PLTW Engineering
Introduction to Engineering Design | Course Outline

Engineers make a world of difference!

Students are introduced to the engineering design process, applying math, science, and engineering standards to identify and design solutions to a variety of real problems. They work both individually and in collaborative teams to develop and document design solutions using engineering notebooks and 3D modeling software.

Are you ready to design the future?

Introduction to Engineering Design (IED) is a high school engineering course in the PLTW Engineering Program. In IED, students explore engineering tools and apply a common approach to the solution of engineering problems, an engineering design process. Utilizing the activity-project-problem-based (APB) teaching and learning pedagogy, students progress from completing structured activities to solving open-ended projects and problems that require them to plan, document, communicate, and develop other professional skills.

Through both individual and collaborative team activities, projects, and problems, students apply systems thinking and consider various aspects of engineering design including material selection, human-centered design, manufacturability, assemblability and sustainability. Students develop skills in technical representation and documentation especially through 3D computer modeling using a Computer Aided Design (CAD) application. As part of the design process, students produce precise 3D-printed engineering prototypes using an additive manufacturing process. Student-developed testing protocols drive decision-making and iterative design improvements.

To inform design and problem solutions addressed in IED, students apply computational methods to inform design by developing algorithms, performing statistical analyses, and developing mathematical models. Students build competency in professional engineering practices including project management, peer review, and environmental impact analysis as part of a collaborative design team. Ethical issues related to professional practice and product development are also presented.

Unit 1	Design and Problem Solving
Unit 2	Assembly Design
Unit 3	Thoughtful Product Design
Unit 4	Making Things Move

Unit 1: Design and Problem Solving

Unit 1 provides an overview of the engineering design process and helps students develop an understanding of the purpose and practice of modeling in engineering communication. Students are introduced to modeling methods and practice modeling skills important to the design of mechanical systems including technical sketching, 3D solid modeling and technical drawing using Computer-Aided Design (CAD), statistical analysis, and prototyping. Emphasis is placed on building CAD skills applied throughout the course. In addition, students learn statistical techniques to evaluate design solutions and apply statistics to inform the design of a game.

Design Basics

Lesson 1.1	Design Basics
Lesson 1.2	Visualization and Solid Modeling
Lesson 1.3	CAD Fundamentals
Lesson 1.4	Product Improvement

Lesson 1.1 Design Basics
In Lesson 1.1 students review and apply an engineering design process to collaboratively design a carnival game. As part of the design process, students practice the art of brainstorming and begin to develop skills in graphically representing ideas through concept sketching. Students also develop and test a solution and improve the design through iteration. In addition, students learn statistical techniques to evaluate design solutions and apply statistics to inform design decisions related to their game design.

Lesson 1.2 Visualization and Solid Modeling
Lesson 1.2 focuses on building student spatial visualization skills. The role of modeling as a means to represent and communicate ideas, designs, and problem solutions is emphasized. Students are introduced to technical sketching and practice sketching isometric views and orthographic projections to represent three-dimensional objects. As part of the design process, students develop basic 3D solid models of simple designs and produce technical drawings using CAD. The lesson culminates in a design project in which students design and prototype a product using additive manufacturing (3D printing).

Lesson 1.3 CAD Fundamentals
Lesson 1.3 focuses on building CAD skills to develop 3D models and technical drawings. Students learn the importance of precision measurement and use dial calipers to make precise measurements, as they come to understand the concepts of precision and accuracy and their implication on engineering design and manufacturing. Students apply statistics to quantify the precision and accuracy of measurements and of measuring tools. Multiple CAD topics are introduced, and students apply the engineering design process and their new CAD skills to design and 3D print a protective case for a product.

Lesson 1.4 Product Improvement
Students work within teams to apply the design process and the skills and knowledge gained in this unit to evaluate and improve the design of a consumer product to meet stakeholder needs. Students will learn effective presentation techniques and present their solutions to an audience.

Unit 2: Assembly Design

Unit 2 emphasizes the design of systems of components. Students are introduced to the concept of reverse engineering and how to investigate and document the design of multi-component systems. Students learn various techniques used to connect components in a system, how systems are designed to allow desired interaction between components, and how to identify and select the materials from which products are made. They are also introduced to methods to improve the manufacturability of a product and reduce production costs. Students learn to apply two methods to create 3D assembly models in CAD and apply those techniques to design and document assemblies.

Assembly Design	
Lesson 2.1	Put it Together
Lesson 2.2	Take it Apart
Lesson 2.3	A Material World
Lesson 2.4	Fix It

Lesson 2.1 Put it Together
Students continue to build skills in CAD. Methods to physically join parts into an assembly (including mechanical fasteners and adhesives as well as press fits and hinges) are presented. Interference and clearance fits are introduced, and students learn to apply tolerances to achieve desired fits between interacting parts. CAD assembly modeling is introduced, and students learn to create simple bottom-up assemblies that realistically simulate physical assemblies. Assemblies are documented in CAD with assembly drawings. Students are challenged to iterate on an earlier design project to incorporate skills and knowledge that they have learned in this lesson.

Lesson 2.2 Take it Apart
Lesson 2.2 exposes students to the application of engineering principles and practices to reverse engineer a consumer product. Reverse engineering involves disassembling and analyzing a product or system in order to understand and document the visual, functional, and/or structural aspects of its design. In this lesson, students assess all three aspects of a product's design. Students are introduced to a second method of CAD assembly modeling, top-down modeling and use it to model the consumer product they have reverse-engineered.
Students will also conduct a case study of a common consumer product to identify ways to improve the manufacturability and ease of assembly of the product. Then they apply the design process again to design and prototype (3D print) an integrated accessory for the reversed engineered product and present the design.

Lesson 2.3 A Material World
Students investigate a variety of materials through experimentation to identify properties that determine material selection. The types of materials investigated include wood, metals, ceramics, plastics, and composites. Properties investigated may include density, conductivity, strength, flexibility, hardness, and so on. Students are then tasked with selecting materials to serve specific purposes. They learn how to assign specific materials to CAD model components and to differentiate between assigning the physical properties of a material to a part and only changing the visual appearance of the part. Finally, students work on a team to imagine the future through research of innovative materials and brainstorm a new consumer product composed of one or more advanced material.

Lesson 2.4 Fix It
Students work collaboratively to reverse engineer and troubleshoot a non-working multi-component mechanical device then re-design the device, produce working drawings, and produce new parts to correct the design and produce a working physical model.

Unit 3: Thoughtful Product Design

Unit 3 introduces students to a broader interpretation of the word design to include universal principles that contribute to successful product design. Students are exposed to design principles (other than the visual design principles presented in Unit 2) that can impact the appeal, usability, safety, and sustainability of a product. Design topics that are introduced or reinforced include product life-cycle, sustainability, manufacturability, human-centered design, and systems thinking.

Thoughtful Product Design	
Lesson 3.1	Responsible Design
Lesson 3.2	More Than Parts
Lesson 3.3	Solve a Problem

Lesson 3.1 Responsible Design
Lesson 3.1 begins with students reverse engineering a multi-material consumer product, then identifying and researching the component materials and the material properties that likely contribute to their selection for use in the product. Students are introduced to life cycle analysis and the principles of sustainable development then compare the life cycle of common competing products. The importance of identifying measurable design criteria to define a successful solution and that can be used to evaluate a potential solution is emphasized in this lesson.

Lesson 3.2 More Than Parts
Students are introduced to the concept of human-centered design as they are led through a design experience focused on user needs, perceptions and behaviors and the design trade-offs necessary in every design process. Students also apply systems thinking to engineering design and consider the ethical implications of engineering decisions. A modern CAD feature, generative design is introduced as a tool to optimize design solutions.
Students use the output from a generative design algorithm to explore and select a design alternative. Finally in pairs, students identify a product and apply human-centered design principles and systems thinking to design a product as they practice collaboration and communication skills. Final products are presented through a short commercial.

Lesson 3.3 Solve a Problem
In teams, students act as an engineering consultant group to solve a problem from a list of problems gathered from school and/or community stakeholders. As part of the design process, the team applies the engineering design process to develop a sustainable solution that includes consideration of material choices and the life cycle of the design solution. As part of the design process students meet with the client to understand user needs, develop effective design criteria to inform the design and create a project design brief. Students also practice important project management skills including developing a task and delivery schedule to manage and monitor project work and periodically reporting out on project process.

Unit 4: Making Things Move

Unit 4 focuses on familiarizing students with basic engineering knowledge related to simple mechanical and electrical systems and the use of mathematical models to represent design ideas and to inform design decisions. Students will apply their new knowledge in the design of an electromechanical solution. Students also learn advanced CAD skills to support the design, documentation, and communication of engineering solutions.

Making Things Move

Lesson 4.1	You've Got to Move It
Lesson 4.2	May the Force Be With You
Lesson 4.3	Automating Motion
Lesson 4.4	Make It Move

Lesson 4.1 You've Got to Move It

Students begin the lesson by reverse engineering a mechanical device to identify simple machines and mechanisms that influence motion and contribute to the function of the device. Students identify different types of motion (rotary, oscillating, linear, reciprocating, and so on) and investigate mechanisms that cause motion (including cams, gears, pulleys, chain and sprockets) and later use these mechanisms to create, transform and control motion to solve a problem. Students take a deep dive into how cams transform motion and use motion graphs to design a cam to create a desired motion. They practice CAD skills by developing models of the mechanisms they investigate and simulating motion in the CAD environment. To support efficient CAD modeling, students also learn to use mathematical functions to represent relationships in dimensional properties of a modeled object within the 3D environment.

Lesson 4.2 May the Force Be With You

In lesson 4.2 students investigate forces that resist motion. First students study spring forces and develop a mathematical model to determine the relationship between spring displacement and force for a given spring. Students then use a spring scale to study the force of friction and consider ways to reduce friction, especially in machine design. Finally, students apply their knowledge of mechanisms, springs and friction to design an automaton to create a desired motion with minimal frictional resistance. As part of the automata design process, each student creates a CAD assembly model of their design, CAD technical drawings, and a physical working model of their design.

Lesson 4.3 Automating Motion

In lesson 4.3 students learn about simple electrical circuits and how to transform electrical power to motion using a motor. Students design and install a circuit to run a hobby motor to power their previously designed automaton. Students build a simple variable resistor as part of their circuit and develop a mathematical model to inform the design of a motor speed control mechanism. Students then revise their physical automaton to incorporate the new electrical system and demonstrate their use of the resulting electromechanical system to control the automaton motion.

Lesson 4.4 Make It Move

In the final lesson of Unit 4, students collaborate to develop an electromechanical system to solve a problem. To solve the problem, team members work closely together to apply the knowledge and skills they have gained in this course and create a public display to present the solution.