Course Title:	Content Area:	Grade Level:	Credit (if applicable)
PLTW Introduction to Engineering and Design	CTE: Engineering and Technology	9-12	1 Credit 2 College credits through University of New Haven upon meeting UNH criteria

Course Description:

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.

Aligned Core Resources:	Connection to the *BPS Vision of the Graduate*
• PLTW Online *(some elements require PLTW login credentials)* • Course Outline - PLTW Intro to Engineering Design • Common Core State Standards for English Language Arts • Common Core State Standards for Mathematics • Next Generation Science Standards • Standards for Technological and Engineering Literacy	**Meaningfully contribute to a global society:** Collaboration **Effectively communicate in a global society:** Communications and Technology Literacy **Demonstrate Academic Knowledge and Skills:** Critical Thinking and Problem Solving

Additional Course Information: *Knowledge/Skill Dependent courses/prerequisites*	Link to *Completed Equity Audit*
Concurrent enrollment in grade-appropriate mathematics class.	Equity Curriculum Review - PLTW Intro to Engineering Design (2024-25)

Standard Matrix

See Standards Alignment - PLTW Intro to Engineering Design for alignment to:

- Common Core State Standards for English Language Standards *(Page 2)*
  - Anchor Standards: Research to Build and Present Knowledge
  - Writing: Text Types and Purposes
  - Reading Informational Text: Key Ideas and Details
- Common Core State Standards for Mathematics *(Page 12)*
  - Geometry: Visualization and Spatial Reasoning
  - Statistics and Probability: Interpreting Categorical and Quantitative Data
  - Statistics and Probability: Making Inferences and Justifying Conclusions
  - Number and Quantity: Quantities
- Next Generation Science Standards *(Page 19)*
  - Engineering Design: Developing Possible Solutions
  - Engineering Design: Evaluating Solutions
  - Engineering Design: Analyzing and Interpreting Data
  - Engineering Design: Optimizing the Design Solution
  - Engineering Design: Developing and Using Models
- Standards for Technological and Engineering Literacy *(Page 29)*
  - Creativity and Innovation
  - Communication and Collaboration
  - Understanding and Applying Engineering Concepts
  - Global Awareness in Engineering

- Technology and Engineering in Design
- Collaboration and Teamwork

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

Unit Title:

Unit 1: Design and Problem Solving

Unit Description:

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.

Relevant Standards: Bold indicates priority

Common Core State Standards for English Language Arts
Common Core State Standards for Mathematics
Next Generation Science Standards
Standards for Technological and Engineering Literacy

Essential Question(s):

1. What are effective ways to generate potential solutions to a problem?
2. When solving an engineering problem, how can you reasonably ensure you have created the best solution possible?
3. How is technical drawing similar to and different from artistic drawing?
4. In what ways can technical drawings help or hinder communication in a global community?
5. Why are spatial visualization skills crucial to engineering success?
6. What advantages does Computer-Aided Design (CAD) provide over traditional paper and pencil design?
7. What would happen if engineers did not follow accepted dimensioning standards and guidelines, but instead, used their own individual dimensioning methods?
8. Why do engineers use models? How reliable is a model?
9. Is it ever advantageous to create a design or solve a problem individually as opposed to using a team approach?

Enduring Understanding(s):

1. Generating potential solutions involves a variety of brainstorming techniques and collaborative methods that encourage creativity and diverse perspectives, allowing for a more comprehensive problem-solving process.
2. Ensuring the best solution involves systematic evaluation through criteria such as feasibility, efficiency, cost-effectiveness, and sustainability, as well as iterative testing and feedback cycles.
3. Recognize that while both technical and artistic drawings serve to communicate ideas, technical drawings prioritize precision, scale, and clarity to convey specific information, whereas artistic drawings focus on expression and visual interpretation.
4. Technical drawings can enhance communication across cultures and languages by providing standardized symbols and dimensions, but may also hinder understanding if the audience lacks familiarity with technical standards.
5. Spatial visualization skills are crucial for engineers as they allow for better understanding of complex designs and the ability to foresee potential issues in three-dimensional spaces.
6. Computer-Aided Design (CAD) offers significant advantages over traditional methods, including enhanced accuracy, ease of modifications, streamlined collaboration, and the ability to simulate and visualize designs in a virtual environment.
7. Not following accepted dimensioning standards could lead to misinterpretation of designs, resulting in errors in construction or manufacturing, and potentially jeopardizing safety and project success.
8. Engineers use models to simplify and test designs, but the reliability of a model can vary based on its fidelity to the real-world system it represents and the assumptions made during its creation.
9. Recognize that while individual work can foster innovation and personal accountability, teamwork often leads to richer insights and more robust

solutions.

Demonstration of Learning:

Students demonstrate learning by applying the engineering design process to solve a real-world problem, showcasing their ability to identify design constraints, brainstorm solutions, create detailed sketches and technical drawings, build a prototype, test and iterate on their design, and effectively communicate their process and findings through written documentation and presentations; all while adhering to engineering ethics and professional practices.

Pacing for Unit

40 Full Class Periods

Family Overview (link below)

Family Overview - PLTW Intro to Engineering Design
Family Overview - PLTW Intro to Engineering Design (Spanish)

Integration of Technology:

MasterCam CAD Software

Unit-specific Vocabulary:

Design process Design brief Constraints Criteria Problem identification Brainstorm	Iterate Research Client Design statement Engineer Innovation	Assess Justification Valid Product CAD (Computer Aided Design) Prototype

Aligned Unit Materials, Resources, and Technology (beyond core resources):

N/A

Opportunities for Interdisciplinary Connections:

- Statistical Analysis: Students use mathematical concepts such as mean, standard deviation, and probability to evaluate design solutions and optimize game performance.
- Geometric Principles: Applying concepts like transformations, symmetry, and coordinate geometry in CAD modeling and technical drawing.
- Mechanics & Forces: Understanding how forces affect mechanical systems and influence design choices.
- Material Properties: Exploring the characteristics of materials used in prototyping and manufacturing, such as strength, durability, and flexibility.
- Programming for CAD Automation: Using scripting and parametric design to create automated CAD models.
- Data Analysis & Visualization: Using spreadsheets or software to analyze statistical data related to design optimization.
- Visual Communication: Developing technical sketching and drawing techniques to clearly communicate design intent.
- Aesthetics & User Experience: Considering color theory, ergonomics, and human-centered design principles in game development.
- Product Development Process: Exploring how engineering designs transition from concept to production.

Anticipated misconceptions:

- Engineering follows a linear process rather than an iterative cycle of prototyping, testing, and refinement.
- Simply using CAD guarantees a well-designed model, without understanding the importance of precise measurements, constraints, and iterative improvements.
- Not appreciating freehand sketching to help with brainstorming, conceptualization, and quick problem-solving before using CAD software.
- Struggle to see how statistical analysis informs design decisions, such as evaluating performance, optimizing features, and refining prototypes.
- View failure as a negative outcome rather than a learning opportunity that leads to design improvements.

• Cost-Benefit Analysis: Evaluating manufacturing costs, material selection, and market demand when designing products.	
Connections to Prior Units:	**Connections to Future Units:**
N/A	**Unit 2: Assembly Design** • The technical sketching, 3D solid modeling, and CAD skills developed in Unit 1 provide the foundation for creating and assembling multiple components in Unit 2. Students apply the engineering design process to understand how individual parts fit together into functional assemblies. **Unit 3: Thoughtful Product Design** • The problem-solving and iterative design skills from Unit 1 help students analyze user needs and constraints when designing products in Unit 3. Statistical techniques from Unit 1 will be used to evaluate product performance and optimize design solutions. **Unit 4: Making Things Move** • The modeling and prototyping techniques introduced in Unit 1 are essential for designing mechanical systems with moving parts in Unit 4. The foundational understanding of problem-solving and constraints from Unit 1 will help students develop functional and efficient mechanical designs.
Differentiation through *Universal Design for Learning*	
UDL Indicator	**Teacher Actions:**

1. Representation
   - Visual Supports: Use diagrams, videos, and animations to illustrate engineering concepts and modeling techniques. This can help students better visualize complex ideas.
   - Text-to-Speech Tools: Incorporate software that reads technical documents and CAD instructions aloud, aiding comprehension for students with reading difficulties.
   - Graphical Organizers: Provide templates for students to organize information about the engineering design process, modeling techniques, and statistical methods visually.
   - Interactive Simulations: Utilize CAD software with simulation capabilities that allow students to manipulate models and visualize the effects of design changes in real-time.
2. Engagement
   - Choice Boards: Create a menu of project options related to the engineering design process, allowing students to select projects that interest them and align with their strengths.
   - Collaborative Learning: Facilitate group projects where students can share ideas and work together on modeling and prototyping tasks. Encourage them to assign roles based on individual strengths.
   - Real-World Applications: Connect lessons to real-world engineering problems or current events, motivating students to see the relevance of what they are learning.
   - Gamification: Incorporate game elements into learning activities, such as competitions for the best design or innovative solution, to increase motivation and engagement.
3. Action and Expression
   - Varied Project Formats: Allow students to choose how they demonstrate their learning, such as through presentations, videos, digital portfolios, or traditional reports.
   - Peer Review: Implement structured peer feedback sessions where students can share their CAD models and prototypes with classmates to receive constructive criticism and suggestions for improvement.
   - Reflection Journals: Encourage students to maintain a journal documenting their design process, challenges faced, and solutions found, promoting metacognitive skills and self-assessment.
   - Use of Technology: Provide access to various technical tools and software that allow students to express their designs and ideas creatively, whether through CAD, 3D printing, or digital modeling.

Supporting Multilingual/English Learners	
Related [CELP standards:](#)	Learning Targets:

1. I can apply brainstorming and structured problem-solving techniques to generate multiple possible solutions to an engineering problem.
   - Level 1: I can identify basic problem-solving techniques, such as brainstorming.
   - Level 2: I can use brainstorming to identify at least two possible solutions to an engineering problem.
   - Level 3: I can apply structured problem-solving methods to generate a variety of solutions for an engineering problem.
   - Level 4: I can evaluate and compare multiple solutions generated through brainstorming and problem-solving techniques.
   - Level 5: I can facilitate group brainstorming and structured problem-solving sessions, leading to innovative solutions for complex engineering problems.
2. I can use an iterative process to refine and improve design solutions based on data and testing.
   - Level 1: I can define what an iterative process is in engineering.
   - Level 2: I can explain the basic steps of an iterative design process.
   - Level 3: I can use an iterative process to make improvements to a design after testing and gathering data.
   - Level 4: I can integrate feedback from multiple iterations to refine a design.
   - Level 5: I can lead a team through a full iterative design process, using testing and data to continuously improve solutions.
3. I can explain the purpose and characteristics of technical drawings and how they differ from artistic drawings.
   - Level 1: I can identify the difference between technical and artistic drawings.
   - Level 2: I can describe the key characteristics of technical drawings, such as accuracy and precision.
   - Level 3: I can explain how technical drawings communicate detailed engineering information.
   - Level 4: I can discuss the role of technical drawings in ensuring safety and functionality in engineering.
   - Level 5: I can evaluate the effectiveness of technical drawings in communicating design intent.
4. I can analyze how standardized technical drawings enable clear communication across different cultures and industries.
   - Level 1: I can explain the concept of standardized technical drawings.
   - Level 2: I can describe how standardization ensures clear communication in technical drawings.
   - Level 3: I can analyze how standardized technical drawings help prevent misunderstandings across cultures and industries.
   - Level 4: I can explain how standardized technical drawings enable global collaboration in engineering projects.
   - Level 5: I can lead discussions on how standardized technical drawings facilitate seamless communication in complex, global engineering projects.
5. I can use spatial visualization techniques to interpret and create engineering drawings.
   - Level 1: I can define spatial visualization in the context of engineering.
   - Level 2: I can interpret simple 2D engineering drawings using spatial visualization techniques.
   - Level 3: I can use spatial visualization to interpret and create 3D models from engineering drawings.
   - Level 4: I can utilize advanced spatial visualization techniques to create detailed and accurate engineering drawings.
   - Level 5: I can integrate spatial visualization into collaborative design processes to ensure clear communication of ideas.
6. I can describe how CAD enhances accuracy, efficiency, and collaboration in engineering design.
   - Level 1: I can explain what CAD is and why it is used in engineering.
   - Level 2: I can describe how CAD improves the accuracy of engineering designs.
   - Level 3: I can explain how CAD enables collaboration between engineers by allowing for shared files and real-time editing.
   - Level 4: I can analyze the advantages and challenges of using CAD in engineering design.
   - Level 5: I can lead the implementation of CAD tools and practices in a collaborative engineering project.
7. I can explain the benefits of hand sketching in the engineering design process.
   - Level 1: I can describe what hand sketching is in engineering.
   - Level 2: I can explain how hand sketching can help visualize ideas quickly and communicate initial concepts.
   - Level 3: I can explain how hand sketching aids in brainstorming and iterative design.
   - Level 4: I can evaluate the role of hand sketching in the overall design process and compare it to digital methods.
   - Level 5: I can mentor others in effectively using hand sketching as part of an engineering design process.
8. I can explain the importance of standardized dimensioning in engineering.
   - Level 1: I can define what standardized dimensioning is in engineering.
   - Level 2: I can explain how standardized dimensioning ensures clarity and consistency in engineering drawings.
   - Level 3: I can describe how standardized dimensioning improves the manufacturing and construction process.
   - Level 4: I can analyze the consequences of not using standardized dimensioning in technical drawings.
   - Level 5: I can lead a team in creating engineering drawings with standardized dimensioning for complex projects.
9. I can identify and evaluate the limitations of physical and digital models in engineering.
   - Level 1: I can describe what physical and digital models are in engineering.
   - Level 2: I can explain how physical and digital models are used to represent engineering designs.
   - Level 3: I can evaluate the strengths and weaknesses of physical and digital models in different engineering contexts.
   - Level 4: I can compare and contrast the limitations of physical and digital models based on cost, accuracy, and time constraints.
   - Level 5: I can design an engineering process that integrates both physical and digital models to optimize design and prototyping.

10. I can evaluate how statistics can be used or misused in engineering analysis.
    - Level 1: I can define statistics and explain how they are used in engineering.
    - Level 2: I can describe how statistics help engineers make decisions based on data.
    - Level 3: I can evaluate the validity of statistical data used in engineering analysis.
    - Level 4: I can assess how statistical tools can be used to improve the accuracy of engineering designs.
    - Level 5: I can lead discussions on ethical considerations when using statistics in engineering.
11. I can analyze sources of measurement error and their impact on engineering design.
    - Level 1: I can identify common sources of measurement error in engineering.
    - Level 2: I can describe how measurement errors can affect engineering designs.
    - Level 3: I can analyze the impact of measurement errors on the performance and safety of an engineering product.
    - Level 4: I can evaluate the significance of different types of measurement errors in engineering analysis.
    - Level 5: I can lead a team in addressing measurement errors and their impact on complex engineering projects.
12. I can evaluate the role of models in engineering and assess their reliability.
    - Level 1: I can define what a model is in the context of engineering.
    - Level 2: I can explain the purpose of using models in engineering design.
    - Level 3: I can evaluate the reliability of a model based on its design, assumptions, and data.
    - Level 4: I can compare the reliability of different models based on engineering requirements and goals.
    - Level 5: I can lead the development and evaluation of engineering models, ensuring their reliability and effectiveness in addressing real-world problems.
13. I can compare the benefits and drawbacks of individual versus team-based problem-solving in engineering.
    - Level 1: I can explain what individual and team-based problem-solving are.
    - Level 2: I can describe when individual problem-solving is more effective and when teamwork is preferred.
    - Level 3: I can compare the effectiveness of individual versus team-based problem-solving in different engineering contexts.
    - Level 4: I can evaluate the benefits and drawbacks of individual and team-based problem-solving in complex engineering projects.
    - Level 5: I can lead a team in solving complex engineering problems, integrating individual and team-based approaches for optimal results.

Lesson Sequence	**Learning Target**	**Success Criteria/ Assessment**
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.		
1	I can apply brainstorming and structured problem-solving techniques to generate multiple possible solutions to an engineering problem.	• I can use brainstorming techniques such as mind mapping and SCAMPER to generate diverse ideas. • I can document and organize potential solutions using sketches and notes. • I can evaluate initial ideas using constraints and criteria to determine feasibility.
2	I can use an iterative process to refine and improve design solutions based on data and testing.	• I can compare multiple design iterations using criteria such as cost, performance, and sustainability. • I can analyze test results and adjust my design accordingly. • I can justify my final design choice using evidence from testing and analysis.
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).		
3	I can explain the purpose and characteristics of technical drawings and how they differ from artistic drawings.	• I can compare and contrast technical and artistic drawings based on precision, purpose, and audience. • I can describe how technical drawings use standardized symbols and annotations to communicate information.

<table>
<tr><td>4</td><td>I can explain the purpose and characteristics of technical drawings and how they differ from artistic drawings.</td><td>● I can compare and contrast technical and artistic drawings based on precision, purpose, and audience.
● I can describe how technical drawings use standardized symbols and annotations to communicate information.</td></tr>
<tr><td colspan="3">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.</td></tr>
<tr><td>5</td><td>I can analyze how standardized technical drawings enable clear communication across different cultures and industries.</td><td>● I can explain how international drafting standards improve global collaboration.
● I can identify challenges that arise when technical drawings lack clarity or do not follow standards.</td></tr>
<tr><td>6</td><td>I can use spatial visualization techniques to interpret and create engineering drawings.</td><td>● I can mentally rotate and visualize 3D objects from 2D drawings.
● I can sketch different views (orthographic, isometric) of an object accurately.</td></tr>
<tr><td>7</td><td>I can describe how CAD enhances accuracy, efficiency, and collaboration in engineering design.</td><td>● I can identify key advantages of CAD, such as precision, editing capabilities, and 3D visualization.
● I can create basic 3D models in CAD and compare them to hand-drawn sketches.</td></tr>
<tr><td>8</td><td>I can explain the benefits of hand sketching in the engineering design process.</td><td>● I can describe how hand sketching is useful for quick idea generation and early-stage design thinking.
● I can create clear technical sketches before transitioning to CAD.</td></tr>
<tr><td>9</td><td>I can explain the importance of standardized dimensioning in engineering.</td><td>● I can apply standard dimensioning rules to technical drawings.
● I can analyze incorrect dimensioning and explain the potential consequences in manufacturing.</td></tr>
<tr><td>10</td><td>I can identify and evaluate the limitations of physical and digital models in engineering.</td><td>● I can explain how models may not fully represent real-world conditions (e.g., material properties, scale limitations).
● I can justify when to use a model versus real-world testing.</td></tr>
<tr><td>11</td><td>I can evaluate how statistics can be used or misused in engineering analysis.</td><td>● I can analyze how data can be manipulated to support different conclusions.
● I can use statistical methods to fairly interpret and validate design performance.</td></tr>
<tr><td colspan="3">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.</td></tr>
<tr><td>12</td><td>I can analyze sources of measurement error and their impact on engineering design.</td><td>● I can explain the difference between systematic and random errors.
● I can use appropriate precision and significant figures in engineering measurements.</td></tr>
<tr><td>13</td><td>I can evaluate the role of models in engineering and assess their reliability.</td><td>● I can explain why engineers use models to test ideas before full-scale production.
● I can identify factors that influence the accuracy of a model.</td></tr>
<tr><td>14</td><td>I can compare the benefits and drawbacks of individual versus team-based problem-solving in engineering.</td><td>● I can explain when individual work might be more efficient in engineering.
● I can describe how team collaboration improves complex problem-solving.</td></tr>
</table>

Unit Title:	
Unit 2: Assembly Design	
Unit Description:	
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.	
Relevant Standards: Bold indicates priority	
Common Core State Standards for English Language Arts Common Core State Standards for Mathematics Next Generation Science Standards **Standards for Technological and Engineering Literacy**	
Essential Question(s):	**Enduring Understanding(s):**
1. Is it necessary to indicate a tolerance for every dimension on a technical drawing? 2. What are the benefits of working drawings when communicating the design of a consumer product? 3. Beyond creating working drawings to document a design, how can CAD be used in and beyond the design process? 4. Why is reverse engineering done? 5. How is information gathered through product disassembly? 6. When is it acceptable for a company to reverse engineer and reproduce a successful consumer product designed by another person/company? 7. Why are many consumer product designs not commercially successful? 8. How do you determine the properties of a material? 9. How does the material chosen for a product impact the design of the product? 10. How does an engineer predict the safety and reliability of a selected material? 11. What strategy would you use to form a design team in order to obtain the best solution possible? 12. Why is a design process so important to follow when creating a solution to a problem?	1. Students will understand when tolerances are necessary in technical drawings and how they impact fit and function. 2. Students will recognize the benefits of working drawings in effectively communicating design intent and manufacturing details. 3. Students will explore how CAD extends beyond technical drawings to include simulations, prototyping, and other engineering applications. 4. Students will analyze the purpose of reverse engineering in improving products, solving problems, and driving innovation. 5. Students will investigate how product disassembly provides insights into materials, manufacturing processes, and design decisions. 6. Students will evaluate when it is ethically and legally acceptable for companies to reverse engineer and reproduce a product. 7. Students will examine the reasons why many consumer product designs fail in the market. 8. Students will learn how to determine the properties of materials through testing and analysis. 9. Students will assess how material selection influences the design, functionality, and manufacturability of a product. 10. Students will explore how engineers predict material safety and reliability using data, simulations, and real-world testing. 11. Students will develop strategies for forming effective design teams to create innovative solutions. 12. Students will understand the importance of following a structured design process to develop successful solutions to engineering challenges.
Demonstration of Learning:	**Pacing for Unit**

<table>
<tr><td>Students demonstrate learning by designing and creating a 3D CAD model of a functional assembly, utilizing proper engineering practices to join parts together, specifying tolerances, and documenting their design through assembly drawings; effectively showcasing their understanding of mechanical fasteners, fits, and the assembly process while applying these concepts to reverse engineer and improve a consumer product.</td><td>40 Full Class Periods</td></tr>
<tr><td>Family Overview (link below)</td><td>Integration of Technology:</td></tr>
<tr><td>Family Overview - PLTW Intro to Engineering Design
Family Overview - PLTW Intro to Engineering Design (Spanish)</td><td>MasterCam CAD Software</td></tr>
<tr><td>Unit-specific Vocabulary:</td><td>Aligned Unit Materials, Resources, and Technology (beyond core resources):</td></tr>
<tr><td><table><tr><td>Orthographic projection
Multiview drawing
Front view
Top view
Right side view</td><td>Dimensioning
Leader line
Dimension line
Tolerance
Scale
Hidden line
Center line</td><td>Edge
Ellipse
Isometric sketch
Oblique sketch
Auxiliary view
Section view
Detail view</td></tr></table></td><td>N/A</td></tr>
<tr><td>Opportunities for Interdisciplinary Connections:</td><td>Anticipated misconceptions:</td></tr>
<tr><td>
• Geometry & Measurement: Apply geometric principles when creating technical drawings and calculating tolerances.
• Statistics & Probability: Analyze product failure rates and material testing data to predict reliability.
• Algebra & Calculus: Use equations to model forces, stress, and material properties in design.
• Forces & Motion: Analyze how forces impact product durability and safety.
• Energy & Thermodynamics: Investigate how heat affects materials and product performance.
• Marketing & Consumer Behavior: Study why some products fail and how market demand shapes design.
• Intellectual Property & Ethics: Discuss patents, copyrights, and ethical considerations in reverse engineering.
• Cost Analysis: Evaluate how material selection and manufacturing affect product pricing.
• Coding & Automation: Explore programming in manufacturing and product testing.
• Aesthetic Design: Examine how color, shape, and texture impact consumer product appeal.
• User Experience (UX) & Human-Centered Design: Explore how psychology and ergonomics influence product design.
• Graphic Design: Create visually clear and effective technical drawings.
• Global Trade & Manufacturing: Investigate how supply chains and material sourcing affect product design.
</td><td>
• Tolerances are needed for every dimension on a technical drawing.
• CAD is just for making drawings.
• Reverse engineering is simply copying other products
• The best material for a product is always the strongest one.
• Once the design process is complete, it doesn’t need to be revisited.
</td></tr>
</table>

• Ethics & Sustainability: Examine environmental impacts of material choices and manufacturing methods.	
Connections to Prior Units:	**Connections to Future Units:**
Unit 1: Design and Problem Solving • Unit 1 introduces foundational design thinking and problem-solving skills that are crucial for Unit 2 (Assembly Design). Students will apply these skills to understand how individual components fit together to create a functional assembly.	**Unit 3: Thoughtful Product Design** • Unit 2 focuses on assembling parts efficiently. These skills will be essential in Unit 3 where students will design products with attention to aesthetics, usability, and material selection, ensuring the parts come together in a user-friendly way. **Unit 4: Making Things Move** • The understanding of how components fit together in **Unit 2** is crucial for designing systems with mechanical movement. This supports students in Unit 4 where they will learn to incorporate moving parts into assemblies.

Differentiation through *Universal Design for Learning*

UDL Indicator	**Teacher Actions:**

1. Representation
    - Visual Aids: Use flowcharts and diagrams to illustrate the components of multi-component systems and the reverse engineering process. This can help students understand system interactions visually.
    - Video Tutorials: Provide access to video demonstrations of reverse engineering techniques and CAD assembly modeling. This allows students to learn at their own pace and revisit complex concepts as needed.
    - Interactive Models: Utilize 3D models that students can manipulate digitally to understand how components fit together and interact. This hands-on experience can reinforce learning.
    - Annotated Examples: Present annotated examples of successful assembly designs, highlighting how different components work together and the considerations for material selection.

2. Engagement
    - Choice in Investigation: Allow students to choose which product to reverse engineer based on their interests, promoting ownership of their learning process.
    - Group Collaboration: Facilitate collaborative group work where students can share insights and strategies while reverse engineering and documenting their findings. This encourages teamwork and diverse perspectives.
    - Guest Speakers: Invite industry professionals to speak about real-world applications of assembly design and reverse engineering, providing students with insights into the relevance of their work.

3. Action and Expression
    - Flexible Presentation Options: Allow students to present their reverse engineering findings and assembly designs in various formats, such as reports, presentations, or digital portfolios.
    - Documentation Templates: Provide structured templates for students to document their reverse engineering process, including component analysis, material selection, and design improvements, ensuring clarity and organization.
    - Hands-On Prototyping: Encourage students to build physical prototypes of their assembly designs using accessible materials. This tactile experience reinforces their understanding of assembly techniques and manufacturability.
    - Feedback Mechanisms: Implement peer review sessions where students can share their documentation and assembly designs with classmates to receive feedback and suggestions for refinement.

Related *CELP standards:*	**Learning Targets:**

1. Students will understand the importance of tolerances in technical drawings and how they impact the manufacturing process.
    Level 1: I can define what tolerances are in technical drawings.
    Level 2: I can explain how tolerances affect the precision and fit of manufactured parts.
    Level 3: I can analyze the impact of tolerances on the manufacturing process and product performance.
    Level 4: I can assess the trade-offs between tighter and looser tolerances in terms of cost and performance.
    Level 5: I can design technical drawings with appropriate tolerances to meet engineering and manufacturing requirements.

2. Students will be able to explain the importance of working drawings in the design communication process.
- Level 1: I can define what a working drawing is in engineering design.
- Level 2: I can explain how working drawings communicate design details to manufacturers.
- Level 3: I can describe the role of working drawings in ensuring the accuracy of construction or manufacturing.
- Level 4: I can evaluate how working drawings facilitate clear communication among engineering teams, clients, and manufacturers.
- Level 5: I can create detailed working drawings that effectively communicate the design intent and specifications.

3. Students will understand the expanded role of CAD in both the design and manufacturing processes.
- Level 1: I can explain what CAD is and its basic uses in engineering.
- Level 2: I can describe how CAD is used to create and modify designs in the engineering process.
- Level 3: I can explain how CAD supports the manufacturing process through simulations and prototyping.
- Level 4: I can assess the advantages of using CAD for both design and manufacturing processes, including cost and time savings.
- Level 5: I can lead a design project that integrates CAD for both design development and the manufacturing process.

4. Students will understand the reasons behind reverse engineering and how it is applied in product development.
- Level 1: I can define reverse engineering in the context of product development.
- Level 2: I can explain why reverse engineering is used to understand existing products and improve designs.
- Level 3: I can describe how reverse engineering is applied to analyze and recreate a product's components.
- Level 4: I can assess how reverse engineering contributes to innovation and competitive advantage in product development.
- Level 5: I can lead a reverse engineering project to analyze an existing product and use the insights to develop new design solutions.

5. Students will be able to describe the process of gathering data and insights through product disassembly.
- Level 1: I can explain what product disassembly is and why it is important.
- Level 2: I can describe the basic steps involved in disassembling a product for analysis.
- Level 3: I can explain how data collected through disassembly is used to understand product design and function.
- Level 4: I can analyze the information obtained from product disassembly to identify design improvements.
- Level 5: I can manage a product disassembly process to gather detailed insights for product redesign and development.

6. Students will understand the ethical and legal boundaries of reverse engineering in the context of intellectual property.
- Level 1: I can define intellectual property and reverse engineering.
- Level 2: I can explain the basic legal and ethical considerations involved in reverse engineering.
- Level 3: I can analyze situations where reverse engineering may violate intellectual property rights.
- Level 4: I can evaluate the ethical implications of reverse engineering in the context of innovation and competition.
- Level 5: I can lead discussions on how to navigate the legal and ethical boundaries of reverse engineering while respecting intellectual property rights.

7. Students will understand the factors that contribute to the commercial success or failure of consumer products.
- Level 1: I can identify factors that influence the commercial success of a product, such as design and cost.
- Level 2: I can explain how consumer needs, marketing, and design affect a product's success.
- Level 3: I can analyze how the price, functionality, and usability of a product impact its commercial success.
- Level 4: I can assess the role of competition, market trends, and customer feedback in the success or failure of consumer products.
- Level 5: I can evaluate and design strategies to enhance the commercial success of consumer products in the marketplace.

8. Students will understand how to assess and select materials based on their properties for engineering applications.
- Level 1: I can identify different types of materials used in engineering, such as metals and plastics.
- Level 2: I can describe how the properties of materials, like strength and durability, influence their use in engineering.
- Level 3: I can explain how to select materials based on their specific properties for a given engineering application.
- Level 4: I can analyze the trade-offs between material properties to select the most appropriate material for a design.
- Level 5: I can lead a process for selecting materials for a complex engineering project based on performance, cost, and environmental impact.

9. Students will understand the impact of material selection on the product's design, functionality, and manufacturing process.
- Level 1: I can define how material selection affects a product's design and function.
- Level 2: I can describe how the choice of material impacts manufacturing processes, such as cost and ease of production.
- Level 3: I can explain how different materials can affect the performance and longevity of a product.
- Level 4: I can analyze how material properties must be considered in both the design and manufacturing stages of a product.
- Level 5: I can assess and optimize material selection in a design to balance cost, functionality, and manufacturability.

10. Students will understand the methods engineers use to predict and assess the safety and reliability of materials.
- Level 1: I can identify common methods used to test the safety and reliability of materials.
- Level 2: I can explain how engineers use testing to evaluate material strength, durability, and performance.
- Level 3: I can describe how engineers use data and modeling to predict material failure under various conditions.
- Level 4: I can assess the safety and reliability of materials based on testing and real-world applications.

Level 5: I can lead the development of testing protocols to predict and ensure the safety and reliability of materials in complex engineering designs.

11. Students will learn how to form effective design teams that can collaborate to find the best solutions.
    - Level 1: I can explain the basic concepts of team collaboration in engineering design.
    - Level 2: I can describe how different team roles contribute to effective design problem-solving.
    - Level 3: I can demonstrate how effective communication and teamwork lead to better design solutions.
    - Level 4: I can analyze how team dynamics influence the success of a design project and suggest improvements.
    - Level 5: I can lead and manage a multidisciplinary design team to collaborate on solving complex engineering challenges.
12. Students will understand the importance of following a structured design process to create effective solutions.
    - Level 1: I can define what a structured design process is in engineering.
    - Level 2: I can describe the steps involved in a structured design process, such as ideation and prototyping.
    - Level 3: I can explain how following a structured design process helps create effective and functional solutions.
    - Level 4: I can analyze how each step of the design process contributes to the final product's success.
    - Level 5: I can lead a design project, ensuring all steps of the structured design process are followed to develop a successful engineering solution.

<table>
<tr><th>Lesson Sequence</th><th>Learning Target</th><th>Success Criteria/ Assessment</th><th>Resources</th></tr>
<tr><td colspan="4">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.</td></tr>
<tr><td>1</td><td>Students will understand the importance of tolerances in technical drawings and how they impact the manufacturing process.</td><td>• Students can explain why tolerances are necessary for ensuring parts fit together and function as intended.
• Students can describe the potential consequences of not indicating tolerances on a technical drawing.
• Students can provide examples of how different tolerances are applied to different types of dimensions on technical drawings.</td><td></td></tr>
<tr><td>2</td><td>Students will be able to explain the importance of working drawings in the design communication process.</td><td>• Students can identify key components of a working drawing and how they communicate detailed information.
• Students can explain how working drawings improve collaboration between engineers, manufacturers, and clients.
• Students can discuss how accurate and clear working drawings can prevent errors and ensure product quality.</td><td></td></tr>
<tr><td>3</td><td>Students will understand the expanded role of CAD in both the design and manufacturing processes.</td><td>• Students can explain how CAD is used to create detailed models and simulations during the design process.
• Students can identify how CAD tools can be used for testing, prototyping, and even generating manufacturing instructions.
• Students can describe how CAD can be used for visualization, collaboration, and documentation beyond the initial design phase.</td><td></td></tr>
<tr><td colspan="4">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.</td></tr>
</table>

4	Students will understand the reasons behind reverse engineering and how it is applied in product development.	• Students can explain the primary reasons for reverse engineering, including understanding a competitor's product or improving an existing design. • Students can provide examples of industries or situations where reverse engineering is commonly used. • Students can discuss the ethical considerations associated with reverse engineering.
5	Students will be able to describe the process of gathering data and insights through product disassembly.	• Students can outline the steps involved in disassembling a product to learn about its components and design. • Students can identify specific types of information that can be obtained through disassembly (e.g., materials used, manufacturing techniques). • Students can explain how product disassembly aids in improving or replicating design features.
6	Students will understand the ethical and legal boundaries of reverse engineering in the context of intellectual property.	• Students can describe when reverse engineering is acceptable (e.g., for research, repair, or education). • Students can explain when it is illegal or unethical to reverse engineer a product (e.g., patent infringement or violation of copyrights). • Students can give examples of cases where reverse engineering has led to legal disputes.
7	Students will understand the factors that contribute to the commercial success or failure of consumer products.	• Students can identify common reasons why consumer products fail, such as poor market research, design flaws, or pricing issues. • Students can analyze the importance of understanding customer needs and market trends in designing successful products. • Students can discuss how failure to innovate or adapt to new technology impacts a product's commercial success.
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.		
8	Students will understand how to assess and select materials based on their properties for engineering applications.	• Students can describe the key properties of materials (e.g., strength, flexibility, thermal conductivity, corrosion resistance). • Students can explain different methods for determining material properties, including testing and research. • Students can select a material based on its suitability for a given engineering project or design.
9	Students will understand the impact of material selection on the product's design, functionality, and manufacturing process.	• Students can explain how material properties affect a product's strength, weight, and durability. • Students can discuss how material selection influences manufacturing processes such as casting, molding, or machining. • Students can provide examples of how the wrong material choice can lead to design flaws or product failure.
10	Students will understand the methods engineers use to predict and assess the safety and reliability of materials.	• Students can describe methods used to test material strength and reliability, such as stress tests or fatigue testing. • Students can explain how engineers use data to predict how a material will behave under different conditions.

		• Students can identify the importance of safety standards and regulations in selecting reliable materials for products.
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.		
11	Students will learn how to form effective design teams that can collaborate to find the best solutions.	• Students can describe the roles and responsibilities of different team members in a design team. • Students can explain how to identify the strengths and weaknesses of team members to create a balanced team. • Students can discuss how communication, collaboration, and conflict resolution contribute to the success of a design team.
12	Students will understand the importance of following a structured design process to create effective solutions.	• Students can explain the steps of a standard design process (e.g., define the problem, brainstorm solutions, prototype, test). • Students can describe how following the design process helps ensure thorough problem-solving and efficient use of resources. • Students can provide examples of how skipping steps in the design process can lead to poor design outcomes.

<table>
<tr><td colspan="2">Unit Title:</td></tr>
<tr><td colspan="2">Unit 3: Thoughtful Product Design</td></tr>
<tr><td colspan="2">Unit Description:</td></tr>
<tr><td colspan="2">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.</td></tr>
<tr><td colspan="2">Relevant Standards: Bold indicates priority</td></tr>
<tr><td colspan="2">Common Core State Standards for English Language Arts
Common Core State Standards for Mathematics
Next Generation Science Standards
Standards for Technological and Engineering Literacy</td></tr>
<tr><td>Essential Question(s):</td><td>Enduring Understanding(s):</td></tr>
<tr><td>1. What does it mean to be ethical in your work?
2. How do ethics impact the manufacturing of products?
3. How do design criteria and constraints limit material choices for a design?
4. What are the benefits of human-centered design?
5. Why is it important to have clear, accurate, and detailed communication among all involved in the design, manufacturing, and distribution process?
6. Why is it important to study a product's life cycle?
7. What are team norms and why do they matter?
8. What questions should you ask yourself before beginning a project?</td><td>1. Students will understand that being ethical means making choices that are fair, honest, and responsible in their work and in their impact on others.
2. Students will recognize that ethics affect the manufacturing process by influencing decisions about sustainability, labor practices, safety, and the environmental impact of products.
3. Students will understand that design criteria and constraints, like cost, function, and user needs, limit the types of materials that can be used in a product.
4. Students will recognize that human-centered design focuses on creating products that meet the needs and preferences of the people who will use them.
5. Students will understand that clear, accurate, and detailed communication ensures that everyone involved in the design, manufacturing, and distribution process is on the same page, preventing mistakes and delays.
6. Students will recognize that studying a product's life cycle helps identify its environmental impact and guides decisions on how to make more sustainable choices.
7. Students will understand that team norms are rules or guidelines that help teams work well together, promoting respect, responsibility, and effective collaboration.
8. Students will ask important questions, like "What problem am I solving?" and "What resources do I need?" to ensure that they are ready and focused before starting a project.</td></tr>
<tr><td>Demonstration of Learning:</td><td>Pacing for Unit</td></tr>
</table>

Students demonstrate learning by applying design principles and systems thinking to solve a real-world problem, showcasing their understanding through detailed sketches, comprehensive design documentation, a well-developed prototype, and a presentation that clearly communicates their design process, rationale, and justification for design decisions, while incorporating feedback from user testing and considering sustainability factors throughout the project.

40 Full Class Periods

Family Overview (link below)

Family Overview - PLTW Intro to Engineering Design
Family Overview - PLTW Intro to Engineering Design (Spanish)

Integration of Technology:

MasterCam CAD Software

Unit-specific Vocabulary:

Measurement units (inches, centimeters, millimeters) Precision Accuracy Mean Median	Mode Standard deviation Data analysis Scatter plot Correlation	Statistical inference Sample size Margin of error Tolerance Dimensioning Design constraints

Aligned Unit Materials, Resources, and Technology (beyond core resources):

N/A

Opportunities for Interdisciplinary Connections:

- Ethical Design and Social Studies: Connect ethical design principles to discussions about social responsibility, fairness, and human rights in social studies, exploring how engineering impacts society and aligns with ethical considerations in global contexts.
- Communication and English/Language Arts: Integrate clear, detailed communication with writing and speaking skills, emphasizing the importance of conveying complex technical information effectively in reports, presentations, and discussions.
- Life Cycle Analysis and Environmental Science: Link the study of a product's life cycle to environmental science concepts like sustainability, resource conservation, and ecological impact, emphasizing the importance of considering long-term environmental effects during the design process.
- Design Constraints and Mathematics/Physics: Connect design constraints to mathematical problem-solving and physics principles, helping students understand how measurements, calculations, and material properties influence design decisions related to forces, weight, and cost.

Anticipated misconceptions:

- Ethical design only concerns personal integrity and doesn't need to account for the environmental or societal impacts of a product.
- Communication among team members doesn't need to be very detailed as long as everyone knows their individual tasks.
- The life cycle of a product only involves its time in use and disposal, ignoring the environmental and social effects during manufacturing.
- Design constraints are just restrictions that limit creativity, so they should be avoided whenever possible to allow for more freedom in design.
- Human-centered design only focuses on making products look good or user-friendly, but doesn't need to consider the practicality or functionality of the design.

Connections to Prior Units:

Unit 1: Design and Problem Solving

- Unit 3 builds on the problem-solving and creative thinking skills learned in Unit 1 by guiding students to apply those skills in developing thoughtful and functional product designs. It

Connections to Future Units:

Unit 4: Making Things Move

- Unit 3 lays the groundwork for Unit 4 by encouraging students to think about how their designs can incorporate movement and mechanical functionality. It introduces concepts

encourages students to consider not only the technical aspects but also user needs and ethical implications, expanding on the foundation of problem-solving. **Unit 2: Assembly Design** ● Unit 3 connects to Unit 2 by focusing on the integration of individual parts into a well-thought-out product design. While Unit 2 emphasized how components fit together, Unit 3 teaches students to consider factors like usability, sustainability, and overall design coherence, making the assembly process more intentional.	related to forces, materials, and energy, which will be crucial when students begin to explore how to create moving components in Unit 4.

Differentiation through *Universal Design for Learning*

UDL Indicator	**Teacher Actions:**

1. Representation
- Case Studies: Provide case studies of successful products that exemplify universal design principles. Analyze these examples in class to highlight how different factors influence product success.
- Interactive Simulations: Use simulations to demonstrate the product life cycle and the impact of design choices on sustainability and manufacturability. This allows students to see the consequences of their decisions in a virtual environment.
- Resource Libraries: Compile a collection of articles, videos, and other resources that explore various aspects of thoughtful product design. This allows students to explore topics that interest them at their own pace.

2. Engagement
- Design Challenges: Present students with real-world problems that require thoughtful product design solutions. Encourage them to apply design principles to develop innovative ideas, fostering creativity and critical thinking.
- Cross-Disciplinary Connections: Integrate lessons with other subjects, such as environmental science or ethics, to show the relevance of design principles across disciplines and increase student interest.
- Peer Collaboration: Encourage collaborative projects where students can work in teams to design a product that meets specific criteria related to usability and sustainability. This promotes teamwork and diverse perspectives.
- Community Involvement: Involve local stakeholders or community members to provide input on design projects, allowing students to understand the impact of their designs on real users.

3. Action and Expression
- Diverse Project Formats: Allow students to express their understanding of design principles through various formats, such as presentations, prototypes, reports, or digital media projects. This enables them to showcase their strengths.
- Reflective Journals: Encourage students to maintain a reflective journal throughout the unit, documenting their design process, challenges faced, and lessons learned related to product design principles. This promotes metacognition and self-assessment.
- User Testing: Incorporate user testing into the design process, allowing students to gather feedback on their prototypes or concepts from peers or community members. This helps them refine their designs based on real user experiences.

Supporting Multilingual/English Learners

Related *CELP standards:*	**Learning Targets:**

1. Students will understand what it means to be ethical in their work and how ethics guide decision-making in engineering.
   Level 1: I can define ethics and explain why they are important in engineering.
   Level 2: I can describe how ethical considerations influence decision-making in engineering projects.
   Level 3: I can analyze how ethical issues can affect the outcomes of engineering designs and decisions.
   Level 4: I can evaluate the impact of ethical decision-making on the long-term success of engineering projects.
   Level 5: I can lead discussions on how engineers can navigate ethical challenges and make responsible decisions in complex projects.
2. Students will understand how ethics impact the manufacturing of products.
   Level 1: I can explain what ethical issues may arise in manufacturing.
   Level 2: I can describe how unethical practices in manufacturing can affect product quality and safety.

Level 3: I can explain how ethical considerations, such as labor practices and environmental impact, influence manufacturing decisions.
Level 4: I can evaluate how companies can implement ethical practices in the manufacturing process to improve outcomes.
Level 5: I can lead initiatives that ensure ethical practices are integrated into the manufacturing process across projects.

3. Students will understand how design criteria and constraints limit material choices for a design.
Level 1: I can define design criteria and constraints in engineering.
Level 2: I can describe how design criteria, such as strength and cost, impact material selection.
Level 3: I can explain how constraints, like weight and environmental impact, limit material choices in a design.
Level 4: I can analyze how different design constraints interact and affect material selection in complex projects.
Level 5: I can make material recommendations based on specific design criteria and constraints to meet project goals.

4. Students will understand the benefits of human-centered design.
Level 1: I can explain what human-centered design is.
Level 2: I can describe how human-centered design focuses on user needs and experiences.
Level 3: I can analyze the benefits of human-centered design in creating products that are functional and user-friendly.
Level 4: I can evaluate how human-centered design improves product satisfaction and user engagement.
Level 5: I can apply human-centered design principles to lead the creation of innovative, user-focused engineering solutions.

5. Students will understand the importance of clear, accurate, and detailed communication among all involved in the design, manufacturing, and distribution process.
Level 1: I can explain why clear communication is important in the engineering process.
Level 2: I can describe how accurate and detailed communication helps reduce errors in design and manufacturing.
Level 3: I can explain how effective communication among teams improves the overall efficiency of a project.
Level 4: I can analyze the consequences of poor communication on the design, manufacturing, and distribution of a product.
Level 5: I can implement strategies to enhance communication across all stages of design, manufacturing, and distribution.

6. Students will understand why it is important to study a product's life cycle.
Level 1: I can define what a product life cycle is.
Level 2: I can explain the stages of a product's life cycle, from design to disposal.
Level 3: I can describe how studying the product life cycle helps engineers identify environmental and economic impacts.
Level 4: I can analyze how different stages of the product life cycle influence the sustainability and cost-effectiveness of a product.
Level 5: I can lead a life cycle analysis for a product to identify areas for improvement in sustainability and efficiency.

7. Students will understand the concept of team norms and why they matter.
Level 1: I can define what team norms are.
Level 2: I can describe how team norms help improve collaboration and productivity.
Level 3: I can explain the role of team norms in creating a respectful and efficient working environment.
Level 4: I can evaluate how well-established team norms contribute to successful team performance and conflict resolution.
Level 5: I can facilitate the development and enforcement of team norms to foster a collaborative, effective team environment.

8. Students will understand the key questions to ask themselves before beginning a project.
Level 1: I can identify basic questions to ask before starting a project.
Level 2: I can describe why it's important to ask questions like "What is the goal of the project?"
Level 3: I can explain how asking the right questions at the beginning of a project helps clarify objectives and scope.
Level 4: I can analyze the impact of asking key questions on project success and avoiding potential pitfalls.
Level 5: I can lead a team in formulating and addressing critical questions before starting complex engineering projects.

Lesson Sequence	**Learning Target**	**Success Criteria/ Assessment**	**Resources**
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.			
1	I can understand what it means to be ethical in their work and how ethics guide decision-making in engineering.	• I can explain the concept of ethics and its application to the engineering profession. • I can identify examples of ethical and unethical behavior in product design and manufacturing. • I can discuss how ethical considerations impact their decisions and actions in an engineering context.	
2	I can understand how ethics impact the manufacturing of products.	• I can explain how ethical issues, such as labor practices, environmental impact, and product safety, influence manufacturing decisions.	

<table>
<tr><td></td><td></td><td>• I can describe the consequences of unethical practices in manufacturing.
• I can identify strategies for ensuring ethical manufacturing processes.</td></tr>
<tr><td>3</td><td>I can understand how design criteria and constraints limit material choices for a design.</td><td>• I can explain how factors such as cost, durability, weight, and environmental impact affect material selection.
• I can discuss how design constraints like size or strength influence the choice of materials for a product.
• I can identify examples where design criteria directly impacted material selection.</td></tr>
<tr><td colspan="3">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.</td></tr>
<tr><td>4</td><td>I can understand the benefits of human-centered design.</td><td>• I can explain what human-centered design is and why it focuses on the end user's needs.
• I can identify how human-centered design improves product usability, accessibility, and overall user experience.
• I can provide examples of products that were enhanced by using human-centered design principles.</td></tr>
<tr><td>5</td><td>I can understand the importance of clear, accurate, and detailed communication among all involved in the design, manufacturing, and distribution process.</td><td>• I can describe how communication impacts the efficiency and success of the design and manufacturing process.
• I can identify potential issues that can arise from poor communication in product development.
• I can explain how accurate documentation, such as technical drawings and specifications, helps avoid misunderstandings.</td></tr>
<tr><td>6</td><td>I can understand why it is important to study a product’s life cycle.</td><td>• I can explain the concept of a product life cycle and its stages (design, manufacturing, use, disposal).
• I can discuss the environmental, economic, and social impacts of each stage of the product life cycle.
• I can analyze how understanding a product’s life cycle can lead to more sustainable design choices.</td></tr>
<tr><td colspan="3">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.</td></tr>
<tr><td>7</td><td>I can understand the concept of team norms and why they matter.</td><td>• I can define team norms and explain how they contribute to team collaboration and productivity.
• I can identify examples of positive and negative team norms in a design team setting.
• I can describe how adhering to team norms helps maintain a healthy, efficient working environment.</td></tr>
<tr><td>8</td><td>I can understand the key questions to ask themselves before beginning a project.</td><td>• I can identify critical questions to ask before starting a project, such as "What is the problem?" and "Who is the end user?"
• I can explain how these questions guide the planning and design phases of a project.
• I can describe how answering these questions helps focus the project’s objectives and leads to better design outcomes.</td></tr>
</table>

Unit Title:	
Unit 4: Making Things Move	
Unit Description:	
Unit 4 builds students' 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.	
Relevant Standards: Bold indicates priority	
Common Core State Standards for English Language Arts Common Core State Standards for Mathematics Next Generation Science Standards **Standards for Technological and Engineering Literacy**	
Essential Question(s):	**Enduring Understanding(s):**
1. What are the benefits of parametric modeling? 2. How can you use a graph to describe motion? 3. How are force and motion related? 4. How can friction be helpful in a vehicle? 5. How are current, voltage, and resistance related in an electrical circuit? 6. Why is safety of the utmost importance when working with electricity or electronics? 7. What is the difference between a DC and AC circuit? 8. How should one decide what information and/or artifacts to include in a portfolio? 9. Why should a portfolio include documentation of the complete design process?	1. Students will understand that parametric modeling allows for easy changes to designs by adjusting key dimensions, which automatically updates the rest of the model, improving efficiency and flexibility in design. 2. Students will recognize that a graph can visually show how an object moves over time, helping to analyze speed, direction, and acceleration. 3. Students will understand that force and motion are connected—force causes objects to move, and motion can be measured and analyzed to understand the effect of different forces. 4. Students will recognize that friction can be useful in vehicles by providing the necessary grip for tires to move safely, control speed, and stop effectively. 5. Students will understand that in an electrical circuit, current, voltage, and resistance are related through Ohm's Law, which helps determine how electricity flows through a circuit. 6. Students will understand that safety is critical when working with electricity or electronics to prevent accidents, injuries, and damage to equipment due to electrical hazards. 7. Students will differentiate between DC (direct current) and AC (alternating current) circuits, understanding how each type of current flows and its uses in different applications. 8. Students will understand that when creating a portfolio, it's important to choose artifacts that show the process, challenges, and solutions in their design, demonstrating growth and learning. 9. Students will recognize that a portfolio should include documentation of the complete design process to show how they arrived at a solution, reflecting their creativity, problem-solving, and decision-making.
Demonstration of Learning:	**Pacing for Unit**
Students demonstrate learning by applying their understanding of mechanical systems and mathematical modeling to design and build an electromechanical solution, showcasing their knowledge through detailed	40 Full Class Periods

<table>
<tr><td>engineering drawings, calculations, a functional prototype, and a comprehensive presentation explaining their design process and reasoning; this typically involves using CAD software to create detailed models, conducting experiments to test their design, and effectively communicating their findings to an audience.</td><td></td></tr>
<tr><td>Family Overview (link below)</td><td>Integration of Technology:</td></tr>
<tr><td>Family Overview - PLTW Intro to Engineering Design
Family Overview - PLTW Intro to Engineering Design (Spanish)</td><td>MasterCam CAD Software</td></tr>
<tr><td>Unit-specific Vocabulary:</td><td>Aligned Unit Materials, Resources, and Technology (beyond core resources):</td></tr>
<tr><td><table><tr><td>Assembly
Assembly drawing
Component
CAD (Computer-Aided Design)
Cartesian coordinate system</td><td>Degree of freedom
Extrusion
Geometric constraint
Model
Origin
Prototype</td><td>Solid modeling
Subassembly
Translation
Working drawing
Annotate
Feature
Revolution
Constraint</td></tr></table></td><td>N/A</td></tr>
<tr><td>Opportunities for Interdisciplinary Connections:</td><td>Anticipated misconceptions:</td></tr>
<tr><td>
Social Studies/History: Ethics in manufacturing (historical context, labor movements, industrialization).
Environmental Science: Ethics in manufacturing and life cycle analysis (environmental impact, sustainability).
Mathematics: Design criteria and constraints, project planning (calculations for material selection, project budgets, and timelines).
Physics: Material properties for design (tensile strength, thermal conductivity, force, motion).
Psychology: Human-centered design (understanding user needs, cognitive behavior).
Art/Design: Aesthetic considerations in human-centered design (visual design, product styling).
Economics: Product life cycle (cost analysis, economic viability, resource allocation).
English/Language Arts: Communication (writing project plans, proposals, and documentation).
</td><td>
Ethics only matter if the product is harmful or dangerous.
More expensive materials are always better because they result in better performance.
Human-centered design is only about making products look good and attractive.
A product's life cycle only matters after it has been released to the market.
You only need to ask questions about what the project looks like at the end.
</td></tr>
<tr><td>Connections to Prior Units:</td><td>Connections to Future Units:</td></tr>
<tr><td>Unit 1: Design and Problem Solving
In Unit 1, students learn how to define problems and find solutions. In Unit 4, they apply these skills to design systems that move, using the same problem-solving steps to create functional movement.
Unit 2: Assembly Design
Unit 2 teaches students how to put different parts together. In Unit 4, they use this knowledge to design moving parts, ensuring everything fits and works properly.
Unit 3: Thoughtful Product Design</td><td>N/A</td></tr>
</table>

• In Unit 3, students learn how to design products that are functional and user-friendly. In Unit 4, they apply these ideas to moving systems, making sure the movement is practical, safe, and easy to use.	
Differentiation through *Universal Design for Learning*	
UDL Indicator	**Teacher Actions:**

1. Representation
    - Dynamic Visualizations: Use animations and simulations to demonstrate mechanical and electrical systems in action. This helps students visualize concepts such as forces, motion, and circuit behavior.
    - Hands-On Demonstrations: Conduct live demonstrations or use video tutorials to showcase simple mechanical and electrical systems, allowing students to observe how these systems function in real time.
    - Mathematical Modeling Tools: Introduce software tools that allow students to create and manipulate mathematical models of electromechanical systems. This enables them to see how changes in variables affect system performance.
    - Annotated Diagrams: Provide diagrams of mechanical systems and electrical circuits with annotations explaining key components and their functions. This aids in understanding complex systems.
2. Engagement
    - Real-World Scenarios: Present students with real-world problems or scenarios that require the design of electromechanical solutions. This encourages them to apply their knowledge in a meaningful context.
    - Interactive Workshops: Organize hands-on workshops where students can collaboratively build simple mechanical and electrical systems, fostering engagement through active participation.
    - Choice in Projects: Allow students to select projects that interest them, such as designing a simple robot or automated device, to increase motivation and ownership of their learning.
3. Action and Expression
    - Flexible Design Presentations: Encourage students to present their electromechanical designs using various formats (e.g., videos, digital portfolios, or live demonstrations), allowing them to choose the medium that best showcases their work.
    - Collaborative Problem-Solving: Implement team-based activities where students design, build, and test electromechanical solutions together. This encourages collaboration and diverse problem-solving approaches.
    - Iterative Design Process: Promote an iterative design process where students can test their prototypes, gather feedback, and make improvements based on their observations and results.
    - Reflective Practices: Encourage students to document their design process, challenges encountered, and solutions developed in a reflective journal, fostering self-assessment and critical thinking.

Supporting Multilingual/English Learners	
Related *CELP standards:*	**Learning Targets:**

1. I can explain the advantages of parametric modeling in engineering design.
    Level 1: I can identify and name basic terms related to parametric modeling with support from visuals or examples.
    Level 2: I can describe one advantage of parametric modeling in simple terms, using sentence frames or keywords.
    Level 3: I can explain at least two advantages of parametric modeling in engineering design, using complete sentences and some technical vocabulary.
    Level 4: I can articulate multiple advantages of parametric modeling, providing examples and connecting ideas to real-world applications in engineering design.
    Level 5: I can critically evaluate the advantages of parametric modeling in engineering design, comparing it to traditional modeling techniques and discussing implications for efficiency and innovation.
2. I can interpret and create graphs to describe an object's motion.
    Level 1: I can recognize basic graphs and identify key components (axes, labels) with support.
    Level 2: I can interpret simple graphs to describe an object's motion, identifying trends (e.g., increasing or decreasing).
    Level 3: I can create basic graphs to represent an object's motion, including labeling axes and providing a title.
    Level 4: I can analyze and interpret complex graphs, explaining the relationship between variables and describing the motion of the object in detail.
    Level 5: I can create and interpret sophisticated graphs, offering insights into the motion of an object, predicting future motion, and justifying conclusions with data.
3. I can explain the relationship between force and motion using Newton's Laws.
    Level 1: I can identify basic terms related to force and motion with support.
    Level 2: I can describe one of Newton's Laws of Motion in simple terms, explaining its connection to force and motion.

Level 3: I can explain all three of Newton's Laws of Motion and how each law relates to the concepts of force and motion, using examples.
Level 4: I can analyze real-world scenarios applying Newton's Laws, discussing how they explain various motions and forces in everyday life.
Level 5: I can evaluate complex systems involving force and motion, applying Newton's Laws to predict outcomes and explain their significance in physics and engineering.

4. I can describe how friction impacts the movement and safety of vehicles.
    - Level 1: I can identify basic terms related to friction and vehicle movement with support.
    - Level 2: I can describe one way friction affects the movement of vehicles in simple terms.
    - Level 3: I can explain multiple ways friction impacts vehicle movement and safety, using complete sentences and examples.
    - Level 4: I can analyze different types of friction (e.g., static, kinetic) and their effects on vehicle performance and safety in various driving conditions.
    - Level 5: I can evaluate the role of friction in vehicle design and safety features, discussing how different materials and designs can enhance or reduce friction for optimal performance.
5. I can explain the relationship between current, voltage, and resistance using Ohm's Law.
    - Level 1: I can identify basic terms like current, voltage, and resistance with support.
    - Level 2: I can describe Ohm's Law in simple terms, stating the relationship between current, voltage, and resistance.
    - Level 3: I can explain Ohm's Law using a formula and provide examples of how changing one variable affects the others.
    - Level 4: I can analyze scenarios involving Ohm's Law, explaining real-world applications and implications of the relationship between current, voltage, and resistance.
    - Level 5: I can evaluate and apply Ohm's Law in complex circuits, discussing its significance in electrical engineering and providing detailed examples of its practical applications.
6. I can explain the importance of safety when working with electrical components.
    - Level 1: I can recognize basic safety terms related to electrical components with support.
    - Level 2: I can describe one safety rule for working with electrical components in simple terms.
    - Level 3: I can explain multiple safety practices that should be followed when working with electrical components, using complete sentences.
    - Level 4: I can analyze safety scenarios in electrical work, discussing the consequences of ignoring safety measures and the importance of following them.
    - Level 5: I can evaluate complex safety situations involving electrical components, proposing solutions and justifying the importance of safety protocols in preventing accidents.
7. I can compare and contrast direct current (DC) and alternating current (AC) circuits.
    - Level 1: I can identify basic terms related to DC and AC circuits with support.
    - Level 2: I can describe one difference between DC and AC circuits in simple terms.
    - Level 3: I can explain at least two similarities and two differences between DC and AC circuits, using complete sentences.
    - Level 4: I can analyze the advantages and disadvantages of DC and AC circuits, providing examples of where each type is used.
    - Level 5: I can evaluate the applications of DC and AC circuits in various technologies, discussing their impact and relevance in modern electrical engineering.
8. I can evaluate and select relevant materials for an engineering portfolio.
    - Level 1: I can identify basic materials related to engineering portfolios with support.
    - Level 2: I can describe one type of material that could be included in an engineering portfolio in simple terms.
    - Level 3: I can explain multiple relevant materials for an engineering portfolio, using complete sentences and examples to support my choices.
    - Level 4: I can analyze the importance of different materials in an engineering portfolio, discussing how they showcase skills and projects effectively.
    - Level 5: I can evaluate and justify the selection of materials for an engineering portfolio, considering factors such as audience, purpose, and professional presentation, and I can create a cohesive and impactful portfolio.
9. I can explain why documenting the design process is essential in engineering.
    - Level 1: I can identify basic terms related to the design process and documentation with support.
    - Level 2: I can describe one reason why documenting the design process is important in simple terms.
    - Level 3: I can explain multiple reasons why documenting the design process is essential in engineering, using complete sentences and examples.
    - Level 4: I can analyze the consequences of poor documentation in engineering projects, discussing how it affects collaboration, communication, and project outcomes.
    - Level 5: I can evaluate best practices for documenting the design process, discussing its long-term benefits for professional development, knowledge transfer, and innovation in engineering.

Lesson Sequence	**Learning Target**	**Success Criteria/ Assessment**	**Resources**
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.		
1	I can explain the advantages of parametric modeling in engineering design.	• I can define parametric modeling and describe how it is used in engineering. • I can explain how parametric modeling improves efficiency, accuracy, and flexibility in design. • I can demonstrate how modifying one parameter affects an entire model.
2	I can interpret and create graphs to describe an object's motion.	• I can identify key components of a motion graph (position-time and velocity-time graphs). • I can analyze a motion graph to determine speed, velocity, and acceleration. • I can create a motion graph based on real-world data or a given scenario.
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.		
3	I can explain the relationship between force and motion using Newton's Laws.	• I can define force and motion and describe how they interact. • I can explain Newton's Laws of Motion and apply them to real-world examples. • I can predict how an object will move when forces are applied to it.
4	I can describe how friction impacts the movement and safety of vehicles.	• I can explain how friction between tires and the road affects acceleration, braking, and control. • I can describe different ways engineers optimize friction for safety (e.g., tire tread design, road surfaces). • I can analyze a real-world situation where friction is beneficial in vehicle performance.
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.		
5	I can explain the relationship between current, voltage, and resistance using Ohm's Law.	• I can define current, voltage, and resistance. • I can apply Ohm's Law ($V = IR$) to calculate unknown values in a circuit. • I can analyze how changes in resistance affect current and voltage.
6	I can explain the importance of safety when working with electrical components.	• I can identify potential hazards when working with electricity and electronics. • I can describe safety procedures and personal protective equipment (PPE) used in electrical work. • I can demonstrate proper safety practices when handling electrical circuits.

7	I can compare and contrast direct current (DC) and alternating current (AC) circuits.	• I can define and describe how DC and AC circuits function. • I can explain common applications of DC and AC in real-world systems. • I can analyze and determine which type of circuit is best suited for a given application.
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.		
8	I can evaluate and select relevant materials for an engineering portfolio.	• I can identify key components of an effective engineering portfolio. • I can choose artifacts that showcase my skills, knowledge, and growth. • I can organize my portfolio to highlight my best work and learning progress.
9	I can explain why documenting the design process is essential in engineering.	• I can describe the steps of the engineering design process. • I can explain how documentation helps track progress, justify decisions, and support innovation. • I can create a portfolio that demonstrates my problem-solving process from start to finish.