mathematical models to represent and understand quantitative relationships.

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;
- 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.

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 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:

- Describe the differences between joinery, fasteners, and adhesives.
- Identify the types of structural connections that exist in a given object.
- Use dial calipers to precisely measure outside and inside diameter, hole depth, and object thickness.
- Identify a given object’s material type.
- Identify material processing methods that are used to manufacture the components of a given commercial product.
- Assign a density value to a material, and apply it to a given solid CAD model.
Perform computer analysis to determine mass, volume, and surface area of a given object.

**Assessment**

*Explanation*

1. Students will classify a sampling of fasteners, joinery and adhesives.
2. Students will explain the value of the disassembly process, what information was discovered, and how it may be used to improve the product’s design.
3. Students will explain how mass properties are used in the design process to evaluate a solid model’s viability as solution to a manufacturing problem.
4. Students will explain the importance of considering different materials for a product’s production.
5. Students will explain what effect changing the surface area of a product will have on the finishing and packaging processes.

*Interpretation*

6. Students will research various materials, properties and processes to identify characteristics similar to their product.

*Application*

7. Students will apply what they have learned about joinery, fasteners and adhesives to their future product design.
8. Students will use a solid modeling software to find the mass, surface area, and volume of a part.
9. Students will change materials and revise the mass analysis of a part.

**Essential Questions**

1. What are the differences between joinery, fasteners, and adhesives?
2. What is the difference between an adhesive and a solvent?
3. How does a design’s material makeup impact the joinery, fasteners, and adhesive methods used to hold its components together?
4. What factors influence the selection of a material for use in a design?
5. For what reasons might a designer need to know the mass, volume, and surface area of an object?
6. What is the difference between an object’s mass and an object’s weight?
7. What is the difference between force and stress?
Key Terms

- Adhesive
- Adhesive Bonding
- Analysis
- Competitor
- Compression
- Fastener
- Hypothesis
- Joinery
- Manufacturing Process
- Mass
- Mechanical Fastener
- Non-Renewable Resource
- Part Interaction
- Renewable Resource
- Reverse Engineering
- Snap-Fit
- Stress
- Surface Area
- Teardown
- Tension
- Torsion
- Volume

Day-by-Day Plans

Total Time: 15 days

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

Day 1:

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

☐ The teacher will distribute Project 3.3.4 Product Disassembly Display and Project 3.3.4a Sample Disassembly Display, and explain how this project will serve as the lesson capstone. Students will be creating a poster presentation of their reverse engineered product in disassembled array with the appropriate components modeled using 3D CAD software.

☐ The teacher will present Wood Fasteners, Joinery, & Adhesives, Metal Fasteners, Joining & Adhesives, and Plastic Fasteners, Welding & Bonding.ppt.

☐ Students will take notes on the nomenclature and how the terms are used to distinguish between the types of processes and materials being used in joining, fastening, and adhering a product. It is imperative that students understand the basic differences between joinery, fasteners, and adhesives.

☐ Optional: The teacher may have students work through the following optional activities in class or as homework assignments after having students view the related PowerPoint presentations:
  - Optional Activity 3.3.1a Wood Joinery Identification
  - Optional Activity 3.3.1b Wood Fasteners Adhesives Classification
  - Optional Activity 3.3.1c Metal Joining Process Identification
- Optional Activity 3.3.1d Metal Fasteners and Adhesive Classification
- Optional Activity 3.3.1e Plastic Welding Procedure Identification
- Optional Activity 3.3.1f Plastic Fasteners Bonding Classification

The teacher will present Product Disassembly.ppt and explain to students the need to take a product apart in order to learn more about how it functions.

**Days 2-4:**
- The teacher will review and distribute Activity 3.3.2 Product Disassembly, Activity 3.3.2a Product Disassembly Chart, and Activity 3.3.2b Materials Usages Charts.
- Students will use Activity 3.3.2a Product Disassembly Chart to record their work, and Activity 3.3.2b Materials Usages Chart to identify the various materials that exist in their reverse engineered products.
- Students will begin disassembling their product used in prior lessons for this unit.

**Day 5:**
- Students will complete Activity 3.3.2a Product Disassembly Chart.
- The teacher will remind students about Activity 3.3.2b Materials and their Usages information sheet and explain how to use the document with the activity.
- The teacher will assist students with the function and material section of the chart using the Activity 3.3.2b Materials Usages Chart.

**Days 6-10:**
- The teacher will introduce Mass Property Analysis.ppt.
- Students will take notes in their engineer’s notebook.
- The teacher will present Activity 3.3.3 Mass Property Analysis and offer students additional practice with the following extra activity:
  - Optional Activity 3.3.3a-g Mass Property Analysis Extras
- Students will begin drawing the parts with a 3D modeling program and complete Activity 3.3.3 Mass Property Analysis.
- The teacher will assist students as needed.

**Days 11-12:**
- The teacher will review expectations of Project 3.3.4 Product Disassembly Display.
- Students will complete Project 3.3.4 Product Disassembly Display by constructing the foam core presentation display to document their disassembly process and related components needed for the display that have not been created earlier.

**Day 13:**
- Students will prepare an oral presentation for the poster session.
Days 14-15:

- The teacher will review the poster session presentation requirements with students.
- Students will give oral presentations and provide feedback to other teams in a poster style presentation.

Instructional Resources

PowerPoint Presentations
- Wood Fasteners, Joinery, & Adhesives
- Product Disassembly
- Mass Property Analysis
- Metal Fasteners, Joining & Adhesives
- Plastic Fasteners, Welding & Bonding

Word Documents
- Optional Activity 3.3.1a Wood Joinery Identification
- **Optional Activity 3.3.1b Wood Fasteners and Adhesives Classification**
- Optional Activity 3.3.1c Metal Joining Process Identification
- Optional Activity 3.3.1d Metal Fasteners and Adhesive Classification
- Optional Activity 3.3.1e Plastic Welding Procedure Identification
- Optional Activity 3.3.1f Plastic Fasteners & Bonding Classification
- Activity 3.3.2 Product Disassembly
- Activity 3.3.2a Product Disassembly Chart
- Activity 3.3.2b Materials Usages Charts
- Activity 3.3.3 Mass Property Analysis
- Optional Activity 3.3.3a-g Mass Property Analysis Extras
- Project 3.3.4 Product Disassembly Display

Answer Keys and Rubrics
- Optional Activity 3.3.1b Wood Fasteners and Adhesives Answer Key
- **Activity 3.3.3 Mass Property Analysis Answer Key**
- Optional Activity 3.3.3a-g Mass Property Analysis Extras Answer Key
Teacher Guidelines

**Inventor Files**

**IED Considerations**

**Lesson 3.3 Key Terms and definitions in Excel**

**Reference Sources**


National Council of Teachers of English (NCTE) and International Reading Association (IRA) (1996). *Standards for English language arts*.


**Note:** Additional resource information is available in the Lesson 3.3 Teacher Notes.

**Lesson 3.4 – Product Improvement by Design**
Lesson 3.4 – Product Improvement by Design

Preface

Technologies begin as inventions, and are often improved over time through the process of innovation. The light bulb is an excellent example. Most people are familiar with incandescent and fluorescent light bulbs. Both Joseph Swan and Thomas Edison invented the incandescent light bulb around 1880. The fluorescent light bulb appeared 55 years later, and was able to produce light using a smaller amount of electricity. It is important that students understand that there is a difference between invention and innovation, and that specific examples can often be argued as both. For example, it could be argued that the fluorescent light bulb was an invention, because the process by which ultraviolet light causes a powder to glow within a glass tube is significantly different from the process of getting a filament to produce visible light through electrical resistance. It could also be argued that the concept of passing electricity through a glass tube for the purpose of generating visible light was the invention, and anything that came after Edison and Swan’s invention would fall in the realm of innovation.

The focus of this unit is reverse engineering, which is a process that does not imply product improvement. However, reverse engineering may be used as a tool to drive product innovation through the identification of a visual, structural, or functional shortcoming. Product improvements may also result from the need for lower costs and shorter production times, changes in materials or processes, or the desire to reduce the global and human impacts that a product has.

In this lesson students will, identify visual, structural, or functional issues with their reverse engineered products, initiate product improvements by writing design briefs, participate in group brainstorming sessions to develop creative ideas, use matrices to make design decisions, develop innovative solutions, and communicate their designs through technical reports.

Concepts

1. Engineers analyze designs to identify shortcomings and opportunities for innovation.
2. Design teams use brainstorming techniques to generate large numbers of ideas in short time periods.
3. Engineers use decision matrices to help make design decisions that are based on analysis and logic.
4. Engineers spend a great deal of time writing technical reports to explain project information to various audiences.

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 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.

**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.

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

**BM C:** The use of technology affects the environment in good and bad ways.

**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.

**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 A:** Everyone can design solutions to a problem.

**BM C:** The design process is a purposeful method of planning practical solutions to problems.

**BM D:** Requirements for a design include such factors as the desired elements and features of a product or system or the limits that are placed on the design.

**BM E:** Design is a creative planning process that leads to useful products and systems.

**BM F:** There is no perfect design.

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

**BM A:** The engineering design process includes identifying a problem, looking for ideas, developing solutions, and sharing solutions with others.

**BM B:** Expressing ideas to others verbally and through sketches and models is an important part of the design process.

**BM D:** When designing an object, it is important to be creative and consider all ideas.

**BM F:** Design involves a set of steps, which can be performed in different sequences and repeated as needed.

**BM G:** Brainstorming is a group problem-solving design process in which each person in the group presents his or her ideas in an open forum.
BM J: Engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.

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

BM D: Invention and innovation are creative ways to turn ideas into real things.

BM G: Invention is a process of turning ideas and imagination into devices and systems.

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

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

BM C: Investigate how things are made and how they can be improved.

BM E: The process of designing involves presenting some possible solutions in visual form and then selecting the best solution(s) from many.

BM I: Specify criteria and constraints for the design.

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 P: Use computers and calculators to access, retrieve, organize, 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 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 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 Standard K-12: 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
- Evolution and equilibrium
- Form and Function

Science as Inquiry Standard A: As a result of activities in grades 9-12, all students should develop understanding of—
- Abilities necessary to do scientific inquiry
- Understandings 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 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.

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 apply mathematics in contexts outside of mathematics.

Representation: Instructional programs from pre-kindergarten through grade 12 should enable all students to—

- 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 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 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:

- Write design briefs that focus on product innovation.
- Identify group brainstorming techniques and the rules associated with brainstorming.
- Use decision matrices to make design decisions.
- Explain the difference between invention and innovation.

Assessment

Explanation

1. Students will explain the differences between a problem statement and a design statement.
2. Students will explain how a design brief can impart bias in the mind of the designer.

Interpretation

1. Students will analyze commercial objects and formulate problem statements, design statements, and constraints that may have been used to initiate the creation of those objects.

Application

1. Students will apply their knowledge of the design process to the innovation of visual, structural, or functional aspects of their reverse engineered products.
2. Students will brainstorm as a class team to generate ideas for various product innovation needs.
Perspective

1. Students will generate a design brief for their reverse engineered product from the perspective of a designer.

Essential Questions

1. What is the purpose of reverse engineering a product?
2. What practices are associated with group brainstorming?
3. Why is brainstorming as a team important when modifying or improving a product?
4. What are some factors to consider when enhancing an existing product?
5. What function does the design brief serve in the design process?
6. What are the elements of a technical report?

Key Terms

<table>
<thead>
<tr>
<th>Appendix</th>
<th>Bias</th>
<th>Brainstorming</th>
</tr>
</thead>
<tbody>
<tr>
<td>Criteria</td>
<td>Decision Matrix</td>
<td>Descriptive Abstract</td>
</tr>
<tr>
<td>Executive Summary</td>
<td>Innovation</td>
<td>Invention</td>
</tr>
<tr>
<td>Product</td>
<td>Purpose</td>
<td>Technical Report</td>
</tr>
</tbody>
</table>

Day-by-Day Plans

Time: 16 days

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

Day 1:

☐ The teacher will present Concepts, Key Terms, and Essential Questions to provide a lesson overview.
☐ The teacher will introduce and distribute Activity 3.4.1a Child Toy Design Brief.
☐ The teacher will present Writing a Design Brief.ppt.
☐ Students will take notes in their engineer’s notebook.
☐ The teacher will introduce and distribute Activity 3.4.1 Writing a Design Brief and Activity 3.4.1b Design Brief Template.
☐ Students will begin work on Activity 3.4.1 Writing a Design Brief.

Days 2-3:

☐ Students will complete Activity 3.4.1 Writing a Design Brief.
☐ The teacher will assist the students with Activity 3.4.1 Writing a Design Brief.
☐ The teacher will assess student work using Activity 3.4.1 Writing a Design Brief Answer Key.
Day 4-5:
- The teacher will administer Activity 3.4.1c Framing a Design Brief Quiz.
- Students will complete the quiz.
- The teacher will assess student work using Activity 3.4.1c Framing a Design Brief Quiz Answer Key.
- The teacher will introduce and distribute Activity 3.4.2 The Deep Dive.
- The teacher will show The Deep Dive DVD.
- Students will watch the film and complete Activity 3.4.2 The Deep Dive.

Day 6-7:
- The teacher will present The Deep Dive.ppt, review Activity 3.4.2 The Deep Dive, and lead the students in a discussion on the difference between invention and innovation.
- Students will take notes in their engineer’s notebook.
- The teacher will introduce and distribute Problem 3.4.3 Product Improvement.
- Students will begin working in teams to identify a visual, structural, or functional shortcoming in their reverse engineered products, and create design briefs to address those problems for homework.

Day 8:
- Students will submit their design briefs from Problem 3.4.3 Product Improvement.
- The teacher will review the design briefs with the class.
- Students will begin brainstorming ideas for each design brief as a class team.

Days 9-13:
- Students will continue brainstorming ideas for each design brief as a class team.
- The teacher will facilitate the brainstorming session and collect the ideas generated.
- Students will continue working on Problem 3.4.3 Product Improvement.
- The teacher will assist the students with Problem 3.4.3 Product Improvement.

Day 14:
- The teacher will present Technical Report Elements.ppt.
- Students will take notes in their engineer’s notebook.
- Students will continue working on Problem 3.4.3 Product Improvement.

Days 15-16:
- Students will complete Problem 3.4.3 Product Improvement and submit their technical reports to the teacher.
- The teacher will assist the students with Problem 3.4.3 Product Improvement.
Instructional Resources

PowerPoint Presentations
- Writing a Design Brief
- The Deep Dive
- Technical Report Elements

Word Documents
- Activity 3.4.1 Writing a Design Brief
- Activity 3.4.1a Child Toy Design Brief
- Activity 3.4.2 The Deep Dive
- Problem 3.4.3 Product Improvement

Assessment
- Activity 3.4.1c Framing a Design Brief Quiz

Answer Keys and Rubrics
- Activity 3.4.1 Writing a Design Brief Answer Key
- Activity 3.4.1c Framing a Design Brief Quiz Answer Key
- Activity 3.4.2 The Deep Dive Answer Key

Teacher Guidelines
- Lesson 3.4 Teacher Notes
- Activity 3.4.1b Design Brief Template
- Problem 3.4.3a Decision Matrix Template
- Problem 3.4.3b Product Improvement Design Brief Template
- Lesson 3.4 Key Terms and definitions in Excel

Reference Sources


National Council of Teachers of English (NCTE) and International Reading Association (IRA) (1996). *Standards for English language arts.*


Unit 4 – Design Problems

Preface

This unit is designed to combine the knowledge and information learned in the previous units to an open ended design problem. Students will apply the design process to create a solution to a problem that currently exists. Students will also learn that by-products are created as a result of the solution, and what impacts they have on the environment and society. The students will also learn how to affectively market a product. They will also have an opportunity to create a virtual team to complete the tasks needed to solve real world problems.

Concepts

1. Market research and demographics provide useful information to companies for developing effective product advertising strategies.
2. Graphic designers are concerned with developing visual messages that make people in a target audience respond in a predictable and favorable manner.
3. The material of a product, how the material is prepared for use, its durability, and ease of recycling all impact a product’s design, marketability, and life expectancy.
4. A conscious effort by product designers and engineers to investigate the recyclable uses of materials will play a vital role in the future of landfills and the environment.
5. Design teams establish group norms through brainstorming and consensus to regulate proper and acceptable behavior by and between team members.
6. Virtual teams rely on communications other than face-to-face contact to work effectively to solve problems.

Essential Questions

Lesson 4.1 Engineering Design Ethics

1. What is meant by engineering design ethics?
2. What is ethics?
3. Why is it important to understand ethics and how it relates to product design?
4. Why is it important to study a product’s lifecycle?
5. What factors influence the selection of materials to make a product?
6. What do you think of when you hear the word impact?
7. How can a manufacturing process impact an environment?
8. How do ethics impact the production of products?
9. What global and human impacts must be considered by all involved with the design, manufacture and distribution of products?
10. Why is it important to have clear, accurate, and detailed communication among all involved in the design, manufacture and distribution process?
11. What laws exist in the United States to protect humans and the environment?
Lesson 4.2 Design Teams

1. Why are teams of people used to solve problems?
2. What are group norms?
3. What does *consensus* mean, and how do teams use it to make decisions?
4. What is the purpose of a Gantt chart?
5. What types of communication methods do virtual teams rely on in the absence of face-to-face contact?
6. How do teams deal with individual team members’ weaknesses?
7. What methods do teams use to formally address conflict between team members?

Lessons

Lesson 4.1 Engineering Design Ethics
Lesson 4.2 Design Teams

Unit Evaluation

The Essential Questions and Conclusion questions at the end of each activity may be used along with the Assessment suggestions provided in each lesson to develop summative assessment tools, such as tests or end of unit projects.
Lesson 4.1 – Engineering Design Ethics

Preface

At the beginning of the 21st Century, it is increasingly obvious that human society is profoundly altering the world. The extent and eventual consequences of human and global impacts on the environment are becoming noticeably clear. Due to changes in population growth, consumer needs and wants, lifestyle, and technology over the past decades, the global environment is changing at an accelerated rate.

More frequently, public and private interest groups are debating the nature of human impacts on the environment. These groups often perform research and recommend ways to minimize the potentially harmful consequences of choices that are made by individuals, consumers, and society. Another recent change is growth of global industrial practice in which products are often made through collaborative efforts. The design, manufacture, and distribution of products often encompass the globe. For example, parts of a product may be made in several different countries, sent to yet another country for assembly, and then shipped and sold globally. Global networking and responsible shared decision-making are necessary skills for today’s designers and engineers.

Ethical issues are considered when deciding on a workable solution to a design or solution to a problem. Often times decisions are made with careful consideration to ethics and how the result can have a ripple effect. Other times ethics are not considered. Understanding design ethics is a part of a design process must be learned and practiced.

This lesson is designed to provide the students with an opportunity to experience shared decision-making, as they investigate different materials, manufacturing processes, and the short and long term impacts that their decision-making may have on society or potentially on the world.

Concepts

1. The material of a product, how the material is prepared for use, its durability, and ease of recycling all impact a product’s design, marketability, and life expectancy.
2. All products made, regardless of material type, may have both positive and negative impacts.
3. In addition to economics and resources, manufacturers must consider human and global impacts of various manufacturing process options.
4. Laws and guidelines have been established to protect humans and the global environment.
5. A conscious effort by product designers and engineers to investigate the recyclable uses of materials will play a vital role in the future of landfills and the environment.
Standards and Benchmarks Addressed

Standards for Technological Literacy

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

**BM H:** Changes caused by the use of technology can range from gradual to rapid and from subtle to obvious.

**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 I:** With the aid of technology, various aspects of the environment can be monitored to provide information for decision-making.

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

**BM K:** Humans devise technologies to reduce the negative consequences of other technologies.

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

National Science Education Standards

**Unifying Concepts and Processes Standard K-12:** 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
- Change, constancy, and measurement

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

- 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
Principles and Standards for School Mathematics

Number Operations Standard: Instructional programs from pre-kindergarten through grade 12 should enable all students to compute fluently and make reasonable estimates.

Data Analysis and Probability Standard: 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.

Standards for English Language Arts

Standard 3: Students apply a wide range of strategies to comprehend, interpret, evaluate, and appreciate texts. They draw on their prior experience, their interactions with other readers and writers, their knowledge of word meaning and other texts, their word identification strategies, and their understanding of textual features (e.g. sound-letter correspondence, sentence structure, context, graphics).

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 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:

- Create a brainstorming list of different products made from common materials that are used daily.
- Research and construct a product impact timeline presentation of a product from the brainstorming list and present how the product may be recycled and used to make other products after its lifecycle is complete.
- Identify the five steps of a product’s lifecycle and investigate and propose recyclable uses for the material once the lifecycle of the product is complete.
Assessment

Explanation

1. Students will explain what is meant by product lifecycle in their engineering notebooks. They may choose to express their explanation in one of the following forms:
   - Write an essay
   - Create a research paper
   - Create a formal presentation using slides

Application

2. Students will investigate materials used daily to make products, and classify the materials from easy to difficult in regards to each material’s recyclable processes.
3. Students will research design ethic issues and make a formal report of their findings.

Perspective

4. Students will identify and discuss various short and long term global and human impacts of their chosen design.

Empathy

5. Students will discuss in their engineering notebook concerns they may have for the environment regarding their chosen product. They will determine how they think they may be able to produce their product responsibly.

Essential Questions

1. What is meant by engineering design ethics?
2. What is ethics?
3. Why is it important to understand ethics and how it relates to product design?
4. Why is it important to study a product’s lifecycle?
5. What factors influence the selection of materials to make a product?
6. What do you think of when you hear the word impact?
7. How can a manufacturing process impact an environment?
8. How do ethics impact the production of products?
9. What global and human impacts must be considered by all involved with the design, manufacture and distribution of products?
10. Why is it important to have clear, accurate, and detailed communication among all involved in the design, manufacture and distribution process?
11. What laws exist in the United States to protect humans and the environment?
Key Terms

Attorney General  By-product  Carcinogen
Ecosystem  EPA  Ergonomics
Ethical  Ethics  Hazard
Impact  Landfill  OSHA
Product lifecycle  Raw Material  Recycle
Refurbish  Refuse  Residue
Trade-off  Waste

Day-by-Day Plans

Time: 8 days

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

Day 1:

☐ The teacher will present Concepts, Key Terms, and Essential Questions, and provide a lesson overview.
☐ The teacher will present Global, Human, and Ethical Impacts.ppt and begin a dialogue with students on how products can provide positive and negative impacts.
☐ The teacher will explain the expectations of Activity 4.1.1 Product Lifecycle.
☐ Students will brainstorm possible products to be used.
☐ Students will divide into groups of two, pick an instructor approved product for Activity 4.1.1 Product Lifecycle and Recycling and begin work.

Day 2:

☐ Students will continue work on Activity 4.1.1 Product Lifecycle and Recycling and report findings as described in the activity.

Day 3:

☐ Students will complete Activity 4.1.1 and present to the class.
☐ The teacher will assess Activity 4.1.1 using the Product Lifecycle Rubric.

Day 4 – 8:

☐ The teacher will introduce and distribute Problem 4.1.2 Engineering Design Ethics Design Brief, Problem 4.1.2a Sample Engineering Design Ethics Design Brief and Problem 4.1.2b Engineering Ethics Design Brief Template.
☐ Students will complete Problem 4.1.2 Engineering Design Ethics Design Brief.
Optional: The teacher may have the students create their design briefs first and then have them exchange their design briefs with students in the class. The students would follow the design briefs in order to do the research and create the report either as a CD cover, book cover, or poster.

The teacher will assess student work through the completion of the problem as well as students’ responses to the Conclusion questions of the problem.

The teacher will lead students in a class discussion of their findings from their research.

Optional: The teacher will have students present their findings or the CD cover, book cover, or posters and may them displayed around the school.

### Instructional Resources

**PowerPoint**
- Presentations
  - Global, Human, and Ethical Impacts

**Word Documents**
- Activity 4.1.1 Product Lifecycle
- Problem 4.1.2 Engineering Design Ethics Design Brief

**Answer Keys**
- Product Lifecycle Rubric

**Teacher Guidelines**
- Lesson 4.1 Teacher Notes
- **Problem 4.1.2a Sample Engineering Design Ethics Design Brief**
- **Problem 4.1.2b Engineering Ethics Design Brief Template**
- **Lesson 4.1 Key Terms and definitions in Excel**

**Reference Sources**


National Council of Teachers of English (NCTE) and International Reading Association (IRA) (1996). *Standards for English language arts*.


Lesson 4.2 – Design Teams

Preface

Problems exist all over, and they vary in their degrees of complexity and importance. Sometimes problems present themselves, such as when a client solicits the services of an engineer. Sometimes they are forecasted, and solutions are invented for a time of future need. Many existing solutions, such as manufacturing processes, have brought about new problems and environmental concerns. Regardless of how problems are identified or where they come from, engineers use the design process to creatively and efficiently solve problems. They have also used their technical knowledge, belief in their ability to succeed, willingness to modify their behavior to meet a specific situation, constructive discontent with the world around them, and their ability to think and “feel” their way through a situation. It is this process, however, that serves as the foundation and link between all fields of engineering.

In this lesson, students will be grouped into virtual design teams based on their interests. Students will learn about group norms, establish rules of acceptable behavior, develop management strategies, and work across virtual boundaries to research and develop solutions to problems of their choosing. The degree to which the teams can solve their problems will most certainly be influenced by the resources that are readily available, such as time, access to tools, materials, and expertise. Each team will use their technical knowledge that they have gained throughout this course, along with their understanding of the design process, to solve the selected design problem. When finished, the teams will develop and deliver individual presentations that chronicle their design’s development.

Evaluation will play a critical role throughout this process. Students will evaluate themselves and each other on a regular basis. The visual, structural, and functional qualities of their final solutions will be evaluated by the entire class, as will their final summary presentations. Students’ notebooks will be the subject of evaluation, along with students’ technical drawings, which should communicate their solutions to the point that they could be manufactured by a third party.

It is important for the students to understand that an acceptable solution is one that fits the constraints and specifications of the design brief. There is no one right way to solve a design problem, but there is always a more functional, structurally sound, cost effective, visually pleasing, and environmentally friendly way.

Concepts

1. Teams of people can accomplish more than one individual working alone.
2. Design teams establish group norms through brainstorming and consensus to regulate proper and acceptable behavior by and between team members.
3. Engineers develop Gantt charts to plan, manage, and control a design team’s actions on projects that have definite beginning and end dates.
4. Virtual teams rely on communications other than face-to-face contact to work effectively to solve problems.
5. Each team member’s strengths are a support mechanism for the other team members’ weaknesses.
6. Conflict between team members is a normal occurrence, and can be addressed using formal conflict resolution strategies.

Standards and Benchmarks Addressed

Standards for Technological Literacy

**Standard 1:** Students will develop an understanding of the characteristics and scope of technology.
- **BM F:** Creative thinking and economic and cultural influences shape technological development.
- **BM G:** The development of technology is a human activity and is the result of individual or corporate needs and the ability to be creative.
- **BM H:** Technology is closely linked to creativity, which has resulted in innovation.
- **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 E:** People plan in order to get things done.
- **BM H:** Resources are the things needed to get a job done, such as tools and machines, materials, information, energy, people, capital, and time.
- **BM L:** Requirements are the limits to designing or making a product or system.
- **BM N:** Systems thinking involves considering how every part relates to others.
- **BM Q:** Malfunctions of any part of a system may affect the function and quality of the system.
- **BM R:** Requirements are the parameters placed on the development of a product or system.
- **BM S:** Trade-off is a decision process recognizing the need for careful compromises among competing factors.
- **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 EE:** Management is the process of planning, organizing, and controlling work.

**Standard 6:** Students will develop an understanding of the role of society in the development and use of technology.
- **BM A:** Products are made to meet individual needs and wants.

**Standard 10:** Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.
- **BM F:** Troubleshooting is a problem-solving method used to identify the cause of a malfunction in a technological system.
BM G: Invention is a process of turning ideas and imagination into devices and systems.
BM J: Technological problems must be researched before they can be solved.
Standard 11: Students will develop abilities to apply the design process.
BM K: Test and evaluate the design in relation to pre-established requirements, such as criteria and constraints, and refine as needed.
BM L: Make a product or system and document the solution.
BM M: Identify the design problem to solve and decide whether or not to address it.
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.
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 C: Recognize and use everyday symbols.
BM E: Select and safely use tools, products, and systems for specific tasks.
BM F: Use computers to access and organize information.
BM G: Use common symbols, such as numbers and words, to communicate key ideas.
BM H: Use information provided in manuals, protocols, or by experienced people to see and understand how things work.
BM K: Operate and maintain systems in order to achieve a given purpose.
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, 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 I: Interpret and evaluate the accuracy of the information obtained and determine if it is useful.
Standard 17: Students will develop an understanding of and be able to select and use information and communication technologies.
BM B: Technology enables people to communicate by sending and receiving information over a distance.
BM C: People use symbols when they communicate by technology.
BM D: The processing of information through the use of technology can be used to help humans make decisions and solve problems.

BM E: Information can be acquired and sent through a variety of technological sources, including print and electronic media.

BM F: Communication technology is the transfer of messages among people and/or machines over distances through the use of technology.

BM H: Information and communication systems allow information to be transferred from human to human, human to machine, and machine to human.

BM J: The design of a message is influenced by such factors as the intended audience, medium, purpose, and nature of the message.

BM K: The use of symbols, measurements, and drawings promotes clear communication by providing a common language to express ideas.

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

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

BM B: Manufactured products are designed.

National Science Education Standards

Unifying Concepts and Processes Standard K-12: 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 understanding of—

- Abilities necessary to do 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 Operations Standard: 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.

Geometry

Instructional programs from pre-kindergarten through
**Standard:** 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 Standard:** Instructional programs from pre-kindergarten through grade 12 should enable all students to solve problems that arise in mathematics and in other contexts; apply and adapt a variety of appropriate strategies to solve problems.

**Communication Standard:** 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.

**Connections Standard:** Instructional programs from pre-kindergarten through grade 12 should enable all students to recognize and apply mathematics in contexts outside of mathematics.

**Representation Standard:** Instructional programs from pre-kindergarten through grade 12 should enable all students to create and use representations to organize, record, and communicate mathematical ideas.

**Standards for English Language Arts**

**Standard 1:** Students read a wide range of print and nonprint texts to build an understanding of texts of themselves, and of the cultures of the United States and the world; to acquire new information; to respond to the needs and demands of society and the workplace; and for personal fulfillment. Among these texts are fiction and nonfiction, classical and contemporary works.

**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 nonprint 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.

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:

- Explain why teams of people are used to solve problems.
- Identify group norms that allow a virtual design team to function efficiently.
- Establish file management and file revision protocols to ensure the integrity of current information.
- Use internet resources, such as email, to communicate with a virtual design team member throughout a design challenge.
- Identify strategies for addressing and solving conflicts that occur between team members.
- Create a Gantt chart to manage the various phases of their design challenge.

Assessment

Explanation

1. Students will explain the advantages and disadvantages of virtual teams.

Application

2. Students will apply the design process to solve a design problem within a virtual team.

Perspective

3. Having the advantage of hind-sight, at the conclusion of the design experience students will reflect on what they would have done differently if the project were to be repeated.

Empathy

4. Students will play the role of the client and offer written constructive criticism to the other teams on their design solutions during their final summary presentations.

Self-Knowledge

5. Students will make thoughtful engineering notebook entries for every class day on the project.

6. Students will conduct formal, periodic self-assessments.
Essential Questions

1. Why are teams of people used to solve problems?
2. What are group norms?
3. What does consensus mean, and how do teams use it to make decisions?
4. What is the purpose of a Gantt chart?
5. What types of communication methods do virtual teams rely on in the absence of face-to-face contact?
6. How do teams deal with individual team members’ weaknesses?
7. What methods do teams use to formally address conflict between team members?

Key Terms

Arbitration  Consensus  Critique
Evaluate  Gantt Chart  Mediation
Negotiation  Norms  Open-Ended
Protocol  Storming  Synergy

Virtual Team

Day-by-Day Activities

Time: 25 days

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

Day 1:

☐ The teacher will present Concepts, Key Terms, and Essential Questions, and provide a lesson overview.
☐ Students will review the design briefs contained in Project 4.2.1 Virtual Design Challenge and identify two challenges that they would be willing to pursue as a final design project.
☐ The teacher will collaborate with his/her IED colleague to pair students up into virtual teams based on their interests.
Day 2:
- The teacher will present Teamwork.ppt and relate the information to class experiences that have occurred since the beginning of the course.
- Students will take notes in their engineer’s notebook.
- The teacher will introduce and distribute Activity 4.2.2 Team Norms, assign students to their virtual teams, and identify their design challenges.
- Students will introduce themselves to their virtual teammates, and begin work on Activity 4.2.2 Team Norms.

Day 3-5:
- Students will work to complete Activity 4.2.2 Team Norms.
- The teacher will work with the students and collaborate with his/her IED colleague to formalize each team’s Gantt chart and list of group norms.
- Students will fill out and submit their first Periodic Self-Evaluation and Periodic Teammate 10-Point Evaluation.

Day 6-18:
- Students will work in their virtual teams on Project 4.2.1 Virtual Design Challenge.
- The teacher will assist the students with their design projects.
- Students will fill out a Periodic Teammate 10-Point Evaluation and Periodic Self-Evaluation every three class periods and submit them to the instructor for assessment.
- The teacher will collaborate with his/her IED colleague to coordinate the exchange of evaluation materials and other related project correspondence.

Day 19-20:
- Students will work on their final summary PowerPoint presentations.
- The teacher will assist the students with their presentations.

Day 21:
- Students will submit all of their associated project drawings and engineer’s notebooks for evaluation.
- Students will begin delivering five-minute summary presentations that chronicle their design experiences, and explain their solutions to the class.
- The teacher will evaluate the students’ presentations using the Summary Presentation Evaluation.
- Students will evaluate each others’ presentations using the Summary Presentation Evaluation.
Day 22-24:
- Students will continue delivering five-minute summary presentations that chronicle their design experiences, and explain their solutions to the class.
- The teacher will evaluate the students’ presentations using the Summary Presentation Evaluation.
- Students will evaluate each others’ presentations using the Summary Presentation Evaluation.

Day 25:
- Students will evaluate the visual, structural, and functional qualities of each team’s solution, and submit their assessments to the instructor.
- Students will fill out a Teammate Performance Summary and submit it to the instructor.
- The teacher will evaluate all documents and collaborate with his/her IED colleague to share evaluation materials.

Instructional Resources
PowerPoint presentations
- Teamwork

Word Documents
- Project 4.2.1 Virtual Design Challenge
- Activity 4.2.2 Team Norms

Evaluation Documents
- Design Project Tally Sheet
- Engineer’s Notebook Evaluation
- Periodic Self-Evaluation
- Periodic Teammate 10-Point Evaluation
- Summary Presentation Evaluation
- Teammate Performance Summary

Teacher Guidelines
- Lesson 4.2 Teacher Notes
- Counselor Conference Design Brief
- Open-Ended Design Problems.ppt
- Lesson 4.2 Key Terms and definitions in Excel
Reference Sources


National Council of Teachers of English (NCTE) and International Reading Association (IRA) (1996). *Standards for English language arts.*


Glossary

A

**Absolute Coordinates:** The exact location of a specific point in terms of X, Y, and Z from the fixed point of origin.

**Accuracy:** 1. The condition or quality of being true, correct, or exact; precision; exactness. 2. The degree of correctness of a quantity or expression.

**Accurate:** Correct in all details.

**Acute Triangle:** A triangle that contains only angles that are less than 90 degrees.

**Adhesive:** Any synthetic product that is used to join materials together.

**Adhesive Bonding:** 1. A plastic joining technique in which a third substance bonds a plastic to another plastic or material such as metal, rubber, ceramic, glass, or wood. 2. The process of fastening parts of metal products together permanently with non-metallic materials.

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

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

**Aligned Dimension:** A system of dimensioning which requires all numerals, figures, and notes to be aligned with the dimension lines so that they may be read from the bottom (for horizontal dimensions) and from the right side (for vertical dimensions).

**American National Standards Institute (ANSI):** 1. A private, non-profit organization that coordinates the development and use of voluntary consensus standards in the United States. 2. The acronym for the America National Standards Institute.

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

**Analysis:** A detailed examination of the elements or structure of something.

**Angle:** The amount of rotation needed to bring one line or plane into coincidence with another, generally measured in radians or degrees.

**Annotate:** To add explanatory notes to.

**Appendix:** A section of additional information at the end of a document.

**Arbitration:** The hearing and determination of a dispute or the settling of differences between parties by a person or persons chosen or agreed to by them.
**Area**: The number of square units required to cover a surface.

**Arrowheads**: Arrowheads are used to indicate the end of a dimension line or leader.

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

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

**Assembly Drawing**: A drawing that shows the various parts of an item when assembled.

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

**Asymmetry**: Symmetry in which both halves of a composition are not identical. Also referred to as informal balance.

**Audience**: The assembled spectators or listeners at an event.

**Attorney General**: The principal legal officer of the Crown or a state.

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

**Auxiliary View**: An orthographic view of an object using a direction of sight other than one of the six basic views (front, top, right-side, rear, bottom, left-side); used to show a surface that is not parallel to any of the principal view planes.

**Axis**: 1. An imaginary line through a body, about which it rotates. 2. An imaginary line about which a regular figure is symmetrically arranged. 3. A fixed reference line for the measurement of coordinates.
**Balance**: A condition in which different elements are equal or in the correct proportions. There are three types of visual balance: symmetry, asymmetry, and radial.

**Balloons**: A circled number identifying each part shown in an assembly drawing. Also called a ball tag or bubble number.

**Baseline Dimensioning**: System of dimensioning in which all dimensions are placed from a datum and not from feature to feature. Also referred to as Datum Dimensioning.

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

**Bilateral Tolerance**: A tolerance in which variation is permitted in both directions from the specified dimension.

**Black Box Model**: A graphic system’s illustration referred to as a *Black Box* because the internal components or process is deemed unknown, or mysterious.

**Blind Hole**: A hole that does not go completely through the workpiece.

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

**Brainstorming**: A group technique for solving problems, generating ideas, stimulating creative thinking, etc. by unrestrained spontaneous participation in discussion.

**Break Line**: A line used to interrupt a drawing if an object will not fit on a drawing sheet.

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

**Broken-Out Section**: A section of an object broken away to reveal an interior feature for a sectional drawing.

**By-product**: Something produced in the making of something else; a secondary result; a side effect.
Cabinet Oblique Drawing: A form of oblique drawing in which the receding lines are drawn at half scale, and usually at a 45 degree angle from horizontal.

Cabinet Oblique Sketch: A form of oblique sketch in which the receding lines are drawn at half scale, and usually at a 45 degree angle from horizontal.

Caliper: A measuring instrument having two usually adjustable jaws used especially to measure diameter or thickness.

Carcinogen: A substance capable of causing cancer.

Cartesian Coordinate System: A rectangular coordinate system created by three mutually perpendicular coordinate axes, commonly labeled X, Y, and Z.

Cavalier Oblique Drawing: A form of oblique drawing in which the receding lines are drawn true size, and usually at a 45 degree angle from horizontal.

Cavalier Oblique Sketch: A form of oblique sketch in which the receding lines are drawn true size, and usually at a 45 degree angle from horizontal.

Centerline: A line type that is used to indicate the axis of symmetry for a part or feature, the symmetrical alignment of a pattern of holes, and the path of motion for moving parts in an assembly.

Chain Dimensioning: Also known as point-to-point dimensioning where dimensions are established from one point to the next.

Chamfer: A small angled surface formed between two surfaces.

Circle: The set of all points in a plane at a given distance from a given point in the plane.

Circumscribe: 1. A triangle located round a polygon such as a circle. 2 To draw a figure around another, touching it at points but not cutting it.

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

Class Interval: A group of values that is used to analyze the distribution of data.

Clearance Fit: The total gap between two mating parts, such as the difference in diameters between a cylindrical shaft and a hole.

Client: A person using the services of a professional person or organization.

Color: The property possessed by an object of producing different sensations on the eye as a result of the way it reflects or emits light.

Competitor: One who competes or is a rival of another business enterprise.

Component: A part or element of a larger whole.

Compound Machine: A mechanism that consists of two or more simple machines.
Compresssion: A force that pushes on or squeezes a material.

Computer-Aided Design or Computer-Aided Drafting (CAD): 1. For design, the use of a computer to assist in the process of designing a part, circuit, building, etc. 2. For drafting, the use of a computer to assist in the process of creating, storing, retrieving, modifying, plotting, and communicating a technical drawing.

Consensus: General agreement.

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

Construction Line: Thin lines that serve as guides while sketching or drawing.

Contrast: 1. The state of being noticeably different from something else when put or considered together. 2. Enhancement of appearance provided by juxtaposing different colors or textures.

Convert: To change money, stocks, or units in which a quantity is expressed into others of a different kind.

Counterbore: A cylindrical recess around a hole, usually to receive a bolt head or nut.

Countersink: A conical-shaped recess around a hole, often used to receive a tapered screw.

Credible: Able to be believed; convincing.

Criteria: Principles or standards by which something may be judged or decided.

Critique: A detailed analysis and assessment.

Cube: A regular solid having six congruent square faces.

Cutting Plane Line: A line drawn on a view where a cut was made in order to define the location of the imaginary section plane.

Cylinder: A solid composed of two congruent circles in parallel planes, their interiors, and all the line segments parallel to the axis with endpoints on the two circles.
Data: Facts and statistics used for reference or analysis.

Data Element: An individual value or bit of information.

Data Set: A group of individual values or bits of information that are related in some way or have some common characteristic or attribute.

Datum: A theoretically exact point, axis, or plane derived from the true geometric counterpart of a specific datum feature. The origin from which the location, or geometric characteristic of a part feature, is established.

Datum Dimension: A dimensioning system where each dimension originates from a common surface, plane, or axis. Also known as baseline dimensioning.

Decision Matrix: A tool for systematically ranking alternatives according to a set of criteria.

Degree: A unit of measurement of angles, equivalent to one ninetieth of a right angle.

Degree of Freedom: The variables by which an object can move. In assemblies, an object floating free in space with no constraints to another object can be moved along three axes of translation and around three axes of rotation. Such a body is said to have six degrees of freedom.

Demographics: The statistical data of a population, esp. those showing average age, income, education, etc.

Depth: The distance from front to back.

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

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

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

Design Process: A systematic problem-solving strategy, with criteria and constraints, used to develop many possible solutions to solve a problem or satisfy human needs and wants and to winnow (narrow) down the possible solutions to one final choice.

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

Designer: A person who designs any of a variety of things. This usually implies the task of creating drawings or in some ways uses visual cues to organize his or her work.
**Detail Drawing:** A dimensioned, working drawing of a single part. Also referred to as part drawing.

**Diameter:** A straight line passing from side to side through the center of a circle or sphere.

**Dimension:** A measurable extent, such as the three principal dimensions of an object is width, height, and depth. Length and thickness are not used because they cannot be applied in all cases. The front view of an object shows only the height and width and not the depth. In fact, any one view of a three-dimensional object can show only two dimensions, the third dimension will be found in an adjacent view.

**Dimension Lines:** Lines that are thin lines capped with arrowheads, which may be broken along their length to provide space for the dimension numerals.

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

**Dual Dimensions:** Where alternate units are displayed within the same dimension (both metric and standard dimensions can shown at the same time).

---

**E**

**Ecosystem:** A biological community of interacting organisms and their physical environment.

**Edge:** 1. The outside limit of an object, a surface, or an area. 2. The line along which two surfaces of a solid meet.

**Element:** A basic constituent part.

**Ellipse:** A regular oval shape, traced by a point moving in a plane so that the sum of its distances from two other points is constant, or resulting when a cone is cut by an oblique plane which does not intersect the base.

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

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

**Engineer’s Notebook:** Also referred to as an Engineer’s Logbook, a Design Notebook, or Designer’s Notebook 1. A record of design ideas generated in the course of an engineer’s employment that others may not claim as their own. 2. An archival record of new ideas and engineering research achievements.

**English System:** Also referred to as the U.S. Customary system. The measuring system based on the foot, second, and pound as units of length, time, and weight or mass.
**Environmental Protection Agency (EPA):** EPA is the acronym for the Environmental Protection Agency.

**Ergonomics:** The study of workplace equipment design or how to arrange and design devices, machines, or workspace so that people and things interact safely and most efficiently.

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

**Ethics:** The moral principles governing or influencing conduct.

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

**Evolution:** A gradual development.

**Executive Summary:** A persuasive summary that provides an overview of the purpose and contents of a report, identifies the issue or need that led to the report, and includes condensed conclusions and recommendations.

**Exploded Assembly:** An assembly drawing in which parts are moved out of position along an axis so that each individual part is visible.

**Extension:** 1. The property of an object by which it occupies space. 2. A set that includes a given and similar set as a subset.

**Extension Lines:** Thin lines used to establish the extent of a dimension. Extension lines begin with a short space from the object and extend to about .125 inches past the last dimension line. Extension lines may cross object lines, center lines, hidden lines, and other extension lines, but may not cross dimension lines.

**Extrusion** 1. A manufacturing process that forces material through a shaped opening. 2. A modeling process that creates a three-dimensional form by defining a closed two-dimensional shape and a length.
Fastener: A hardware device that mechanically joins or affixes two or more objects together.

Fillet: A rounded interior blend between two surfaces. Some uses are to strengthen joining surfaces or to allow a part to be removed from a mold.

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

Foot: A unit of linear measure equal to 12 inches or 30.48 cm.

Foreshorten: To show lines or objects shorter than their true size. Foreshortened lines are not perpendicular to the line of sight.

Form: 1. Having the three dimensions of length, width, and depth. Also referred to as a solid. 2. The organization, placement or relationship of basic elements, as volumes or voids in a sculpture, so as to produce a coherent image.

Formula: A mathematical relationship or rule expressed in symbols.

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

Frequency: The rate at which something occurs over a particular period or in a given sample.

Full Section: A sectional drawing based on a cutting plane line that extends completely through an object.

Function: The kind of action or activity proper to a person, thing, or institution; the purpose for which something is designed or exists; role.

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

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

Geometric Constraint: Constant, non-numerical relationships between the parts of a geometric figure. Examples include parallelism, perpendicularity, and concentricity.

Gestalt: The principle that maintains that the human eye sees objects in their entirety before perceiving their individual parts.

Graph: A diagram showing the relation between variable quantities, typically of two variables measured along a pair of lines at right angles.
Graphic Design: The art of combining text and pictures in advertisements, magazines, books, etc.

Grid: A network of lines that cross each other to form a series of squares or rectangles.

Half Section: A sectional drawing based on a cutting plane line that cuts through one-quarter of an object. A half section reveals half of the interior and half of the exterior.

Harmony: 1. The quality of forming a pleasing and consistent whole. 2. Agreement or concord.

Hazard: A danger or risk.

Height: The measurement of someone or something from head to foot or from base to top.

Hidden Line: A line type that represents an edge that is not directly visible, because it is behind or beneath another surface.

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

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

Hypothesis: 1. An assumption made on the basis of limited evidence as a starting point for further investigation. 2. A proposed explanation for an observation. Hypothesis is an educated guess which forms a basis for a test.

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

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

Inch: A unit of linear measure equal to one twelfth of a foot or 2.54 cm.

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

Input: Something put into a system, such as resources, in order to achieve a result.

Inscribe: To draw a figure within another so that their boundaries touch but do not intersect.
International Organization for Standardization (ISO): A non-governmental global organization whose principal activity is the development of technical standards through consensus.

Interference: The amount of overlap that one part has with another when assembled.

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

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

Isometric Drawing: A form of pictorial drawing in which all three drawing axes form equal angles of 120 degrees with the plane of projection.

Isometric Sketch: A form of pictorial sketch in which all three drawing axes form equal angles of 120 degrees with the plane of projection.

Iterative: Describing a procedure or process that repeatedly executes a series of operations until some condition is satisfied. An iterative procedure may be implemented by a loop in a routine.

Joinery: The process of connecting or joining two pieces of wood together through the use of various forms of wood joints. In fine woodworking, common forms of joinery include dovetail joinery, mortise-and-tenon joinery, biscuit joinery, lap joints, spline joints, etc.

Juxtapose: To place close together.

Key: A rectangular or semicircular shape used to prevent parts, such as gears or wheels, from turning on a shaft.

Keyseat: A slot in a shaft to receive a key.

Keyway: A slot in a hub or material around a shaft that receives a key.
**L**

**Landfill:** A low area of land that is built up from deposits of solid refuse in layers covered by soil.

**Leaders:** Lines that are thin and used to connect a specific note to a feature.

**Least Material Condition (LMC):** The smallest size limit of an external feature and the largest size limit of an internal feature.

**Legible:** How recognizable a short amount of text is.

**Limits of Dimension:** The largest and smallest possible boundaries to which a feature may be made as related to the tolerance of the dimension.

**Line:** 1. A long thin mark on a surface. 2. A continuous extent of length, straight or curved, without breadth or thickness; the trace of a moving point. 3. Long, narrow mark or band.

**Line Conventions:** Standardization of lines used on technical drawings by line weight and style.

**Line Weight:** Also called line width. The thickness of a line, characterized as thick or thin.

**Local Notes:** Connected to specific features on the views of the drawing. Also known as annotations.

**Location Dimension:** A location dimension that defines the relationship of features of an object.

**Logo:** An emblematic design adopted by an organization to identify its products.

**M**

**Manufacture:** To make something, especially on a large scale using machinery.

**Manufacturer’s Joint:** The seam of a carton where the two edges of the box blank are joined together by stitching, gluing, or taping.

**Manufacturing Process:** The transformation of raw material into finished goods through one or more of the following: Casting and Molding, Shaping and Reshaping for forming, Shearing, Pulverizing, Machining, for material removal, or Joining by transforming using heat or chemical reaction to bond materials.

**Market Research:** The activity of gathering information about consumers’ needs and preferences.

**Marketing:** The promotion and selling of products or services.

**Mass:** The amount of matter an object contains.
**Maximum Material Condition (MMC):** The largest size limit of an external feature and the smallest size limit of an internal feature.

**Mean:** The average or central value of a set of quantities.

**Measure:** To determine the size, amount, or degree of something by comparison with a standard unit.

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

**Mechanical Fastener:** A hardware device, such as a bolt or screw, that is used to mechanically join or affix two or more plastic objects together.

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

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

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

**Message Analysis:** The process of deciding what information needs to go into the graphic design, as well as how to effectively use the design elements and principles to present the information. This analysis is based on a thorough analysis of the audience.

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

**Metric System:** The decimal measuring system based on the meter, liter, and gram as units of length, capacity, and weight or mass.

**Millimeter:** A metric unit of linear measure equal to 1/1000 of a meter.

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

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

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

**Multiview Drawings:** Views of an object projected onto two or more orthographic planes.

**Multiview Sketches:** Views of an object projected onto two or more orthographic planes.
Negotiation: Mutual discussion and arrangement of the terms of a transaction or agreement.

Nominal Size: The designation of the size established for a commercial product.

Non-Renewable Resource: A resource or raw material that cannot be grown or replaced once used.

Normal Distribution: A function that represents the distribution of variables as a symmetrical bell-shaped graph.

Norms: Principles of right action, binding upon the members of a group and serving to guide, control, or regulate proper and acceptable behavior.

Numeric Constraint: A number value, or algebraic equation that is used to control the size or location of a geometric figure.

Object Line: A heavy solid line used on a drawing to represent the outline of an object.

Oblique Drawing: A type of drawing involving a combination of a flat, orthographic front with depth lines receding at a selected angle, usually 45 degrees.

Oblique Sketch: A type of sketch involving a combination of a flat, orthographic front with depth lines receding at a selected angle, usually 45 degrees.

Observation: The act or instance of noticing or perceiving.

Obtuse Triangle: A triangle with one angle that is greater than 90 degrees.

Occupation Safety and Health Administration (OSHA): A government organization whose mission is to assure the safety and health of America’s workers by setting and enforcing standards; providing training, outreach, and education; establishing partnerships; and encouraging continual improvement in workplace safety and health.

Offset Section: A sectional drawing created by a cutting plane bent at right angles to features as though they were in the same plane.

Open-Ended: Not having fixed limits; unrestricted; broad.

Origin: A fixed point from which coordinates are measured.

Orthographic Projection: A method of representing three-dimensional objects on a plane having only length and breadth. Also referred to as Right Angle Projection.

Output: The results of the operation of any system.
**Packaging:** Materials used to wrap or protect goods.

**Parallelogram:** A quadrilateral with opposite sides parallel.

**Parameter:** A quantity which is fixed for the case in question but may vary in other cases.

**Parametric Modeling:** A CAD modeling method that uses parameters to define the size and geometry of features and to create relationships between features. Changing a parameter value updates all related features of the model at once.

**Part Interaction:** A kind of action which occurs as two or more objects have an effect upon one another.

**Parts List:** A list of materials or parts specified for a project. Also referred to as a bill of materials or BOM.

**Pattern:** A repeated decorative design.

**Perspective Drawing:** A form of pictorial drawing in which vanishing points are used to provide the depth and distortion that is seen with the human eye. Perspective drawings can be drawn using one, two, and three vanishing points.

**Perspective Sketch:** A form of pictorial sketch in which vanishing points are used to provide the depth and distortion that is seen with the human eye. Perspective drawings can be drawn using one, two, and three vanishing points.

**Persuasive:** 1. Good at persuading someone to do or believe something. 2. Providing sound reasoning or argument.

**Phantom Line:** A line used to show the alternate positions of an object or matching part without interfering with the main drawing.

**Pi:** The numerical value of the ratio of the circumference of a circle to its diameter of approximately 3.14159.

**Pictograph:** A pictorial symbol for a word or phrase.

**Pictorial Drawing:** A drawing that shows an object’s height, width, and depth in a single view.

**Pictorial Sketch:** A sketch that shows an object’s height, width, and depth in a single view.

**Plane:** A flat surface on which a straight line joining any two points would wholly lie.

**Pneumatics:** A type of fluid power that uses compressed air or other neutral gases.

**Point:** A location in space. Points have no dimensions.

**Polar Coordinates:** The location of a point as given by an angle and a distance.
**Polygon:** A closed geometric figure in a plane formed by connecting line segments endpoint to endpoint with each segment intersecting exactly two others. Polygons are classified by the number of sides they have, such as a triangle has three sides, a quadrilateral has four sides, and a pentagon has five sides.

**Portfolio:** A set of pieces of creative work intended to demonstrate a person’s ability.

**Precise:** Exact in measuring, recording, etc.

**Precision:** Exact in measuring, recording, etc.

**Principle:** The method of formation, operation, or procedure exhibited in a given instance.

**Prism:** A solid geometric figure whose two ends are similar, equal, and parallel rectilinear figures, and whose sides are parallelograms.

**Problem:** An unwelcome or harmful matter needing to be dealt with.

**Problem Identification:** The recognition of an unwelcome or harmful matter needing to be dealt with.

**Problem Statement:** A part of design brief that clearly and concisely identifies a client’s or target consumer’s problem, need, or want.

**Process:** 1. Human activities used to create, invent, design, transform, produce, control, maintain, and use products or systems; 2. A systematic sequence of actions that combines resources to produce an output.

**Product:** A tangible artifact produced by means of either human or mechanical work, or by biological or chemical process.

**Product Lifecycle:** Stages a product goes through from concept and use to eventual withdrawal from the market place.

**Profile:** An outline of something as seen from one side.

**Projection Line:** A horizontal or vertical line that can be used to locate entities in an adjacent view.

**Projection Plane:** An imaginary surface on which the view of the object is projected and drawn. This surface is imagined to exist between the object and the observer.

**Proportion:** 1. The relationship of one thing to another in size, amount, etc. 2. Size or weight relationships among structures or among elements in a single structure.

**Protocol:** The accepted code of behavior in a particular situation.

**Prototype:** A full-scale working model used to test a design concept by making actual observations and necessary adjustments.

**Protractor:** An instrument for measuring angles, typically in the form of a flat semicircle marked with degrees along the curved edge.
**Purpose:** The reason for which something is done or for which something exists.

**Q**

**Quadrilateral:** A four-sided polygon.

**Quality:** The degree of excellence of something as measured against other similar things.

**R**

**Radial Symmetry:** Symmetry about a central axis.

**Radius:** A straight line from the center to the circumference of a circle or sphere.

**Range:** The measure of variation that is the difference between the highest and lowest scores.

**Ratio:** The quantitative relation between two amounts showing the number of times one value contains or is contained within the other.

**Raw Material:** Any natural resource that is used to make finished products.

**Readability:** How easy an extended amount of text is to read.

**Rectangle:** A parallelogram with 90 degree angles. A square is also a rectangle.

**Recycle:** To reclaim or reuse old materials in order to make new products.

**Reference Dimension:** A dimension, usually without a tolerance, used for information purposes only. A reference is a repeat of a given dimension or established from other values shown on a drawing. Reference dimensions are enclosed in ( ) on the drawing.

**Refurbish:** To renovate or redecorate.

**Refuse:** Matter thrown away as worthless.

**Regular Polygon:** A polygon with equal angles and equal sides.

**Relative Coordinates:** The location of a point as given by the distance from the last point specified.

**Removed Section:** A sectional view removed from the area of the cutting plane and positioned in another location.

**Renewable Resource:** A resource or raw material that can be grown and replaced.

**Repeatability:** The ability to replicate or duplicate a result.

**Research:** The systematic study of materials and sources in order to establish facts and reach new conclusions.
Residue: A small amount of something that remains after the main part has gone or been taken or used.

Reverse Engineering: The process of taking something apart and analyzing its workings in detail, usually with the intention to understand function, prepare documentation, electronic data, or construct a new or improved device or program, without actually copying from the original.

Revision Block: A brief listing of revisions made to a drawing since it was initially released to manufacture.

Revolution: Creating a 3D solid or surface by revolving a 2D shape about an axis.

Revolved Section: A sectional view that is revolved 90 degrees and perpendicular with the plane of projection.

Rhythm: A regularly recurring sequence of events or actions.

Rib: A relatively thin flat member acting as a brace support. Also called a web.

Right Triangle: A triangle that has a 90 degree angle.

Rotation: Turning around an axis or center point.

Round: A rounded exterior blend between two surfaces.

Scale: 1. A straight-edged strip of rigid material marked at regular intervals and used to measure distances. 2. A proportion between two sets of dimensions used in developing accurate, larger or smaller prototypes, or models of design ideas.

Scale Model: An enlarged or reduced representation of an object that is usually intended for study purposes.

Scoring: Making an impression or crease in a box blank to facilitate bending, folding, or tearing.

Section Lines: Lines that are used to represent the material through which a cut is made in order to show an interior sectional view.

Sectional View: A drawing that shows the interior of an object as it would appear if cut in half or quartered.

Sequential: Forming or following a logical order or sequence.

Shading: The representation of light and shade on a drawing or map.

Shape: The two-dimensional contour that characterizes an object or area, in contrast to three-dimensional form.
Size: How large or small a person or thing is.

Size Dimensions: Placed directly on a feature to identify a specific size or may be connected to a feature in the form of a note.

Sketch: A rough drawing representing the main features of an object or scene and often made as a preliminary study.

Snap-Fit: A molded-in piece in a plastic assembly that is designed to form a mechanical joint system where part-to-part attachment is accomplished with locating and locking features to connect components together.

Solid: A three-dimensional body or geometric figure.

Solid Modeling: A type of 3D CAD modeling that represents the volume of an object, not just its lines and surfaces. This allows for analysis of the object’s mass properties.

Solution: 1. A method or process for solving a problem. 2. The answer to or disposition of a problem.

Space: 1. The dimensions of height, depth, and width within which all things exist and move. 2. A free or unoccupied area or expanse.

Spotface: A shallow recess like a counterbore, used to provide a good bearing surface for a fastener.

Square: A regular polygon with four equal sides and four 90 degree angles.

Standard: Something considered by an authority or by general consent as a basis of comparison.

Statistics: Collection of methods for planning experiments, obtaining data, organizing, summarizing, presenting, analyzing, interpreting, and drawing conclusions based on data.

Storming: A phase of team development that is marked by conflict.

Stress: The pressure or tension exerted on a material object.

Subassembly: An assembled part that is a part of a larger assembly.

Surface Area: 1. The sum of all the areas of all the faces or surfaces that enclose a solid. 2. The sum of all the areas of all surfaces of a solid.

Surface Finish: The waviness, roughness, lay, and flaws of a surface. Also referred to as surface texture.

Survey: An investigation of the opinions or experience of a group of people, based on a series of questions.

Symbol: A thing that represents or stands for something else, especially a material object representing something abstract.
Symbolism: 1. The use of symbols to represent ideas or qualities. 2. The symbolic meaning attached to material objects.

Symmetry: The correspondence in size, shape, and relative position of parts on opposite sides of a median line or about a central axis. Also referred to as formal balance.

Synergy: When the unit or team becomes stronger than the sum of the individual members.

System: A group of interacting, interrelated, or interdependent elements or parts that function together as a whole to accomplish a goal.

Tap: To cut internal threads.

Taper: Gradual diminution of width or thickness in an elongated object.

Target Consumer: A person or group for which product or service design efforts are intended.

Team: A collection of individuals, each with his/her own expertise, brought together to benefit a common goal.

Teardown: The process of taking apart a product to better understand it.

Technical Report: A document that conveys the results of scientific and technical research, and provides recommendations for action.

Technical Working Drawing: A drawing that is used to show the material, size, and shape of a product for manufacturing purposes.

Tension: A force that pulls on a material.

Texture: The feel, appearance, or consistency of a surface, substance, or fabric.

Three-Dimensional: Having the dimensions of height, width, and depth.

Time Line Chart: A one-axis chart used to display past and/or future events, activities, requirements, etc., in the order they occurred or are expected to occur for the purposes of analysis and communication.

Title Block: A table located in the bottom right-hand corner of an engineering drawing that identifies, in an organized way, all of the necessary information that is not given on the drawing itself. Also referred to as a title strip.

Tolerance: The total permissible variation in a size or location dimension.

Tone: The general effect of color or of light and shade in a picture.

Torsion: The twisting of a material.
**Trade-off:** An exchange of one thing in return for another: especially relinquishment of one benefit or advantage for another regarded as more desirable.

**Transition Fit:** have limits of size indicating that either a clearance or an interference may result when mating parts are assembled.

**Translation:** Motion in which all particles of a body move with the same velocity along parallel paths.

**Triangle:** A polygon with three sides.

**Two-Dimensional:** Having the dimensions of height and width, height and depth, or width and depth only.

**Type:** Printed characters or letters.

**Typography:** The style and appearance of printed matter.

**U**

**Unidirectional Dimension:** A dimensioning system which requires all numerals, figures, and notes to be lettered horizontally and be read from the bottom of the drawing sheet.

**Unilateral Tolerance:** A tolerance in which variation is permitted in only one direction from the specified dimension.

**Unit:** A standard quantity in terms of which other quantities may be expressed.

**Unity:** The state of being united or forming a whole.

**V**

**Value:** The lightness or darkness of a color in relation to a scale ranging from white to black.

**Vanishing Point:** A vanishing point is a point in space, usually located on the horizon, where parallel edges of an object appear to converge.

**Variation:** A change or slight difference in condition, amount, or level.

**Variety:** A thing which differs in some way from others of the same general class.

**Vertex:** Each angular point of a polygon, polyhedron, or other figure.

**Views:** Views is shorthand for multiview projection, which is a system used to view an object. The six mutually perpendicular directions any object may be viewed are top, front, right-side, rear, left-side, and bottom. Top, front, and right-side views are also referred to as the three regular views because they are the three views most frequently used.
**Virtual Team:** A group of people that rely primarily or exclusively on electronic forms of communication to work together in accomplishing goals.

**Visualize:** To form a mental image of; imagine.

**Volume:** The amount of space occupied by a substance or object or enclosed within a container.

**W**

**Waste:** Material which is eliminated or discarded as no longer useful or required.

**Width:** The measurement or extent of something from side to side.

**Working Drawings:** Drawings that convey all of the information needed to manufacture and assemble a design.

**Working Sketches:** Sketches that convey all of the information needed to manufacture and assemble a design.

**X**

**Y**

**Z**

**Zoning:** A system of numbers along the top and bottom margins, and letters along the left and right margins of a drawing sheet that allows the viewer to identify drawing features within a specific location or zone on the drawing.