INTRODUCTION TO ENGINEERING DESIGN

Project Lead the Way

Introduction to Engineering Design (IED) is a course available to PLTW schools throughout the United States. Each section has the applicable standards broken out and identified for instructor use. Project Lead the Way, Inc. brought together a team of master instructors from all over the country to write the curriculum and support materials. This document was designed to be a complete teaching curriculum, not just a curriculum outline or guide. The curriculum is composed of twelve (12) units of instruction. Each unit begins with a Unit Overview, which contains a Preface and a Daily Lesson Plan. Each section contains a background narrative which is meant to be read to the students, a list of Vocabulary/Terms, the Math, Science, and Technology standards which the section addresses, a list of Performance Objectives, a list of suggested Activities for the students to complete, a list of Resources, a set of Assessments with answers. At the end of the curriculum guide are three additional sections: a Glossary, an Appendix of Rules, and an Appendix of Rubrics.

NATIONAL STANDARDS

1.0 Science Inquiry Standard
- 1.1 Ability necessary to do scientific inquiry
- 1.2 Understandings about scientific inquiry

1.0 Numbers and Operations Standard
- 1.1 Understand numbers, ways of representing numbers, relationships among numbers, and numbering systems
- 1.2 Understand the meaning of operations and how they relate to each other
- 1.3 Use computational tools and strategies fluently and estimate appropriately

1.0 The Nature of Technology Standard
- 1.1 The scope of technology includes the way in which it works in everyday life and how it shapes the world
- 1.2 Technology has core principle, which provides an organizing framework
- 1.3 There are relationships among technologies and connections to other fields of study

2.0 Physical Science Standard
- 2.1 Structure of atoms
- 2.2 Structure and properties of matter
- 2.3 Chemical reactions
- 2.4 Motions and forces
- 2.5 Conservation of energy and increase in disorder
- 2.6 Interactions of energy and matter

2.0 Patterns, Functions, and Algebra Standard
- 2.1 Understand various types of patterns and functional relationships
- 2.2 Use symbolic forms to represent and analyze mathematical situations and structures
- 2.3 Use mathematical models and analyze change in both real and abstract contexts

2.0 Technology and Society Standard
- 2.1 The use of technology causes cultural, social, economic, and political effects of technology on society
- 2.2 The use of technology has positive and negative effects on the environment
- 2.3 People share the development and use of technology
- 2.4 Technology has been one of the main driving forces in human history
- 3.0 Life Science Standard
- 3.1 The cell
- 3.2 Molecular basis of heredity
- 3.3 Biological evolution
- 3.4 Interdependence of organisms
- 3.5 Matter, energy, and organization in living systems
- 3.6 Behavior of organisms

3.0 Geometry and Spatial Sense Standard
- 3.1 Analyze characteristics and properties of two and three-dimensional geometric objects

- 3.2 Select and use different representational systems, including coordinate geometry and graph theory
- 3.3 Recognize the usefulness of transformations and symmetry in analyzing mathematical situations
- 3.4 Use visualization and spatial reasoning to solve problems both within and outside of mathematics

3.0 Design Standard

- 3.1 The attributes of design establish the foundation for the design process
- 3.2 Engineering design is a specific problem solving method that is commonly send to solve technological problems
- 3.3 Troubleshooting, research and development, invention and innovation, and experimentation are all means for solving design problems

4.0 Science and Technology Standard

- 4.1 Abilities of technological design
- 4.2 Understandings about science and technology

4.0 Measurement Standard

- 4.1 Understand attributes, units, and systems of measurement
- 4.2 Apply a variety of techniques, tools, and formulas for determining measurements

4.0 Abilities for a Technological World Standard

- 4.1 Develop the abilities necessary to apply the design process
- 4.2 Develop the abilities necessary for using and maintaining technological products and systems
- 4.3 Develop the abilities necessary to assess the impact of products and systems

5.0 Science in Personal and Social Perspectives Standard
- 5.1 Personal and community health
- 5.2 Population growth
- 5.3 Natural resources
- 5.4 Environmental quality
- 5.5 Natural and human-induced hazards
- 5.6 Science and technology in local, national, and global challenges

5.0 Data Analysis, Statistics, and Probability Standard
- 5.1 Pose questions and collect, organize, and represent data to answer those questions
- 5.2 Interpret data using methods of exploratory data analysis
- 5.3 Develop and evaluate inferences, predictions, and arguments that are based on data
- 5.4 Understand and apply basic notions of chance and probability

5.0 The Designed World Standard
- 5.1 Medical technologies are used to maintain, restore, and improve human health
- 5.2 Agricultural and related biotechnologies are used to provide food, fiber, fuel, chemicals, and other goods
- 5.3 Energy and power technologies are used to run other technologies
- 5.4 Information and communication technologies are used to record, store, manipulate, transmit, and display information
- 5.5 Transportation technologies are used to move people and goods
- 5.6 Manufacturing technologies are used to produce goods
- 5.7 Construction technologies are used to design, build, and maintain the physical infrastructure

6.0 History and Nature of Science Standard
- 6.1 Science as a human endeavor
- 6.2 Nature of scientific knowledge
- 6.3 Historical perspectives

6.0 Problem Solving Standard
- 6.1 Build new mathematical knowledge through their work with problems
- 6.2 Develop a disposition to formulate, represent, abstract, and generalize situations within and outside mathematics
- 6.3 Apply a wide variety of strategies to solve problems and adapt the strategies to new situations

CURRICULUM OUTLINE

Introduction to Engineering Design

The expanded curriculum outline is intended to help the instructor, who may not be familiar with all aspects of this field of study, with an overview of topics that are included in sub-headings. Unit and section titles may be unfamiliar to an individual. The expanded outline will give a more in-depth listing of topics, which an instructor may want to study before presenting a unit or section. The allocation of time to each of the topics may be found in the daily lesson plans that are included in each unit overview. If books are not available on these topics in your school, the Internet is a great place to search.

Unit 1 Introduction

1.1 History of Design
- 1.1.1 Artistic
  - 1.1.1.1. Periods
  - 1.1.1.2. Styles
  - 1.1.1.3. Form and Function
- 1.1.2 Technical
  - 1.1.2.1. Tools
  - 1.1.2.2. Materials
  - 1.1.2.3. Measurement

1.2 Professional Organizations
- 1.2.1 International Technology Education Association (ITEA)
- 1.2.2 Society of Manufacturing Engineers (SME)
- 1.2.3 American Society of Mechanical Engineers (ASME)
- 1.2.4 Society of Women Engineers (SWE)
- 1.2.5 American Design and Drafting Association (ADDA)
- 1.2.6 American Society of Interior Designers (ASID)
- 1.2.7 American Institutes of Architects (AIA)
- 1.2.8 Association of Professional Landscape Designers (APLD)
- 1.2.9 Institute of Electrical and Electronics Engineers (IEEE)
- 1.2.10 American Institute of Chemical Engineers (AICHE)
- 1.2.11 Society of Automotive Engineers (SAE)
- 1.2.12 American Society of Civil Engineers (ASCE)

1.3 Career Opportunities
- 1.3.1 Mechanical
  - 1.3.1.1. Product Design
  - 1.3.1.2. Drafter
  - 1.3.1.3. Design Technician
  - 1.3.1.4. Manufacturing Design: Jigs and Fixtures, Dies, Assemblies, and Details
- 1.3.2 Electronic-Electrical
  - 1.3.2.1. Circuits, Printed Circuit Boards

1.3.2.2. Integrated Circuits
1.3.2.3. Electrical, Electromechanical
1.3.2.4. Computers
1.3.3 Applications for Electronic and Mechanical Design

1.3.3.1. Marine
1.3.3.2. Aerospace
1.3.3.3. Transportation
1.3.3.4. Mining
1.3.4 Architectural Engineering and Construction (AE & C)

1.3.4.1. Civil: Facilities, Dams, Airports, Roads, and Mapping
1.3.4.2. Structural: Buildings, Plants, and Power Generation
1.3.4.3. Piping: Solar, Nuclear, Chemical, Process, Power, and Hydroelectric
1.3.5 Technical Illustration

1.3.5.1. Product Literature: Advertising, Sales, Presentations, Service Manuals, and Display
1.4 Education Requirements

Unit 2 Introduction to Design

2.1 Design Process
2.1.1. Problem Identification
2.1.1.1. Market Research
2.1.1.2. Design Brief
2.1.1.3. Specifications and Constraints
2.1.1.3.1. Aesthetics
2.1.1.3.2. Time
2.1.1.3.3. Information
2.1.1.3.4. Capital
2.1.1.3.5. Tools and Machines
2.1.1.3.6. Energy
2.1.1.3.7. Material
2.1.1.3.8. People
2.1.1.3.9. Ethics
2.1.2. Conceptualization
2.1.2.1. Research
2.1.2.1.1. Data Collection and Organization
2.1.2.1.2. Resources for Information
2.1.2.1.2.1. Internet Search
2.1.2.1.2.2. Literature Search
2.1.2.1.2.3. Existing Products
2.1.2.1.2.4. Interviews
2.1.2.1.3. Brainstorming
2.1.2.1.3.1. Definition
2.1.2.1.3.2. Rules for Brainstorming

2.1.2.1.3.3.Techniques
2.1.2.1.4. Thumbnail Sketches
2.1.3. Refinement of Preliminary Ideas
2.1.3.1. Identify Workable Solutions
2.1.3.2. Develop Detailed/Annotated Sketches
2.1.3.3. Assemble Graphical Analysis of Possible Solutions
2.1.3.3.1. Descriptive Geometry
2.1.3.3.2. Vector Analysis
2.1.3.3.3. Drawings
2.1.3.3.4. Modeling
2.1.4. Design Analysis
2.1.4.1. Compare Alternatives and Specifications
2.1.4.2. Create a Decision Making Matrix
2.1.4.3. Refining Alternative Solutions
2.1.4.4. Narrow Design Solutions
2.1.5. Development and Implementation
2.1.5.1. Detailed Documentation of Final Design
2.1.5.1.1. Working Drawings
2.1.5.1.2. Reports
2.1.5.2. Prototyping of Design Solution
2.1.5.3. Testing and Analysis
2.1.6. Optimization
2.1.6.1. Reassess Design Specifications
2.1.6.2. Implement Modifications
2.1.6.3. Update Drawings and Models
2.1.7. Presentation
2.1.7.1. Oral Report
2.1.7.2. Written Report
2.1.7.3. Visual Aids/Models
2.2 Principles and Elements of Design
2.2.1. Principles
2.2.1.1. Balance
2.2.1.1.1. Formal
2.2.1.1.2. Informal
2.2.1.2. Rhythm
2.2.1.3. Emphasis
2.2.1.4. Proportion
2.2.1.5. Unity
2.2.1.6. Repetition
2.2.1.7. Opposition
2.2.1.8. Subordination
2.2.1.9. Transition

2.2.1.10. Creativity
2.2.2. Elements
2.2.2.1. Lines

2.2.2.2. Forms
2.2.2.3. Color
2.2.2.4. Light and Shadow
2.2.2.5. Space
2.2.2.6. Materials or Texture

Unit 3 Student Portfolio Development

3.1 Portfolio Development
- 3.1.1. Title Page and Table of Contents
- 3.1.2. An Organized Design Brief(s)
- 3.1.3. Evidence of Research
- 3.1.4. Student Sketches
- 3.1.5. Several Developed Possible Solutions
- 3.1.6. Matrix Used to Make Selections
- 3.1.7. Set of Fully Developed Working Drawings
- 3.1.8. Screen Captures or Other Proof of Verification
- 3.1.9. Copy of Report, Photo of Model, or Any Other Presentation Medium Used
- 3.1.10. Self Evaluation Sheet
- 3.1.11. Any Other Documentation that Demonstrates the Thought Process behind the Solution to the Problem

Unit 4 Sketching and Visualization

4.1 Techniques
- 4.1.1. Penciling Methods
- 4.1.2. Proportion
- 4.1.3. Composition
- 4.1.4. Basic Construction
- 4.1.5. Additive
- 4.1.6. Subtractive
- 4.1.7. Grids
- 4.1.8. Enlargement Techniques

4.2 Pictorial
- 4.2.1. Oblique
- 4.2.2. One Point Perspective
- 4.2.3. Isometric
- 4.2.4. Two Point Perspective
- 4.2.5. Shading

4.3 Annotated Sketches
- 4.3.1. Multi-view or Orthographic
- 4.3.2. Principle Views
- 4.3.3. Orders of Views
  - 4.3.3.1. First Angle Projection
  - 4.3.3.2. Third Angle Projection
- 4.3.4. Line Types and Precedence

4.3.5. Selection of Views

4.3.5.1. One View
4.3.5.2. Two View
4.3.5.3. Three View
4.3.5.4. Measurement

Unit 5 Geometric Relationships

5.1 Forms and Shapes

5.1.1. Points
5.1.2. Lines
5.1.2.1. Polygons
5.1.2.1.1. Inscribed
5.1.2.1.2. Circumscribed
5.1.2.2. Triangles
5.1.2.2.1. Equilateral
5.1.2.2.2. Isosceles
5.1.2.2.3. Right
5.1.2.2.4. Scalene
5.1.2.3. Quadrilateral
5.1.2.3.1. Square
5.1.2.3.2. Rectangle
5.1.2.3.3. Rhombus
5.1.2.3.4. Trapezoid
5.1.2.4. Other Polygons
5.1.2.4.1. Pentagon
5.1.2.4.2. Hexagon
5.1.2.4.3. Octagon
5.1.2.5. Angles
5.1.2.5.1. Vertex
5.1.2.5.2. Acute
5.1.2.5.3. Right
5.1.2.5.4. Obtuse
5.1.2.5.5. Complementary
5.1.2.5.6. Supplementary
5.1.2.5.7. Bisector
5.1.2.6. Circles
5.1.2.6.1. Center Point
5.1.2.6.2. Circumference
5.1.2.6.3. Diameter
5.1.2.6.4. Radius
5.1.2.6.5. Chord
5.1.2.6.6. Arc
5.1.2.7. Ellipses

5.2 Geometric Constraints

5.2.1. Horizontal
5.2.2. Vertical
5.2.3. Parallel
5.2.4. Perpendicular
5.2.5. Tangent
5.2.6. Concentric
5.2.7. Coplanar
5.2.8. Collinear
5.2.9. Coincident
5.2.10. Fixed Point
5.2.11. Equal

5.3 Cartesian Coordinate System
5.3.1. X, Y, and Z Axis
5.3.2. Right Hand Rule
5.3.3. Absolute
5.3.4. Relative/Incremental
5.3.5. Polar

5.4 Origin Planes
5.4.1. XY
5.4.2. XZ
5.4.3. YZ

Unit 6 Modeling

6.1 Conceptual
6.1.1. Idea Generation
6.1.2. Freehand Sketching
6.1.3. Verbal Description

6.2 Graphical
6.2.1. Charts
6.2.2. Graphs
6.2.2.1. Line Graph
6.2.2.2. Bar Graph
6.2.2.3. Pie Graph
6.2.2.4. Pictograph
6.2.3. Diagrams

6.3 Physical
6.3.1. Appearance Model/Mock-Ups
6.3.2. Prototype
6.3.3. Scale

6.4 Mathematical
6.4.1. Calculations and Dimensional Analysis
6.4.2. Statistical
6.4.3. Force Analysis

6.5 Computer
6.5.1. Parametric Design

6.5.2. Adaptive Design
6.5.3. Basic Sketch

6.5.3.1. Constraints
6.5.3.2. Dimensions
6.5.4. Work Features

6.5.4.1. Planes
6.5.4.2. Axis
6.5.4.3. Points

6.5.5. Feature Creation

6.5.5.1. Extrusion
6.5.5.2. Hole Features
6.5.5.3. Fillets and Rounds
6.5.5.4. Chamfers
6.5.5.5. Patterns
6.5.5.6. Shells
6.5.5.7. Revolve
6.5.5.8. Sweeping
6.5.5.9. Lofting
6.5.5.10. Helix
6.5.6. Model Editing

6.5.6.1. Sketch Editing
6.5.6.1.1. Edit Dimensioning
6.5.6.1.2. Constraints
6.5.6.1.3. Geometry

6.5.6.2. Feature Editing
6.5.6.2.1. Selection Set
6.5.6.2.2. Parameters
6.5.6.2.3. Direction
6.5.6.2.4. Boolean Operation

Unit 7 Assembly Modeling

7.1 Adding Components
7.1.1. Base Component
7.1.2. Place Existing Component
7.1.3. Create Component in Place
7.1.4. Patters of Components
7.1.5. Replace Components
7.1.6. Part Manipulation

7.1.6.1. Move

7.1.6.2. Rotate
7.2 Assembly Constraints
7.2.1. Insert
7.2.2. Tangent
7.2.3. Angle
7.2.4. Mate
7.2.5. Flush
7.3 Part Libraries
7.3.1. Fasteners
7.3.2. Springs
7.3.3. Bearings
7.3.4. Gears
7.3.5. Cams
7.3.6. Shafts
7.3.7. Pulleys
7.3.8. Keys
7.4 Sub-Assemblies
7.4.1. Creating Sub-Assemblies
7.4.2. Placing Sub-Assemblies
7.5 Driving Constraints
7.5.1. Range of Motion
7.5.2. Angle
7.5.3. Parameters
7.5.4. Equations
7.5.5. Collision Detection
7.6 Adaptive Design
7.6.1. Adaptive Sketches
7.6.2. Adaptive Parts
7.6.3. Adaptive Features
7.6.4. Driving Adaptivity

Unit 8 Model Analysis and Verification

8.1 Mass Properties
8.1.1. Volume
8.1.2. Density
8.1.3. Mass
8.1.4. Surface Area
8.1.5. Centroid
8.1.6. Moment of Inertia
8.1.7. Products of Inertia
8.1.8. Radii of Gyration
8.1.9. Principal Axis
8.1.10. Principal Moments
8.2 Tolerancing
8.2.1. Statistical
8.2.2. Maximum and Minimum

8.2.3. Clearance Fit
8.2.4. Allowance
8.2.5. Interference
8.2.6. Types of Fit

Unit 9 Model Documentation

9.1 Working Drawings
9.1.1. Drawing Layout

9.1.1.1. Sheet Styles and Sizes
9.1.1.2. Borders
9.1.1.3. Title Blocks
9.1.1.4. Scale
9.1.1.5. Revision Block
9.1.2. Drawing Views

9.1.2.1. Orthographic
9.1.2.2. Isometric
9.1.2.3. Section
9.1.2.3.1. Half
9.1.2.3.2. Full
9.1.2.3.3. Offset
9.1.2.3.4. Removed
9.1.2.3.5. Revolved
9.1.2.3.6. Broken-out
9.1.2.3.7. Aligned
9.1.2.4. Detail Views
9.1.2.5. Auxiliary
9.1.2.6. Assembly
9.1.2.5.1. General
9.1.2.5.2. Exploded
9.1.2.5.2.1. Explosion Factor
9.1.2.5.2.2. Trails
9.1.2.5.2.3. Tweaks
9.2 Dimensioning
9.2.1. Standards

9.2.1.1. ANSI
9.2.1.2. ISO
9.2.1.3. JIS
9.2.1.4. DOD
9.2.1.5. MIL
9.2.2. Methods

9.2.2.1. Aligned
9.2.2.2. Unidirectional

9.2.3. Types of Dimensions

9.2.3.1. Size
9.2.3.2. Location
9.2.4. Rules and Practices
9.2.5. Linear

9.2.5.1. Chain Dimensioning
9.2.5.2. Datum Dimensioning
9.2.6. Dimensioning Angles

9.2.6.1. Angular Method
9.2.6.2. Coordinate Method
9.2.7. Dimensioning Arcs and Circles

9.2.7.1. Radius
9.2.7.2. Diameter
9.2.7.3. Center Marks and Lines
9.2.8. Dimensioning Curved Features
9.2.9. Dimensioning Special Features

9.2.9.1. Chamfers
9.2.9.2. Fillets and Rounds
9.2.9.3. Tapers
9.2.9.4. Conical Shapes
9.2.9.5. Slots
9.2.9.6. Keyseats
9.2.9.7. Repetitive Features and Reference Dimensions
9.2.9.7.1 Rectangular
9.2.9.7.2 Polar

9.2.10. Tolerancing
9.2.10.1. Unilateral
9.2.10.2. Bilateral
9.2.10.3. Limits
9.2.10.4. Allowance
9.3 Annotation
9.3.1. Notes
9.3.1.1. General
9.3.1.2. Local
9.3.2. Hole Notes
9.3.2.1. Drilled
9.3.2.2. Countersink
9.3.2.3. Counterbore
9.3.2.4. Spotface

9.3.3 Multiple Features
9.3.3.1. Leaders
9.3.3.2. Balloons
9.3.3.3. Bill of Materials
9.3.3.4. Symbols
9.3.3.5. Specifications
9.3.3.5.1 General
9.3.3.5.2 Proprietary

Unit 10 Presentation

10.1 Communication Techniques
10.1.1. Voice Variation
10.1.2. Eye Contact
10.1.3. Posture
10.1.4. Attire
10.1.5. Practiced and Prepared
10.1.6. Projecting Confidence
10.2 Presentation Aids
10.2.1. Visual Aids
10.2.1.1. Charts
10.2.1.2. Graphs
10.2.1.3. Mock-ups
10.2.1.4. Prototypes
10.2.1.5. Video Tapes
10.2.1.6. 35mm Slide Show
10.2.1.7. Poster Boards
10.2.1.8. Computer Graphics
10.2.1.8.1. Slide Show Presentation
10.2.1.8.2. Three-Dimensional Solid Modeling

10.2.1.8.2.1. Assembly Models
10.2.1.8.2.2. Presentation Models
10.2.1.8.2.3. Animation Clips
10.2.1.8.2.4. HTML Documents
10.2.2. Written Documentation

10.2.2.1. Engineering Notebook
10.2.2.2. Specification Sheets
10.2.2.3. Technical Drawings
10.2.2.4. Presentation Outline/Graphic Organizer
10.2.2.5. Technical Report

Unit 11 Production

11.1 Designs for Manufacturability
11.1.1. Material Specification
11.1.2. Size and Configuration
11.1.3. Production Run

11.1.4. Tolerance Requirement
11.1.5. Machine and Tooling Operations
11.2 Process Planning
11.2.1. Design for Standard Machines
11.2.2. Design to Limit the Number of Processes
11.2.3. Process Routing
11.3 Trends toward Automated Manufacturing
11.3.1. CNC
11.3.2. FMS
11.3.3. CIM
11.4 Materials Procurement, Handling, and Cost Analysis
11.5 Quality Control
11.6 Manpower and Facility Requirements
11.7 Packaging

Unit 12 Marketing

12.1 Product Cost Analysis
12.1.1. Engineering Design

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