Lakewood High School

Department of Engineering Technology

Introduction to Engineering Design
Curriculum [IED 20]
(2022 update)

Original Adoption:	New
Created by:	PLTW - Project Lead the Way
Revised on:	March 17, 2022
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Introduction to Engineering Design Curriculum (2022 update)	
Content Area: Engineering	
Course Title: Introduction to Engineering Design	**Grade Level:** 10 -11
Unit 1: Design and Problem Solving	44 days
Design Basics Visualization & Design Modeling CAD Fundamentals Product improvement Design a Game Project	
Unit 2: Assembly Design	41 days
2.1 Put it Together 2.2 Take it apart 2.3 A Material World 2.4 Fix It	
Unit 3: Thoughtful Product Design	38 days
3.1 Responsible Design 3.2 More than Parts 3.3 Solve a Problem	
Unit 4: Making Things Move	40 days
4.1 You've Got to Move It 4.2 May the Force Be With You 4.3 Automating Motion 4.4 Make it Move	

Philosophy

The curriculum will provide expert instruction for the NGSS. We will implement the NGSS with confidence to ensure our students master 21st century science skills. We will combine instruction in Science and Engineering Practices, Disciplinary Core Ideas, and Crosscutting Concepts to meet the rigor of the Performance Expectations within the NGSS.

This course is designed as a comprehensive introduction to the engineering profession. Classroom discussions and presentations will inform the students of the many different avenues available to one in the field of engineering. The emphasis of the course is the concept of communication, specifically those methods used in the field of engineering to convey design intent, including writing, drawing and public speaking.

Designed for 10th or 11th grade students, the major focus of IED is the design process and its application. The class will utilize coursework developed by Project Lead the Way, (PLTW). Through hands-on projects, students apply engineering standards and document their work. Students use industry standard 3D modeling software to help them design solutions to solve proposed problems, document their work using an engineer's notebook, and communicate solutions to peers and members of the professional community. Students will have the opportunity to practice their creative abilities both individually and in group design projects.

Students taking this course will make use of NEPRIS, which allows you to watch videos of people working in our industry. It also allows us to "invite" guest speakers into our classroom and interact with our students. This will satisfy our student's initial experiences in the design field along with providing them an awareness of the many career avenues and opportunities available to them.

Career Ready Practices:

Through instruction in life and career skills, all students acquire the knowledge and skills needed to prepare for life as citizens and workers in the 21st century. For further clarification see NJ World Class Standards at www.NJ.gov/education/aps/cccs/career/

- **CRP1.** Act as a responsible and contributing citizen and employee.
- **CRP2.** Apply appropriate academic and technical skills.
- **CRP4.** Communicate clearly and effectively and with reason.
- **CRP5.** Consider the environmental, social and economic impacts of decisions.
- **CRP6.** Demonstrate creativity and innovation.
- **CRP7.** Employ valid and reliable research strategies.
- **CRP8.** Utilize critical thinking to make sense of problems and persevere in solving them.
- **CRP11.** Use technology to enhance productivity.
- **CRP12.** Work productively in teams while using cultural global competence.

9.3 – Career & Technical Education (CTE) Content Area: 21st Century Life and Careers:

These standards outline what students should know and be able to do upon completion of a CTE Program of Study.

ARCHITECTURE & CONSTRUCTION CAREER CLUSTER®	
Number Standard	**Statement**
9.3.12.AC.1	Use vocabulary symbols and formulas common to architecture and construction
9.3.12.AC.2	Use architecture and construction skills to create and manage a project.
9.3.12.AC.6	Read, interpret and use technical drawings, documents and specifications to plan a project.
PATHWAY:	**CONSTRUCTION (AC-CST)**
9.3.12.AC-CST.3	Implement testing and inspection procedures to ensure successful completion of a construction project.
9.3.12.AC-CST.5	Apply practices and procedures required to maintain jobsite safety.
9.3.12.AC-CST.8	Demonstrate the construction crafts required for each phase of a construction project.
9.3.12.AC-CST.9	Safely use and maintain appropriate tools, machinery, equipment and resources to accomplish construction project goals.
PATHWAY:	**DESIGN/PRE-CONSTRUCTION (AC-DES)**
9.3.12.AC-DES.1	Justify design solutions through the use of research documentation and analysis of data.
9.3.12.AC-DES.6	Apply the techniques and skills of modern drafting, design, engineering and construction to projects.
9.3.12.AC-DES.7	Employ appropriate representational media to communicate concepts and project design.
ARTS, A/V TECHNOLOGY & COMMUNICATIONS CAREER CLUSTER®	
PATHWAY:	**PRINTING TECHNOLOGY (AR-PRT)**
9.3.12.AR-PRT.1	Manage the printing process, including customer service and sales, scheduling, production and quality control.
9.3.12.AR-PRT.2	Demonstrate the production of various print, multimedia or digital media products.
PATHWAY:	**VISUAL ARTS (AR-VIS)**
9.3.12.AR-VIS.2	Analyze how the application of visual arts elements and principles of design communicate and express ideas.
9.3.12.AR-VIS.3	Analyze and create two and three-dimensional visual art forms using various media.

MANUFACTURING CAREER CLUSTER®	
CAREER CLUSTER® :	**MANUFACTURING (MN)**
9.3.MN.2	Analyze and summarize how manufacturing businesses improve performance.
PATHWAY:	**HEALTH, SAFETY, & ENVIRONMENTAL ASSURANCE (MN-HSE)**
9.3.MN-HSE.1	Demonstrate the safe use of manufacturing equipment.
9.3.MN-HSE.3	Demonstrate a safety inspection process to assure a healthy and safe manufacturing environment.
9.3.MN-LOG.4	Manage inventory using logistics and control processes and procedures.
PATHWAY:	**MANUFACTURING PRODUCTION PROCESS DEVELOPMENT (MN-PPD)**
9.3.MN-PPD.3	Monitor, promote and maintain a safe and productive workplace using techniques and solutions that ensure safe production of products.
9.3.MN-PPD.5	Develop procedures to create products that meet customer needs.
PATHWAY:	**PRODUCTION (MN-PRO)**
9.3.MN-PRO.1	Diagnose production process problems and take corrective action to meet production quality standards.
9.3.MN-PRO.5	Demonstrate the safe use of manufacturing equipment.
MANUFACTURING CAREER CLUSTER®	
PATHWAY:	**QUALITY ASSURANCE (MN-QA)**
9.3.MN-QA.1	Evaluate production operations for product and process quality.
SCIENCE, TECHNOLOGY, ENGINEERING & MATHEMATICS CAREER CLUSTER®	
CAREER CLUSTER®:	**SCIENCE, TECHNOLOGY, ENGINEERING & MATHEMATICS (ST)**
9.3.ST.1	Apply engineering skills in a project that requires project management, process control and quality assurance.
9.3.ST.2	Use technology to acquire, manipulate, analyze and report data.
9.3.ST.3	Describe and follow safety, health and environmental standards related to science, technology, engineering and mathematics (STEM) workplaces.
9.3.ST.4	Understand the nature and scope of the Science, Technology, Engineering & Mathematics Career Cluster and the role of STEM in society and the economy.
9.3.ST.6	Demonstrate technical skills needed in a chosen STEM field.
PATHWAY:	**ENGINEERING & TECHNOLOGY CAREER PATHWAY (ST-ET)**
9.3.ST-ET.1	Use STEM concepts and processes to solve problems involving design and/or production.
9.3.ST-ET.2	Display and communicate STEM information.
9.3.ST-SM.2	Apply science and mathematics concepts to the development of plans, processes and projects that address real world problems.
9.3.ST-SM.3	Analyze the impact that science and mathematics has on society.
9.3.ST-SM.4	Apply critical thinking skills to review information, explain statistical analysis, and to translate, interpret and summarize research and statistical data.

Suggested Options for Differentiation	
• Restructure lesson using UDL principals (http://www.cast.org/our-work/about-udl.html#.VXmoXcfD_UA) • Provide students with multiple choices for how they can represent their understandings (e.g. multisensory techniques-auditory/visual aids; pictures, illustrations, graphs, charts, data tables, multimedia, modeling). • Provide opportunities for students to connect with people of similar backgrounds (e.g. conversations via digital tool such as SKYPE, experts from the community helping with a project, journal articles, and biographies). • Provide multiple grouping opportunities for students to share their ideas and to encourage work among various backgrounds and cultures (e.g. multiple representation and multimodal experiences). • Engage students with a variety of Science and Engineering practices to provide students with multiple entry points and multiple ways to demonstrate their understandings. • Use project-based science learning to connect science with observable phenomena. • Structure the learning around explaining or solving a social or community-based issue. • Provide ELL students with multiple literacy strategies.	
Collaborate with after-school programs or clubs [TSA] to extend learning opportunities. Follow all IEP modifications/504 plan * Teacher tutoring * Peer tutoring * Cooperative learning groups * Modified assignments * Differentiated instruction Presentation accommodations allow a student to: * Listen to audio recordings instead of reading text * Work with fewer items per page or line and/or materials in a larger print size * Hear instructions orally * Have another student share class notes with him * Be given an outline of a lesson * Use visual presentations of verbal material, such as word webs and visual organizers Response accommodations allow a student to: * Give responses in a form (oral or written) that's easier for him * Use a spelling dictionary or electronic spell-checker – available on the core page	Setting accommodations allow a student to: * Work or take a test in a different setting, such as a quiet room with few distractions * Sit where he learns best (for example, near the teacher) Timing accommodations allow a student to: * Take more time to complete a task or a test during lunch or afterschool * Have extra time to process oral information and directions * Take frequent breaks, such as after completing a task Scheduling accommodations allow a student to: * Take more time to complete a project * Take a test in several timed sessions or over several days with prior notification Organization skills accommodations allow a student to: * Use an alarm to help with time management * Mark texts with a highlighter

Unit 1: Design and Problem Solving	**Duration:** 44 days

Standards/Learning Targets

Focus Standards (Major Standards)

HS-ETS1-1. Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

HS-ETS1-3 Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

17.9-12.P Students will develop an understanding of and be able to select and use information and communication technologies.
P. There are many ways to communicate information, such as graphic and electronic means.

17.9-12.Q Students will develop an understanding of and be able to select and use information and communication technologies.
Q. Technological knowledge and processes are communicated using symbols, measurement, conventions, icons, graphic images, and languages that incorporate a variety of visual, auditory, and tactile stimuli.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Engaging in Argument from Evidence - Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence. Constructing Explanations and Designing Solutions **Obtaining, Evaluating, and Communicating Information** - Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. - Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem. - Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.	**ETS1.B: Developing Possible Solutions** - When evaluating solutions it is important to take into account a range of constraints including cost, safety, reliability and aesthetics and to consider social, cultural and environmental impacts. (secondary to HS-LS2-7) (secondary to HS-LS4-6) (secondary to HS-ESS3-2),(secondary HS-ESS3-4) (HS-ETS1-3) - Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. (HS-ETS1-4) (secondary to HS-LS4-6)	**Cause and Effect: Mechanism and Prediction** - Systems can be designed to cause a desired effect. - Changes in systems may have various causes that may not have equal effects. **Systems and System Models** - Systems can be designed to do specific tasks. **Scale, Proportion, and Quantity** - The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. - Patterns observable at one scale may not be observable or exist at other scales.

Supporting and Additional Standards

English Language Arts

AS.R.1 – Reading: Read closely to determine what the text says explicitly and to make logical inferences from it; cite specific textual evidence when writing or speaking to support conclusions drawn from the text.

AS.R.7 – Reading: Integrate and evaluate content presented in diverse formats and media, including visually and quantitatively, as well as in words.

AS.R.10 – Reading: Read and comprehend complex literary and informational texts independently and proficiently.

AS.W.2 – Writing: Write informative/explanatory texts to examine and convey complex ideas and information clearly and accurately through the effective selection, organization, and analysis of content.

AS.W.4 – Writing: Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

AS.W.5 – Writing: Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach.

AS.W.6 – Writing: Use technology, including the Internet, to produce and publish writing and to interact and collaborate with others.

AS.W.7 – Writing: Conduct short as well as more sustained research projects based on focused questions, demonstrating understanding of the subject under investigation.

AS.W.8 – Writing: Gather relevant information from multiple print and digital sources, assess the credibility and accuracy of each source, and integrate the information while avoiding plagiarism.

AS.W.9 – Writing: Draw evidence from literary or informational texts to support analysis, reflection, and research.

AS.W.10 – Writing: Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of tasks, purposes, and audiences.

AS.SL.1 - Speaking and Listening: Prepare for and participate effectively in a range of conversations and collaborations with diverse partners, building on others' ideas and expressing their own clearly and persuasively.

AS.SL.2 - Speaking and Listening: Integrate and evaluate information presented in diverse media and formats, including visually, quantitatively, and orally.

AS.SL.4 - Speaking and Listening: Present information, findings, and supporting evidence such that listeners can follow the line of reasoning and the organization, development, and style are appropriate to task, purpose, and audience.

AS.SL.5 - Speaking and Listening: Make strategic use of digital media and visual displays of data to express information and enhance understanding of presentations.

AS.SL.6 - Speaking and Listening: Adapt speech to a variety of contexts and communicative tasks, demonstrating command of formal English when indicated or appropriate.

AS.L.1 – Language: Demonstrate command of the conventions of standard English grammar and usage when writing or speaking.

AS.L.2 – Language: Demonstrate command of the conventions of standard English capitalization, punctuation, and spelling when writing.

AS.L.6 – Language: Acquire and use accurately a range of general academic and domain-specific words and phrases sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.

9-10.W.1 – Writing: Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.

9-10.W.1.a – Writing: Introduce precise claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that establishes clear relationships among claim(s), counterclaims, reasons, and evidence.

9-10.W.1.b – Writing: Develop claim(s) and counterclaims fairly, supplying evidence for each while pointing out the strengths and limitations of both in a manner that anticipates the audience's knowledge level and concerns.

9-10.W.1.c – Writing: Use words, phrases, and clauses to link the major sections of the text, create cohesion, and clarify the relationships between claim(s) and reasons, between reasons and evidence, and between claim(s) and counterclaims.

9-10.W.1.d – Writing: Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.

9-10.W.1.e – Writing: Provide a concluding statement or section that follows from and supports the argument presented.

9-10.W.2.a – Writing: Introduce a topic; organize complex ideas, concepts, and information to make important connections and distinctions; include formatting (e.g., headings), graphics (e.g., figures, tables), and multimedia when useful to aiding comprehension.

9-10.W.2.b – Writing: Develop the topic with well-chosen, relevant, and sufficient facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic.

9-10.W.2.d – Writing: Use precise language and domain-specific vocabulary to manage the complexity of the topic.

9-10.W.2.e – Writing: Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.

9-10.W.2.f – Writing: Provide a concluding statement or section that follows from and supports the information or explanation presented (e.g., articulating implications or the significance of the topic).

9-10.W.4 – Writing: Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. (Grade-specific expectations for writing types are defined in standards 1–3 above.)

9-10.W.5 – Writing: Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience.

9-10.W.7 – Writing: Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

9-10.W.8 – Writing: Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation.

9-10.W.9 – Writing: Draw evidence from literary or informational texts to support analysis, reflection, and research.

9-10.W.10 – Writing: Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of tasks, purposes, and audiences.

9-10.SL.1 - Speaking and Listening: Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 9–10 topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.

9-10.SL.4 - Speaking and Listening: Present information, findings, and supporting evidence clearly, concisely, and logically such that listeners can follow the line of reasoning and the organization, development, substance, and style are appropriate to purpose, audience, and task.

9-10.SL.5 - Speaking and Listening - Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest.

9-10.SL.6 - Speaking and Listening - Adapt speech to a variety of contexts and tasks, demonstrating command of formal English when indicated or appropriate.

9-10.L.1 - Language - Demonstrate command of the conventions of standard English grammar and usage when writing or speaking.

9-10.L.2 - Language - Demonstrate command of the conventions of standard English capitalization, punctuation, and spelling when writing.

9-10.L.2.c - Language - Spell correctly.

9-10.L.6 - Language - Acquire and use accurately general academic and domain-specific words and phrases, sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.

9-10.RST.4 - Reading Science/Technical - Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9–10 texts and topics.

9-10.RST.8 - Reading Science/Technical - Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem.

9-10.WHST.1 - Writing HS/S/T - Write arguments focused on discipline-specific content.

9-10.WHST.1.a - Writing HS/S/T - Introduce precise claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that establishes clear relationships among the claim(s), counterclaims, reasons, and evidence.

9-10.WHST.1.b - Writing HS/S/T - Develop claim(s) and counterclaims fairly, supplying data and evidence for each while pointing out the strengths and limitations of both claim(s) and counterclaims in a discipline-appropriate form and in a manner that anticipates the audience's knowledge level and concerns.

9-10.WHST.1.c - Writing HS/S/T- Use words, phrases, and clauses to link the major sections of the text, create cohesion, and clarify the relationships between claim(s) and reasons, between reasons and evidence, and between claim(s) and counterclaims.

9-10.WHST.1.d - Writing HS/S/T- Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.

9-10.WHST.1.e - Writing HS/S/T- Provide a concluding statement or section that follows from or supports the argument presented.

9-10.WHST.2 - Writing HS/S/- Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.

9-10.WHST.2.a - Writing HS/S/T - Introduce a topic and organize ideas, concepts, and information to make important connections and distinctions; include formatting (e.g., headings), graphics (e.g., figures, tables), and multimedia when useful to aiding comprehension.

9-10.WHST.2.b - Writing HS/S/T - Develop the topic with well-chosen, relevant, and sufficient facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic.

9-10.WHST.2.d - Writing HS/S/T - Use precise language and domain-specific vocabulary to manage the complexity of the topic and convey a style appropriate to the discipline and context as well as to the expertise of likely readers.

9-10.WHST.2.e - Writing HS/S/T - Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.

9-10.WHST.2.f - Writing HS/S/T - Provide a concluding statement or section that follows from and supports the information or explanation presented (e.g., articulating implications or the significance of the topic).

9-10.WHST.4 - Writing HS/S/T: Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

9-10.WHST.5 - Writing HS/S/T: Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience.

9-10.WHST.7 - Writing HS/S/T: Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

9-10.WHST.8 - Writing HS/S/T: Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation.

9-10.WHST.9 - Writing HS/S/T: Draw evidence from informational texts to support analysis, reflection, and research.

9-10.WHST.10 - Writing HS/S/T: Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

Mathematics

MP.2 Reason abstractly and quantitatively. (HS-ETS1-1),(HS-ETS1-3),(HS-ETS1-4)

MP.4 Model with mathematics. (HS-ETS1-1),(HS-ETS1-2),(HS-ETS1-3),(HS-ETS1-4)

G.MG.1 - Modeling with Geometry: Use geometric shapes, their measures, and their properties to describe objects (e.g., modeling a tree trunk or a human torso as a cylinder).

MP.4 Model with mathematics. (HS-ETS1-1),(HS-ETS1-2),(HS-ETS1-3),(HS-ETS1-4)

Instructional Plan	**Unit 1.1: Design Basics**
Suggested Activities	**Resources "Project Lead The Way "**
Activities, Projects, and Problems (A P B)	**Knowledge / Skills**
1.1.1 Design as a Process	KS 1.3.1, KS 1.4.2, KS 2.1.3, KS 2.1.4, KS 2.1.5, KS 2.1.6, KS 3.2.4, KS 7.3.1, KS 8.1.3, KS 13.1.2
1.1.2 Iterate and Redesign	KS 2.1.2, KS 2.1.3, KS 2.1.4, KS 2.1.5, KS 2.1.6, KS 3.2.2, KS 3.2.3, KS 3.2.4, KS 8.1.3, KS 12.2.1
1.1.3 Concept Sketching	KS 1.2.2, KS 6.2.1, KS 7.3.1, KS 7.3.2, KS 13.1.2
1.1.4 Targeting Success Using Data [P]	KS 1.4.2, KS 2.1.6, KS 3.1.2, KS 3.2.2, KS 3.2.3, KS 4.1.1, KS 4.1.2, KS 4.2.1, KS 4.2.2, KS 7.2.4, KS 8.1.1, KS 8.1.2, KS 8.1.3, KS 8.1.4, KS 10.1.1, KS 10.1.2, KS 10.1.3, KS 12.2.1, KS 12.4.1, KS 12.4.2, KS 13.1.2, KS 13.2.1
1.1.5 Design a Game Project [B]	KS 1.1.2, KS 1.2.2, KS 1.4.2, KS 2.1.2, KS 2.1.3, KS 2.1.4, KS 2.1.5, KS 2.1.6, KS 2.1.7, KS 3.1.2, KS 3.2.1, KS 3.2.3, KS 3.2.4, KS 5.1.2, KS 7.3.2, KS 8.1.1, KS 8.1.2, KS 8.1.3, KS 8.1.4, KS 10.1.2, KS 12.2.1, KS 12.4.1, KS 12.4.2

Evidence of Student Learning		
Activities (A) Projects (P) Problems (B)	**Assessment FOR Learning**	**Assessment OF Learning**
1.1.1 Design as a Process	-- Instant Challenge / box plots	-- application of box plots
1.1.2 Iterate and Redesign [P]	-- Instant Challenge / summary statistics	-- Summary Statistics #5 - 9
1.1.3 Concept Sketching	-- Realistic and proportional representations in sketches	-- Realistic and proportional representations in sketches
1.1.4 Targeting Success Using Data [P]	-- Creation of Excel spreadsheet	-- Completion of #7 – 9 and #10 - 19
1.1.5 Design a Game Project [B]	-- Creation of design brief -- Completion of deliverables -- creation and use of decision matrix	-- Creation of design sketches -- Creation of prototype -- Collection and interpretation of data

DOMAIN / OBJECTIVES: Students will understand that …	
D1 Engineering Mindset	O1.3 Persevere to solve a problem or achieve a goal. O1.4 Make judgments and decisions based on evidence.
D2 Design Process	O2.1 Apply an iterative design process to creatively address a need or solve a problem.
D3 Experimental Design	O3.2 Use appropriate statistical methods and visualization techniques to justify claims based on evidence.
D7 Collaboration	O7.1 Facilitate an effective team environment to promote successful goal attainment
D8 Communication	O8.1 Communicate effectively with an audience based on audience characteristics

D13 Modeling	O13.1 Develop models and simulations to represent information, processes, and/or objects to an appropriate level of abstraction for the intended purpose.

KNOWLEDGE and SKILLS: Students will …

KS 1.3.1 Demonstrate risk taking in engineering, scientific, or computational processes.
KS 1.4.2 Collect, analyze, and interpret information relevant to the problem or opportunity at hand to support engineering decisions.
KS 2.1.3 Apply effective techniques and appropriate guidelines to generate multiple creative ideas and potential solutions to a problem.
KS 2.1.4 Carry out a plan to compare competing solution ideas and justify the selection of a solution path with respect to design requirements and constraints.
KS 2.1.5 Develop a potential solution and implement a plan to test and evaluate the solution with respect to design criteria and constraints.
KS 2.1.6 Identify design flaws of and potential enhancements to a proposed design solution.
KS 3.2.1 Graphically represent experimental data for a single count or measurement with charts and/or plots on the real number line, such as dot plots, box plots and histograms.
KS 3.2.4 Draw conclusions related to the hypothesis and support conclusions using experimental data.
KS 7.1.3 Develop ideas and create products through positive interdependence among all teammates.
KS 8.1.3 Initiate and participate in a range of open and effective interactions (one-on-one, in groups, and teacher-led) with diverse participants and across cultures, building on others' ideas and expressing one's own clearly and persuasively.
KS 13.1.2 Develop a model to accurately represent information or important characteristics of an object, data, process, or design idea for an intended purpose. [Notes on scope: the intended purpose may vary and could include organizing information to show relationships; providing a visual representation of the object/design to demonstrate how the object might "look"; a functional model to demonstrate the operation; a prototype of a specific component to test fit, performance, durability, or compatibility with other components in a system; and so on. The model could be a conceptual model, a mathematical model, a computer/virtual model, or a physical model, as appropriate for the testing scenario.]

Core Instructional and Supplemental Materials

Project Lead the Way (PLTW) Curriculum
http://pltw.org

Engineering Design – An Introduction 2nd Edition
Karsnitz, O'Brien, Hutchinson, 2013 Delmar, Cengage Learning
ISBN-13: 978-1-111-64582-3 and ISBN-10: 1-111-64583-5

NEPRIS - Connecting Industry to Every Classroom
http://nepris.com.

Autodesk Inventor
http://autodesk.com

Fusion 360
http://autodesk.com

Lynda.com (Online Tutorials)
http://lynda.com

Teacher Notes:

- Don't waste time here, it will happen. Follow the time limits as closely as possible – you will get better results.

Instructional Plan	Unit 1.2: Visualization and Design Modeling
Suggested Activities	**Resources "Project Lead The Way "**
Activities, Projects, and Problems (A P B)	**Knowledge / Skills**
1.2.1 Isometric Sketching	KS 1.2.2, KS 7.3.2, KS 13.1.2, KS 13.3.3
1.2.2 3D Modeling Software	KS 13.5.1, KS 13.5.2
1.2.3 Multiview Drawings	KS 1.2.2, KS 7.3.2, KS13.3.2, KS13.3.3, KS13.3.4, KS13.3.6, KS13.6.1
1.2.4 Fundamentals of Dimensioning [P]	KS 7.3.2, KS 13.3.4, KS 13.6.1, KS 13.6.2
1.2.5 Sketches, Extrusions, and Revolutions [B]	KS 13.1.1, KS 13.1.2, KS 13.3.1, KS 13.5.2
1.2.6 Charmed Project [P]	KS 2.1.3, KS 2.1.5, KS 8.1.3, KS 12.5.1, KS 13.1.1, KS 13.1.2, KS13.3.2, KS13 .5.1, KS13.6.1

Evidence of Student Learning		
Activities (A) Projects (P) Problems (B)	**Assessment FOR Learning**	**Assessment OF Learning**
1.2.1 Isometric Sketching	-- Creation of isometric, oblique, and perspective sketches	-- Creation of isometric, oblique, and perspective sketches
1.2.2 3D Modeling Software	-- Autodesk Inventor Professional -- Autodesk Fusion 360	-- Creation and storage of models using additive and subtractive approaches
1.2.3 Multiview Drawings	-- Glass box HO -- Multiview sketch cards	-- Creation of sketches
1.2.4 Fundamentals of Dimensioning [P]	-- 1.2.4 Dimensioning cards	-- Creation of sketches
1.2.5 Sketches, Extrusions, and Revolutions [B]	-- # 3 - 5, #6, #7- 8 and #9	-- In new folder create socket, extrusion -- Create cylinder using revolve
1.2.6 Charmed Project [P]	-- Creation of design brief -- Completion of deliverables -- Creation and use of decision matrix	-- Creation of design sketches -- Creation of prototype -- Collection and interpretation of data

DOMAIN / OBJECTIVES: Students will understand that …	
D1 Engineering Mindset	O1.2 Demonstrate curiosity, creativity, flexibility, and adaptability to change.
D2 Design Process	O2.1 Apply an iterative design process to creatively address a need or solve a problem
D7 Collaboration	O7.3 Analyze and evaluate the work of others to provide helpful feedback.
D8 Communication	O8.1 Communicate effectively with an audience based on audience characteristics.

D12 Computational Thinking	O12.5 Apply abstraction to generalize problems and solutions.
D13 Modeling	O13.1 Develop models and simulations to represent information, processes, and/or objects to an appropriate level of abstraction for the intended purpose. O13.3 Use engineering graphics to represent physical objects O13.5 Create and interpret a computer model or simulation of simple objects, assemblies, or systems to inform engineering decisions and solve problems. O13.6 Create technical drawings using 3D computer-aided design (CAD) software to document a design according to standard engineering practices.

KNOWLEDGE and SKILLS: Students will …

KS 1.2.2 Seek out and use feedback to improve work and positively influence one's personal and professional development.
KS 2.1.3 Apply effective techniques and appropriate guidelines to generate multiple creative ideas and potential solutions to a problem.
KS 2.1.5 Develop a potential solution and implement a plan to test and evaluate the solution with respect to design criteria and constraints.
KS 7.3.2 Provide effective feedback to peers
KS 8.1.3 Initiate and participate in a range of open and effective interactions (one-on-one, in groups, and teacher-led) with diverse participants and across cultures, building on others' ideas and expressing one's own clearly and persuasively.
KS 12.5.1 Identify what has been made more general by an abstraction and what details have been hidden or removed.
KS 13.1.1 Recognize that models use abstraction to represent a simplified version of a complex phenomenon and there is no guarantee that the Recognize that models use abstraction to represent a simplified version of a complex phenomenon and there is no guarantee that the model accurately represents the real object or phenomenon. List differences (potential or real) between model behavior and the behavior of the real object, system, or process that it represents, and identify limitations of the model. (Limitations may include specific characteristics being studied, accuracy, precision, range of conditions, and so on.)
KS 13.1.2 Develop a model to accurately represent information or important characteristics of an object, data, process, or design idea for an intended purpose. [Notes on scope: the intended purpose may vary and could include organizing information to show relationships; providing a visual representation of the object/design to demonstrate how the object might "look"; a functional model to demonstrate the operation; a prototype of a specific component to test fit, performance, durability, or compatibility with other components in a system; and so on. The model could be a conceptual model, a mathematical model, a computer/virtual model, or a physical model, as appropriate for the testing scenario.]
KS 13.3.1 Identify three-dimensional objects generated by rotation of a two-dimensional object.
KS 13.3.2 Build a physical representation of an object or system based on graphical representations of the object or system. (Includes building solid objects, electrical circuits, mechanical devices, and complex systems according to technical drawings.)
KS 13.3.3 Hand sketch isometric views of a simple object or part at a given scale using the actual object, a detailed verbal description of the object, pictorial view of the object, or set of orthographic projections.
KS 13.3.4 Identify errors and omissions in orthographic projections and multiview drawings (including errors in line locations, line types, Identify errors and omissions in orthographic projections and multiview drawings (including errors in line locations, line types, number of views, scale, dimensioning, and view orientation) to fully detail an object or part using the actual object, a detailed verbal description of the object, or a pictorial and isometric view of the object.
KS 13.3.6 Identify necessary/appropriate views to fully detail a part or assembly
KS 13.5.1 Create a computer model to represent an object or conceptual idea and inform design decisions.
KS 13.5.2 Correctly build and constrain a three-dimensional solid computer model to accurately represent the physical characteristics and behaviors of a design idea or real object. Scope: This could include the appropriate application of geometric (horizontal, vertical, parallel, perpendicular, tangent, concentric) and dimensional constraints, as well as modeling other physical properties (density, color, texture, and so on).
KS 13.6.1 Generate an annotated multiview technical drawing using CAD software to fully describe a simple part.
KS 13.6.2 Apply appropriate and sufficient annotation (including dimensioning) methods to a drawing to fully describe an object or system using accepted technical drawing techniques.

Core Instructional and Supplemental Materials	
Project Lead the Way (PLTW) Curriculum http://pltw.org **Engineering Design – An Introduction** 2nd Edition Karsnitz, O'Brien, Hutchinson, 2013 Delmar, Cengage Learning ISBN-13: 978-1-111-64582-3 and ISBN-10: 1-111-64583-5 **NEPRIS -** Connecting Industry to Every Classroom http://nepris.com.	**Autodesk Inventor** http://autodesk.com **Fusion 360** http://autodesk.com **Lynda.com** (Online Tutorials) http://lynda.com
Teacher Notes: • Provide as much time to sketching as possible, it will help the student to understand the 3D CAD universe more clearly.	

Instructional Plan	**Unit 1.3: CAD Fundamentals**
Suggested Activities	***Resources "Project Lead The Way "***
Activities, Projects, and Problems (A P B)	***Knowledge / Skills***
1.3.1..Measure it	KS 3.1.1, KS 3.2.2, KS 3.2.3, KS 8.1.3, KS 10.1.1, KS 10.1.2, KS 10.1.3, KS 10.1.4,
1.3.2 Making Holes in CAD	KS 10.1.4, KS 13.1.2, KS 13.3.7, KS 13.5.2
1.3.3..Constraining a sketch	KS 13.1.2, KS13.3.6, KS 13.5.1, KS 13.5.2, KS 13.6.1, KS 13.6.2
1.3.4..CAD Modeling skills	KS 1.2.2, KS 7.3.2, KS13.3.6, KS 13.6.1, KS 13.6.2
1.3.5 Documenting a Design	KS 13.1.2, KS13.3.5, KS13.3.6, KS 13.6.1, KS 13.6.2
1.3.6..I Section That	KS 1.1.2, KS 1.2.2, KS 1.2.3, KS 1.3.2, KS 2.1.2, KS 2.1.3, KS 2.1.4, KS 2.1.5, KS 2.1.6, KS 8.1.2, KS 8.1.4, KS 9.2.2, KS, KS 13.1.1, KS 13.1.2, KS13.3.3, KS 13.5.1, KS 13.5.2, KS 13.6.1, KS 13.6.2

Evidence of Student Learning		
Activities (A) Projects (P) Problems (B)	**Assessment FOR Learning**	**Assessment OF Learning**
1.3.1..Measure it	-- activity #1 - 8 -- activity #9 – 19 -- Activity 20 (substitute Automoblox cars)	-- Explain that all measurements are an approximation of the true value of a quantity. -- Use measurement devices based on the level of precision and accuracy needed. -- Apply inferential reasoning to make and/or support claims about the data.
1.3.2 Making Holes in CAD	-- create a drill block -- activity #1 - 4 -- activity #5 + 6	-- Read and interpret a hole note to identify the size and type of hole specified. -- Create and constrain a 3D model to represent the physical characteristics of a physical object.
1.3.3..Constraining a sketch	-- activity #1 - 3 -- activity #4 - 8 -- activity #17 - 25	-- Apply constraints when building the geometry of a 3D solid CAD model. -- Create and constrain a 3D model to represent the physical characteristics of a design idea or physical object.
1.3.4..CAD Modeling skills	-- activity #1 - 8 -- activity #9 - 13 -- activity #14 - 21	-- Correctly build and constrain a three-dimensional solid computer model to accurately represent the physical characteristics and behaviors of a design idea or real object. -- Apply extrude, taper, loft, and shell features
1.3.5 Documenting a Design	-- activity #1 - 8	-- Use CAD software to generate a multiview drawing from a 3D solid model.
1.3.6..I Section That	-- Creation of design brief -- Completion of deliverables -- Creation and use of decision matrix	-- Creation of design sketches -- Creation of prototype -- Collection and interpretation of data

DOMAIN / OBJECTIVES: Students will understand that …	
D1 Engineering Mindset	O1.1 Demonstrate independent thinking and self-direction in pursuit of accomplishing a goal. O1.2 Demonstrate curiosity, creativity, flexibility, and adaptability to change. O1.3 Persevere to solve a problem or achieve a goal
D2 Design Process	O2.1 Apply an iterative design process to creatively address a need or solve a problem.
D3 Experimental Design	O3.1 Design and perform an experimental protocol to investigate a phenomenon and/or gain knowledge. O3.2 Use appropriate statistical methods and visualization techniques to justify claims based on evidence
D7 Collaboration	O7.3 Analyze and evaluate the work of others to provide helpful feedback.
D8 Communication	O8.1 Communicate effectively with an audience based on audience characteristics.

D9 Engineering Design	O9.2 Optimize performance of a mechanical part or assemble
D10 Engineering Science	O10.1 Using a variety of measuring devices, measure and report quantities accurately and to a precision appropriate for the purpose.
D13 Modeling	O13.1 Develop models and simulations to represent information, processes, and/or objects to an appropriate level of abstraction for the intended purpose. O13.3 Use engineering graphics to represent physical objects O13.5 Create and interpret a computer model or simulation of simple objects, assemblies, or systems to inform engineering decisions and solve problems. O13.6 Create technical drawings using 3D computer-aided design (CAD) software to document a design according to standard engineering practices.

KNOWLEDGE and SKILLS: Students will …

KS 1.1.2 Plan and use time effectively in pursuit of accomplishing a goal without direct oversight.
KS 1.2.2 Seek out and use feedback to improve work and positively influence one's personal and professional development.
KS 1.2.3 Reflect critically on past experiences to inform future progress.
KS 1.3.2 Demonstrate persistence in accomplishing a difficult challenge
KS 2.1.2 Define measurable visual, functional, and structural design requirements (criteria) and realistic constraints against which solution alternatives can be evaluated and optimized. [Note that criteria and constraints should include considerations of cost, safety, reliability, manufacturability, and aesthetics, as well as possible social, cultural, and environmental impacts.]
KS 2.1.3 Apply effective techniques and appropriate guidelines to generate multiple creative ideas and potential solutions to a problem.
KS 2.1.4 Carry out a plan to compare competing solution ideas and justify the selection of a solution path with respect to design requirements and constraints.
KS 2.1.5 Develop a potential solution and implement a plan to test and evaluate the solution with respect to design criteria and constraints.
KS 2.1.6 Identify design flaws of and potential enhancements to a proposed design solution.
KS 3.1.1 Develop a testable hypothesis, experimental controls and important variables (independent and dependent) address a problem or answer a question.
KS 3.2.2 Use statistics appropriate to the shape of the data distribution to compare center (median, mean) and spread (interquartile range) of two or more different data sets. Interpret differences in shape, center, and spread in the context of the data sets.
KS 7.3.2 Provide effective feedback to peers
KS 8.1.2 Use sketches, tables, charts, and graphs when appropriate to clearly communicate information and in making arguments and claims in oral, written, and visual presentations.
KS 8.1.3 Initiate and participate in a range of open and effective interactions (one-on-one, in groups, and teacher-led) with diverse participants and across cultures, building on others' ideas and expressing one's own clearly and persuasively.
KS 8.1.4 Present information, findings, and supporting evidence clearly, concisely, and logically in writing in which the development, organization, and style are appropriate to task, purpose, and audience.
KS 9.2.2 Define basic fabrication processes and analyze if a product can be built as designed.
KS 10.1.1 Explain that all measurements are an approximation of the true value of a quantity.
KS 10.1.2 Describe the accuracy and precision of a measurement or measuring device and differentiate between the two.
KS 10.1.3 Use dimensional analysis and unit conversions to transform data to consistent units or to units appropriate for a particular purpose or model.
KS 10.1.4 Choose a measurement device based on the level of precision and accuracy needed.
KS 13.1.1 Recognize that models use abstraction to represent a simplified version of a complex phenomenon and there is no guarantee that the Recognize that models use abstraction to represent a simplified version of a complex phenomenon and there is no guarantee that the model accurately represents the real object or phenomenon. List differences (potential or real) between model behavior and the behavior of the real object, system, or process that it represents, and identify limitations of the model. (Limitations may include specific characteristics being studied, accuracy, precision, range of conditions, and so on.)
KS 13.1.2 Develop a model to accurately represent information or important characteristics of an object, data, process, or design idea for an intended purpose. [Notes on scope: the intended purpose may vary and could include organizing information to show relationships; providing a visual representation of the object/design to demonstrate how the object might "look"; a functional model to demonstrate the operation; a prototype of a specific component to test fit, performance, durability, or compatibility with other components in a system; and so on. The model could be a conceptual model, a mathematical model, a computer/virtual model, or a physical model, as appropriate for the testing scenario.]
KS 13.3.3 Hand sketch isometric views of a simple object or part at a given scale using the actual object, a detailed verbal description of the object, pictorial view of the object, or

set of orthographic projections.

KS 13.3.5 Identify errors and omissions in a full- or half-section view (including errors in line locations, line types, location of cutting plane line, scale, dimensioning, and view orientation) to fully detail an object or part.

KS 13.3.6 Identify necessary/appropriate views to fully detail a part or assembly

KS 13.3.7 Read and interpret a hole note to identify the size and type of hole specified

KS 13.5.1 Create a computer model to represent an object or conceptual idea and inform design decisions.

KS 13.5.2 Correctly build and constrain a three-dimensional solid computer model to accurately represent the physical characteristics and behaviors of a design idea or real object. Scope: This could include the appropriate application of geometric (horizontal, vertical, parallel, perpendicular, tangent, concentric) and dimensional constraints, as well as modeling other physical properties (density, color, texture, and so on).

KS 13.6.1 Generate an annotated multiview technical drawing using CAD software to fully describe a simple part.

KS 13.6.2 Apply appropriate and sufficient annotation (including dimensioning) methods to a drawing to fully describe an object or system using accepted technical drawing techniques.

Core Instructional and Supplemental Materials

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NEPRIS - Connecting Industry to Every Classroom
http://nepris.com.

Autodesk Inventor
http://autodesk.com

Fusion 360
http://autodesk.com

Lynda.com (Online Tutorials)
http://lynda.com

Teacher Notes:

- Coordinate with TSA advisor to get these students as much CAD time as possible
- Offer lunch and afterschool options for practice.

Unit 2: Assembly Design	**Duration:** 41 days

Standards/Learning Targets

Focus Standards (Major Standards) STL

Standards for Technological Literacy

2.9-12.Z Students will develop an understanding of the core concepts of technology.
Z. Selecting resources involves trade-offs between competing values, such as availability, cost, desirability, and waste.

2.9-12.AA Students will develop an understanding of the core concepts of technology.
AA. Requirements involve the identification of the criteria and constraints of a product or system and the determination of how they affect the final design and development.

2.9-12.BB Students will develop an understanding of the core concepts of technology.
BB. Optimization is an ongoing process or methodology of designing or making a product and is dependent on criteria and constraints.

2.9-12.DD Students will develop an understanding of the core concepts of technology.
DD. Quality control is a planned process to ensure that a product, service, or system meets established criteria.

8.9-12.H Students will develop an understanding of the attributes of design.
H. The design process includes defining a problem, brainstorming, researching and generating ideas, identifying criteria and specifying constraints, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype.

8.9-12.I Students will develop an understanding of the attributes of design.
I. Design problems are seldom presented in a clearly defined form.

8.9-12.J Students will develop an understanding of the attributes of design.
J. The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.

8.9-12.K Students will develop an understanding of the attributes of design.
K. Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other.

9.9-12.I Students will develop an understanding of engineering design.
I. Established design principles are used to evaluate existing designs, to collect data, and to guide the design process.

9.9-12.J Students will develop an understanding of engineering design.
J. Engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.

9.9-12.K Students will develop an understanding of engineering design.
K. A prototype is a working model used to test a design concept by making actual observations and necessary adjustments.

9.9-12.L Students will develop an understanding of engineering design.
L. The process of engineering design takes into account a number of factors.

11.9-12.N Students will develop the abilities to apply the design process.
N. Identify criteria and constraints and determine how these will affect the design process.

11.9-12.O Students will develop the abilities to apply the design process.
O. Refine a design by using prototypes and modeling to ensure quality, efficiency, and productivity of the final product.

11.9-12.P Students will develop the abilities to apply the design process.
P. Evaluate the design solution using conceptual, physical, and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed.

11.9-12.Q Students will develop the abilities to apply the design process.
Q. Develop and produce a product or system using a design process.

11.9-12.R Students will develop the abilities to apply the design process.
R. Evaluate final solutions and communicate observation, processes, and results of the entire design process, using verbal, graphic, quantitative, virtual, and written means, in addition to three-dimensional models.

12.9-12.L Students will develop the abilities to use and maintain technological products and systems.

L. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

12.9-12.P Students will develop the abilities to use and maintain technological products and systems.
P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

17.9-12.P Students will develop an understanding of and be able to select and use information and communication technologies.
P. There are many ways to communicate information, such as graphic and electronic means.

17.9-12.Q Students will develop an understanding of and be able to select and use information and communication technologies.
Q. Technological knowledge and processes are communicated using symbols, measurement, conventions, icons, graphic images, and languages that incorporate a variety of visual, auditory, and tactile stimuli.

HS-PS2-1. Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration. [Clarification Statement: Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object rolling down a ramp, or a moving object being pulled by a constant force.]

HS-PS2-3. Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.* [Clarification Statement: Examples of evaluation and refinement could include determining the success of the device at protecting an object from damage and modifying the design to improve it. Examples of a device could include a football helmet or a parachute.]

HS-ETS1-2. Engineering Design Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

HS-ETS1-3. Engineering Design Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

HS.ETS1.4 - Engineering Design Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

The Student Learning Objectives above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Asking Questions and Defining Problems - Evaluate a question to determine if it is testable and relevant. - Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory. **Developing and Using Models** - Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. - Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations. **Planning and Carrying Out Investigations** - Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models,	**ETS1.A: Defining and Delimiting Engineering Problems** • Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. • Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. • Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (secondary to HS-PS2-3) **ETS1.B: Developing Possible Solutions** • When evaluating solutions, it is important to take into	**Systems and System Models** • Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. **Structure and Function** • Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. • The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials. **Patterns** • Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena • Patterns of performance of designed systems can be analyzed and interpreted to reengineer and improve the

supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled.

- Select appropriate tools to collect, record, analyze, and evaluate data. Make directional hypotheses that specify what happens to a dependent variable when an independent variable is manipulated.

Analyzing and Interpreting Data

- Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.
- Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible.
- Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations.

Using Mathematics and Computational Thinking

- Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system.
- Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m3, acre-feet, etc.)

Constructing Explanations and Designing Solutions

- Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects.
- Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.

Engaging in Argument from Evidence

- Compare and evaluate competing arguments or design solutions in light of currently accepted explanations, new evidence, limitations (e.g., trade-offs), constraints, and ethical issues.
- Respectfully provide and/or receive critiques on scientific arguments by probing reasoning and evidence, challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining additional information required to resolve

account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.

ETS1.C: Optimizing the Design Solution

- Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (tradeoffs) may be needed.

system.

- Mathematical representations are needed to identify some patterns.

Scale, Proportion, and Quantity

- Patterns observable at one scale may not be observable or exist at other scales.

Stability and Change

- Feedback (negative or positive) can stabilize or destabilize a system.
- Systems can be designed for greater or lesser stability.

contradictions. - Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence. - Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and/or logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations).		

Supporting and Additional Standards

English Language Arts

AS.W.2 –Writing - Write informative/explanatory texts to examine and convey complex ideas and information clearly and accurately through the effective selection, organization, and analysis of content.

AS.W.4 –Writing - Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

AS.W.6 – Writing Use technology, including the Internet, to produce and publish writing and to interact and collaborate with others.

AS.W.10 –Writing - Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of tasks, purposes, and audiences.

AS.SL.1 - Speaking and Listening - Prepare for and participate effectively in a range of conversations and collaborations with diverse partners, building on others' ideas and expressing their own clearly and persuasively.

AS.L.6 – Language - Acquire and use accurately a range of general academic and domain-specific words and phrases sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.

AS.L.1 – Language Demonstrate command of the conventions of standard English grammar and usage when writing or speaking.

AS.L.2 – Language Demonstrate command of the conventions of standard English capitalization, punctuation, and spelling when writing.

AS.SL.4 - Speaking and Listening Present information, findings, and supporting evidence such that listeners can follow the line of reasoning and the organization, development, and style are appropriate to task, purpose, and audience.

AS.SL.5 - Speaking and Listening Make strategic use of digital media and visual displays of data to express information and enhance understanding of presentations.

9-10.SL.1 - Speaking and Listening Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 9–10 topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.

9-10.W.10 –Writing - Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of tasks, purposes, and audiences.

9-10.L.6 – Language Acquire and use accurately general academic and domain-specific words and phrases, sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.

WHST.11-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation

RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-ETS1-1),(HS-ETS1-3)

RST.11-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. (HS-ETS1-1),(HS-ETS1-3)

9-10.RST.3 - Reading Science/Technical Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.

9-10.RST.4 - Reading Science/Technical Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9–10 texts and topics.

9-10.WHST.2 - Writing HS/S/T Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.

9-10.WHST.2.a - Writing HS/S/T Introduce a topic and organize ideas, concepts, and information to make important connections and distinctions; include formatting (e.g., headings), graphics (e.g., figures, tables), and multimedia when useful to aiding comprehension.

9-10.WHST.2.b - Writing HS/S/T Develop the topic with well-chosen, relevant, and sufficient facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic.

9-10.WHST.2.d - Writing HS/S/T Use precise language and domain-specific vocabulary to manage the complexity of the topic and convey a style appropriate to the discipline and context as well as to the expertise of likely readers.

9-10.WHST.2.e - Writing HS/S/T Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.

9-10.WHST.4 - Writing HS/S/T Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

9-10.WHST.10 - Writing HS/S/T Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

Mathematics

N.Q.1 - Quantities - Use units as a way to understand problems and to guide the solution of multistep problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.

N.Q.2 - Quantities - Define appropriate quantities for the purpose of descriptive modeling.

N.Q.3 - Quantities - Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

N.VM.1 - Vector and Matrix Quantities (+) Recognize vector quantities as having both magnitude and direction. Represent vector quantities by directed line segments, and use appropriate symbols for vectors and their magnitudes (e.g., v, |v|, ||v||, v).

N.VM.3 - Vector and Matrix Quantities (+) Solve problems involving velocity and other quantities that can be represented by vectors.

A.CED.1 - Creating Equations Create equations and inequalities in one variable and use them to solve problems. Include equations arising from linear and quadratic functions, and simple rational and exponential functions.

A.CED.2 - Creating Equations Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.

A.CED.3 - Creating Equations - Represent constraints by equations or inequalities, and by systems of equations and/or inequalities, and interpret solutions as viable or non-viable options in a modeling context. For example, represent inequalities describing nutritional and cost constraints on combinations of different foods.

A.CED.4 - Creating Equations Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. For example, rearrange Ohm's law V = IR to highlight resistance R.

F.IF.7.a - Interpreting Functions - Graph linear and quadratic functions and show intercepts, maxima, and minima.

S.ID.1 - Interpreting Categorical and Quantitative Data - Represent data with plots on the real number line (dot plots, histograms, and box plots).

S.ID.4 - Interpreting Categorical and Quantitative Data - Use the mean and standard deviation of a data set to fit it to a normal distribution and to estimate population percentages. Recognize that there are data sets for which such a procedure is not appropriate. Use calculators, spreadsheets, and tables to estimate areas under the normal curve.

A.REI.3 - Reasoning with Equations and Inequalities Solve linear equations and inequalities in one variable, including equations with coefficients represented by letters.

A.REI.4.b - Reasoning with Equations and Inequalities Solve quadratic equations by inspection (e.g., for x2 = 49), taking square roots, completing the square, the quadratic formula and factoring, as appropriate to the initial form of the equation. Recognize when the quadratic formula gives complex solutions and write them as a ± bi for real numbers a and b.

F.IF.7.a - Interpreting Functions Graph linear and quadratic functions and show intercepts, maxima, and minima.

G.GMD.3 - Geometric Measurement and Dimension Use volume formulas for cylinders, pyramids, cones, and spheres to solve problems.

G.GMD.4 - Geometric Measurement and Dimension Identify the shapes of two-dimensional cross-sections of three- dimensional objects, and identify three-dimensional objects

generated by rotations of two-dimensional objects.

G.MG.1 - Modeling with Geometry Use geometric shapes, their measures, and their properties to describe objects (e.g., modeling a tree trunk or a human torso as a cylinder).

G.MG.2 - Modeling with Geometry Apply concepts of density based on area and volume in modeling situations (e.g., persons per square mile, BTUs per cubic foot).

G.MG.3 - Modeling with Geometry Apply geometric methods to solve design problems (e.g., designing an object or structure to satisfy physical constraints or minimize cost; working with typographic grid systems based on ratios).

Instructional Plan:	**Unit 2.1: Put it Together**
Suggested Activities	**Resources "Project Lead The Way "**
Activities, Projects, and Problems (A P B)	**Knowledge / Skills**
2.1.1 Tolerate This	KS 4.1.1, KS 4.1.2, KS 4.2.1, KS4.2.2, KS 10.1.2, KS 10.1.4, KS 10.2.1, KS 13.4.1, KS 13.4.2, KS 13.4.3, KS 13.4.4, KS 13.5.1, KS 13.5.2, KS 13.6.2
2.1.2 Hold It Together!	KS 8.1.2, KS 8.1.4, KS 8.1.5, KS 9.1.5
2.1.3 Putting It Together	KS 9.1.6, KS 13.5.1, KS 13.5.4
2.1.4 Document the Assembly [P]	KS 13.3.6, KS 13.4.4, KS 13.5.2, KS 13.5.4, KS 13.6.1, KS 13.6.2, KS 13.6.3
2.1.5 Redesign a Protective Case [B]	KS 2.1.1, KS 2.1.2, KS 2.1.3, KS 2.1.4, KS 8.1.3, KS 8.1.4, KS 9.1.5, KS 13.1.2, KS 13.3.6, KS 13.4.4, KS 13.5.1, KS 13.5.2, KS 13.5.4, KS 13.6.1, KS 13.6.2, KS 13.6.3

Evidence of Student Learning		
Activities (A) Projects (P) Problems (B)	**Assessment FOR Learning**	**Assessment OF Learning**
2.1.1 Tolerate This	-- product variation #1 – 6 -- Investigate #7 - 10	-- application tolerances -- proper use of allowances
2.1.2 Hold It Together!	-- each team collecting and presenting data, representing how materials are held together	-- Presentation of the team's research -- ability to communicate ideas
2.1.3 Putting It Together	-- Build an assembly of parts	-- blocks # 1 – 4 -- selfie stick # 5 - 7
2.1.4 Document the Assembly [P]	-- Create a multiview drawing of the assembly #1 – 4 -- Create a parts list of the assembly #5 - 6	-- Produce a complete annotated assembly drawing #7+8
2.1.5 Redesign a Protective Case [B]	-- Creation of design brief -- Completion of deliverables -- creation and use of decision matrix	-- Creation of design sketches -- Creation of prototype -- Collection and interpretation of data

DOMAIN / OBJECTIVES: Students will understand that …	
D2 Design Process	O2.1 Apply an iterative design process to creatively address a need or solve a problem.
D4 Career Awareness	O4.1 Demonstrate awareness of the education and skills required for professional practice in an engineering field. O4.2 Analyze the role of engineering professionals in society.
D8 Communication	O8.1 Communicate effectively with an audience based on audience characteristics.
D9 Engineering Design	O9.1 Analyze a consumer product using reverse engineering techniques to document visual, functional, and structural aspects of the design.
D10 Engineering Science	O10.1 Using a variety of measuring devices, measure and report quantities accurately and to a precision appropriate for the purpose. O10.2 Apply scientific knowledge related to frictional forces, to solve a problem or design a physical system.
D13 Modeling	O13.1 Develop models and simulations to represent information, processes, and/or objects to an appropriate level of abstraction for the intended purpose. O13.3 Use engineering graphics to represent physical objects. O13.4 Apply appropriate engineering tolerances to specify the allowable variation, size of individual features, and orientation and location between features of an object. O13.5 Create and interpret a computer model or simulation of simple objects, assemblies, or systems to inform engineering decisions and solve problems. O13.6 Create technical drawings using 3D computer-aided design (CAD) software to document a design according to standard engineering practices.

KNOWLEDGE and SKILLS: Students will …

KS 2.1.1 Synthesize an ill-formed problem into a meaningful, well-defined problem using relevant information.

KS 2.1.2 Define measurable visual, functional, and structural design requirements (criteria) and realistic constraints against which solution alternatives can be evaluated and optimized. [Note that criteria and constraints should include considerations of cost, safety, reliability, manufacturability, and aesthetics, as well as possible social, cultural, and environmental impacts.]

KS 2.1.3 Apply effective techniques and appropriate guidelines to generate multiple creative ideas and potential solutions to a problem.

KS 2.1.4 Carry out a plan to compare competing solution ideas and justify the selection of a solution path with respect to design requirements and constraints.

KS 4.1.1 Define engineering as the creation of solutions, such as new and improved products, technologies, systems and processes), to meet the needs of people and society.

KS 4.1.2 Identify technical and nontechnical skills common to all engineering disciplines that are gained from specialized and intense education, training, and experience, including problem solving, the design process, data processing and interpretation, handling uncertainty, systems thinking, and modeling.

KS 4.2.1 Describe the discipline of mechanical engineering and a variety of sub-disciplines and technical roles related to mechanical engineering

KS 4.2.2 Identify and describe contemporary engineering issues of local, global and cultural significance.

KS 8.1.2 Use sketches, tables, charts, and graphs when appropriate to clearly communicate information and in making arguments and claims in oral, written, and visual presentations.

KS 8.1.3 Initiate and participate in a range of open and effective interactions (one-on-one, in groups, and teacher-led) with diverse participants and across cultures, building on others' ideas and expressing one's own clearly and persuasively.

KS 8.1.4 Present information, findings, and supporting evidence clearly, concisely, and logically in writing in which the development, organization, and style are appropriate to task, purpose, and audience.

KS 8.1.5 Present information, findings, and supporting evidence clearly, concisely, and logically, such that listeners can follow the line of reasoning and the organization, development, substance, and style are appropriate to purpose, audience, and task.

KS 9.1.5 Describe methods to rigidly join parts of an assembly (including press fits, special joints, adhesives, mechanical fasteners)

KS 9.1.6 Identify joints that allow movement between interfacing parts in an assembly and the degrees of freedom that it removes from the movement between parts (including slots, hinges, ball and socket, rotating knobs).

KS 10.1.2 Describe the accuracy and precision of a measurement or measuring device and differentiate between the two.

KS 10.1.4 Choose a measurement device based on the level of precision and accuracy needed.

KS 10.2.1 Explain that friction is a force that opposes motion.

KS 13.1.2 Develop a model to accurately represent information or important characteristics of an object, data, process, or design idea for an intended purpose. [Notes on scope: the intended purpose may vary and could include organizing information to show relationships; providing a visual representation of the object/design to demonstrate how the object might “look”; a functional model to demonstrate the operation; a prototype of a specific component to test fit, performance, durability, or compatibility with other components in a system; and so on. The model could be a conceptual model, a mathematical model, a computer/virtual model, or a physical model, as appropriate for the testing scenario.]

KS 13.3.6 Identify necessary/appropriate views to fully detail a part or assembly.

KS 13.4.1 Identify and differentiate among a limit dimension, unilateral tolerance, and bilateral tolerance.

KS 13.4.2 Determine the specified dimension, tolerance, upper limit, and lower limit for any given dimension and related tolerance (or any distance that is dependent on the given dimensions) show on a technical drawing.

KS 13.4.3 Determine the allowance between two mating parts of an assembly based on dimensions given on a technical drawing

KS 13.4.4 Identify the need for and specify appropriate dimensions to create a clearance fit or interference fit where appropriate.

KS 13.5.1 Create a computer model to represent an object or conceptual idea and inform design decisions.

KS 13.5.2 Correctly build and constrain a three-dimensional solid computer model to accurately represent the physical characteristics and behaviors of a design idea or real object. Scope: This could include the appropriate application of geometric (horizontal, vertical, parallel, perpendicular, tangent, concentric) and dimensional constraints, as well as modeling other physical properties (density, color, texture, and so on).

KS 13.5.4 Correctly apply joints to constrain multi-component models and/or simulate realistic relative motion of the component parts.

KS 13.6.1 Generate an annotated multiview technical drawing using CAD software to fully describe a simple part.

KS 13.6.2 Apply appropriate and sufficient annotation (including dimensioning) methods to a drawing to fully describe an object or system using accepted technical drawing techniques.

KS 13.6.3 Generate an assembly drawing using CAD software to identify component parts and show details of assembly using part identification numbers, a parts list, and other annotations, as appropriate.

Core Instructional and Supplemental Materials	
Project Lead the Way (PLTW) Curriculum http://pltw.org **Engineering Design – An Introduction** 2nd Edition Karsnitz, O'Brien, Hutchinson, 2013 Delmar, Cengage Learning ISBN-13: 978-1-111-64582-3 and ISBN-10: 1-111-64583-5 **NEPRIS -** Connecting Industry to Every Classroom http://nepris.com.	**Autodesk Inventor** http://autodesk.com **Fusion 360** http://autodesk.com **Lynda.com** (Online Tutorials) http://lynda.com

Teacher Notes:

- There are many items that need to be 3D printed ahead of time.
- Make use of the automoblox vehicles for measuring (from the old curriculum).

Instructional Plan:	**Unit 2.2: Take it Apart**
Suggested Activities	**Resources "Project Lead The Way "**
Activities, Projects, and Problems (A P B)	**Knowledge / Skills**
2.2.1 What Is Reverse Engineering?	KS 6.1.1, KS 9.1.1, KS 9.1.2, KS 9.1.3, KS 9.1.4, KS 11.1.1,
2.2.2 Visual Analysis	KS 4.1.2, KS 9.1.1, KS 9.1.2,
2.2.3 Functional Analysis and the Black Box	KS 9.1.1, KS 9.1.3, KS 11.1.2, KS 12.1.1, KS 12.2.2, KS 12.5.1, KS 13.1.1, KS 13.1.2
2.2.4 Structural Analysis and Product Disassembly	KS 9.1.1, KS 9.1.2, KS 9.1.4, KS 13.1.2
2.2.5 CAD Design Tools	KS 13.1.2, KS 13.3.1, KS 13.5.1, KS 13.5.2,
2.2.6 Top-down or Bottom-up?	KS 1.2.4, KS 1.4.1, KS 8.1.2, KS 9.1.4, KS 13.1.1, KS 13.1.2, KS 13.5.1, KS 13.5.2, KS 13.5.3, KS 13.5.4,
2.2.7 Design for Manufacturability and Assembly	KS 1.4.2, KS 1.4.3, KS 2.1.3, KS 2.1.4, KS 2.1.6, KS 6.1.2, KS 7.1.2, KS 8.1.2, KS 8.1.3, KS 9.2.1, KS 9.2.4, KS 13.1.2,
2.2.8 Design an Integrated Assembly	KS 1.1.2, KS 1.2.2, KS 1.2.3, KS 2.1.2, KS 2.1.3, KS 2.1.4, KS 2.1.5, KS 2.1.6, KS 4.1.2, KS 7.2.3, KS 7.3.2, KS 8.1.1, KS 8.1.2, KS 8.1.3, KS 8.1.4, KS 9.1.1, KS 9.1.5, KS 9.1.6, KS 9.2.1, KS 11.1.1, KS 13.1.2, KS 13.4.2, KS 13.4.4, KS 13.5.1, KS 13.5.2, KS 13.5.4, KS 13.6.2, KS 13.6.3

Evidence of Student Learning		
Activities (A) Projects (P) Problems (B)	**Assessment FOR Learning**	**Assessment OF Learning**
2.2.1 What Is Reverse Engineering?	-- product description #1 – 4 -- disassemble the system #5 - 7	-- application documentation -- proper use of reverse engineering
2.2.2 Visual Analysis	-- activity #1 – 5 -- activity #6 -11	-- ability to apply visual design principles and elements -- Produce a Design Matrix
2.2.3 Functional Analysis and the Black Box	-- activity #1 - 6 -- activity #7 - 14	-- describe what a product does -- Perform a functional analysis of a product or system to determine the purpose
2.2.4 Structural Analysis and Product Disassembly	-- document product disassembly #1 - 7 -- Activity #8 - 14	-- Produce a model of the selected part(s) -- Create a structural / visual analysis of system
2.2.5 CAD Design Tools	-- modify Coffee Maker Water Heating Tube Subassembly -- activity #2 – 3 -- activity #4	-- apply sweep modeling feature to modify design -- apply revolve and shell features to modify design -- apply thread feature to update the design
2.2.6 Top-down or Bottom-up?	-- Activity #1 – 4 -- top down #5 and assemble #6 - create pen digitally using bottom-up #7 - 8	-- In teams reverse engineer a shuttle pen using top down and bottom-up methods -- ability to compare both methods

2.2.7 Design for Manufacturability and Assembly optional	-- activity / problem #1 – 4 -- calculations #5 - 7	-- Apply DFMA Guidelines -- Calculate complexity
2.2.8 Design an Integrated Assembly	-- Creation of design brief -- Completion of deliverables -- creation and use of decision matrix	-- Creation of design sketches -- Creation of prototype -- Collection and interpretation of data

DOMAIN / OBJECTIVES: Students will understand that …	
D1 Engineering Mindset	O1.1 Demonstrate independent thinking and self-direction in pursuit of accomplishing a goal. O1.2 Demonstrate curiosity, creativity, flexibility, and adaptability to change. O1.4 Make judgments and decisions based on evidence
D2 Design Process	O2.1 Apply an iterative design process to creatively address a need or solve a problem.
D4 Career Awareness	O4.1 Demonstrate awareness of the education and skills required for professional practice in an engineering field.
D6 Professionalism and Ethics	O6.1 Apply personal and professional ethical standards as they relate to the habits and characteristics of an engineering professional. O6.2 Consider the impact of potential engineering solutions on future generations to inform the development of sustainable solutions.
D7 Collaboration	O7.1 Facilitate an effective team environment to promote successful goal attainment. O7.2 Contribute individually to overall collaborative efforts. O7.3 Analyze and evaluate the work of others to provide helpful feedback.
D8 Communication	O8.1 Communicate effectively with an audience based on audience characteristics.
D9 Engineering Design	O9.1 Analyze a consumer product using reverse engineering techniques to document visual, functional, and structural aspects of the design. O9.2 Optimize performance of a mechanical part or assembly.
D11 Systems Thinking	O11.1 Apply systems thinking to consider how an engineering problem and its solution may be thought of as containing subsystems and as being a sub-system of a larger system.
D12 Computational Thinking	O12.1 Apply problem decomposition skills to break down data, problems, and processes into manageable parts. O12.2 Use algorithms to create a solution with or without the use of a computer program. O12.5 Apply abstraction to generalize problems and solutions.
D13 Modeling	O13.1 Develop models and simulations to represent information, processes, and/or objects to an appropriate level of abstraction for the intended purpose. O13.3 Use engineering graphics to represent physical objects. O13.4 Apply appropriate engineering tolerances to specify the allowable variation, size of individual features, and orientation and location between features of an object. O13.5 Create and interpret a computer model or simulation of simple objects, assemblies, or systems to inform engineering decisions and solve problems. O13.6 Create technical drawings using 3D computer-aided design (CAD) software to document a design according to standard engineering practices.

KNOWLEDGE and SKILLS: Students will …

KS 1.1.2 Plan and use time effectively in pursuit of accomplishing a goal without direct oversight.
KS 1.2.2 Seek out and use feedback to improve work and positively influence one's personal and professional development.
KS 1.2.3 Reflect critically on past experiences to inform future progress.
KS 1.2.4 Successfully adjust to changes that impact work. Adapt to varied roles, job responsibilities, and schedules.
KS 1.4.1 Find relevant data in credible sources such as literature, databases, and policy documents.
KS 1.4.2 Collect, analyze, and interpret information relevant to the problem or opportunity at hand to support engineering decisions.
KS 1.4.3 Evaluate point of view, reasoning, and use of evidence and rhetoric, in oral or written communication and identify deficiencies, limitations and biases.
KS 2.1.1 Synthesize an ill-formed problem into a meaningful, well-defined problem using relevant information.
KS 2.1.2 Define measurable visual, functional, and structural design requirements (criteria) and realistic constraints against which solution alternatives can be evaluated and optimized. [Note that criteria and constraints should include considerations of cost, safety, reliability, manufacturability, and aesthetics, as well as possible social, cultural, and environmental impacts.]
KS 2.1.3 Apply effective techniques and appropriate guidelines to generate multiple creative ideas and potential solutions to a problem.
KS 2.1.4 Carry out a plan to compare competing solution ideas and justify the selection of a solution path with respect to design requirements and constraints.
KS 2.1.5, Develop a potential solution and implement a plan to test and evaluate the solution with respect to design criteria and constraints.
KS 2.1.6 Explain that engineers have a responsibility to serve the public interest, their clients, and the profession with a high degree of honesty, integrity, and accountability. This responsibility is defined in professional codes of ethics.
KS 4.1.2 Identify technical and nontechnical skills common to all engineering disciplines that are gained from specialized and intense education, training, and experience, including problem solving, the design process, data processing and interpretation, handling uncertainty, systems thinking, and modeling.
KS 6.1.1 Explain that engineers have a responsibility to serve the public interest, their clients, and the profession with a high degree of honesty, integrity, and accountability. This responsibility is defined in professional codes of ethics.
KS 6.2.1 Explain that different engineering solutions can have significantly different impacts on individuals, society, and the natural world.
KS 7.1.2 Monitor, solicit, negotiate, and balance diverse views and beliefs to reach shared understanding, common ground and workable solutions. Identify basic resolution strategies and employ those strategies as necessary and appropriate
KS 7.2.3 Present all work to be/being done individually in a timely manner to the team to gather feedback, inform revision, and gain consensus.
KS 7.3.2 Provide effective feedback to peers.
KS 8.1.1 According to best practices, effectively document engineering or scientific work in an organized notebook so someone unfamiliar with the work can follow and understand the process.
KS 8.1.2 Use sketches, tables, charts, and graphs when appropriate to clearly communicate information and in making arguments and claims in oral, written, and visual presentations.
KS 8.1.3 Initiate and participate in a range of open and effective interactions (one-on-one, in groups, and teacher-led) with diverse participants and across cultures, building on others' ideas and expressing one's own clearly and persuasively.
KS 8.1.4 Present information, findings, and supporting evidence clearly, concisely, and logically in writing in which the development, organization, and style are appropriate to task, purpose, and audience.
KS 9.1.1 Describe the processes and purposes of reverse engineering**.**
KS 9.1.2 Perform a visual analysis of a natural or man-made object and describe the apparent visual principles and elements of design.
KS 9.1.3 Perform a functional analysis of a product or system to determine the purpose, inputs and outputs, and operation of a product or system.
KS 9.1.4 Perform a structural analysis of a product or system to determine the materials used, the form of component parts, as well as the configuration and interaction of component parts when assembled (if applicable).
KS 9.1.5 Describe methods to rigidly join parts of an assembly (including press fits, special joints, adhesives, mechanical fasteners)
KS 9.1.6 Identify joints that allow movement between interfacing parts in an assembly and the degrees of freedom that it removes from the movement between parts (including slots, hinges, ball and socket, rotating knobs).
KS 9.2.1 Apply the principles of design for manufacturability and assembly of mechanical products
KS 9.2.4 Describe how design quality concepts such as performance, usability, accessibility, reliability, safety, etc. impact product development.
KS 11.1.1 Describe a system in terms of its components and/or subsystems and their interactions. For example, describe the components of an electronic circuit, including source, path, and load; describe how an electronic circuit provides power to a larger system to produce mechanical motion; describe the subsystems of a building, including power system, communication system, lighting system, ventilation system, water system, sewer system, safety system, social system, transportation system, structural system, and so on; describe how the water system and sewer system interact in your home. Predict what the effect of making a change to a component of a system will have on the system as a whole.
KS 11.1.2 Describe a system using a black box model indicating inputs and outputs, boundaries

KS 12.1.1 Separate a complex process into multiple subprocesses that can be implemented in an organized way to complete the larger process.
KS 12.2.2 Write a set of ordered instructions (with or without a computer) involving multiple discrete steps to accomplish a complex task or achieve a desired result.
KS 12.5.1 Identify what has been made more general by an abstraction and what details have been hidden or removed.
KS 13.1.1 Recognize that models use abstraction to represent a simplified version of a complex phenomenon and there is no guarantee that the Recognize that models use abstraction to represent a simplified version of a complex phenomenon and there is no guarantee that the model accurately represents the real object or phenomenon. List differences (potential or real) between model behavior and the behavior of the real object, system, or process that it represents, and identify limitations of the model. (Limitations may include specific characteristics being studied, accuracy, precision, range of conditions, and so on.)
KS 13.1.2 Develop a model to accurately represent information or important characteristics of an object, data, process, or design idea for an intended purpose. [Notes on scope: the intended purpose may vary and could include organizing information to show relationships; providing a visual representation of the object/design to demonstrate how the object might "look"; a functional model to demonstrate the operation; a prototype of a specific component to test fit, performance, durability, or compatibility with other components in a system; and so on. The model could be a conceptual model, a mathematical model, a computer/virtual model, or a physical model, as appropriate for the testing scenario.]
KS 13.3.1 Identify three-dimensional objects generated by rotation of a two-dimensional object.
KS 13.4.2 Determine the specified dimension, tolerance, upper limit, and lower limit for any given dimension and related tolerance (or any distance that is dependent on the given dimensions) show on a technical drawing.
KS 13.4.4 Identify the need for and specify appropriate dimensions to create a clearance fit or interference fit where appropriate.
KS 13.5.1 Create a computer model to represent an object or conceptual idea and inform design decisions.
KS 13.5.2 Correctly build and constrain a three-dimensional solid computer model to accurately represent the physical characteristics and behaviors of a design idea or real object. Scope: This could include the appropriate application of geometric (horizontal, vertical, parallel, perpendicular, tangent, concentric) and dimensional constraints, as well as modeling other physical properties (density, color, texture, and so on).
KS 13.5.3 Create relationships among part features and dimensions using parametric formulas
KS 13.5.4 Correctly apply joints to constrain multi-component models and/or simulate realistic relative motion of the component parts.
KS 13.6.2 Apply appropriate and sufficient annotation (including dimensioning) methods to a drawing to fully describe an object or system using accepted technical drawing techniques.
KS 13.6.3 Generate an assembly drawing using CAD software to identify component parts and show details of assembly using part identification numbers, a parts list, and other annotations, as appropriate.

Core Instructional and Supplemental Materials

Project Lead the Way (PLTW) Curriculum
http://pltw.org

Engineering Design – An Introduction 2nd Edition
Karsnitz, O'Brien, Hutchinson, 2013 Delmar, Cengage Learning
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NEPRIS - Connecting Industry to Every Classroom
http://nepris.com.

Autodesk Inventor
http://autodesk.com

Fusion 360
http://autodesk.com

Lynda.com (Online Tutorials)
http://lynda.com

Teacher Notes:

Instructional Plan:	**Unit 2.3: A Material World**
Suggested Activities	**Resources "Project Lead The Way "**
Activities, Projects, and Problems (A P B)	**Knowledge / Skills**
2.3.1 Material Properties	KS 3.1.1, KS 3.1.2, KS 3.1.3., KS 3.1.4, KS 3.1.5, KS 8.1.1, KS 8.1.2, KS 10.1.2, KS 10.1.3, KS 10.1.4, KS 10.3.2, KS 10.3.3,
2.3.2 Evaluating Materials	KS 1.4.4, KS 2.1.6, KS 6.2.1, KS 6.2.3, KS 8.1.3, KS 8.1.7, KS 10.3.1, KS 10.3.2, KS 10.3.4, KS 10.3.5
2.3.3 CAD Material Appearance and Analysis	KS 10.3.1, KS 10.3.2, KS 10.3.4, KS 10.3.5, KS 13.1.1, KS 13.1.2, KS 13.5.1, KS 13.5.2
2.3.4 Imagine the Future	KS 2.1.1, KS 2.1.3, KS 4.1.1, KS 6.2.1, KS 8.1.1, KS 8.1.2, KS 8.1.3, KS 8.1.4, KS 8.1.6, KS 9.2.4, KS 10.3.1, KS 10.3.2, KS 10.3.5, KS 13.1.2, KS 13.4.2, KS 13.4.4, KS 13.5.1, KS 13.5.2

Evidence of Student Learning		
Activities (A) Projects (P) Problems (B)	**Assessment FOR Learning**	**Assessment OF Learning**
2.3.1 Material Properties	-- activity #1 – 4 -- Investigate #6 - 17	-- assess properties of mass, weight, volume, and density -- investigate these properties for unknowns
2.3.2 Evaluating Materials	-- activity #2 – 3 -- activity #4 – 7 -- optimize design (optional)	-- ability to compare properties -- ability to design a habitat for life on Mars -- apply rubric to solve updated problem
2.3.3 CAD Material Appearance and Analysis	-- activity #1 – 3 -- activity #4 – 7 -- activity #8 + 9 (optional)	-- ability to create a new material in CAD -- ability to use a new material in CAD -- ability to inference test these materials
2.3.4 Imagine the Future (optional)	-- Creation of design brief -- Completion of deliverables -- creation and use of decision matrix	-- Creation of design sketches -- Creation of prototype -- Collection and interpretation of data

DOMAIN / OBJECTIVES: Students will understand that …	
D1 Engineering Mindset	O1.4 Make judgments and decisions based on evidence
D2 Design Process	O2.1 Apply an iterative design process to creatively address a need or solve a problem.
D3 Experimental Design	O3.1 Design and perform an experimental protocol to investigate a phenomenon and/or gain knowledge.
D4 Career Awareness	O4.1 Demonstrate awareness of the education and skills required for professional practice in an engineering field.
D6 Professionalism and Ethics	O6.2 Consider the impact of potential engineering solutions on future generations to inform the development of sustainable solutions.

D8 Communication	O8.1 Communicate effectively with an audience based on audience characteristics.
D9 Engineering Design	O9.2 Optimize performance of a mechanical part or assembly.
D10 Engineering Science	O10.1 Using a variety of measuring devices, measure and report quantities accurately and to a precision appropriate for the purpose. O10.3 Apply basic materials science concepts to inform a design process.
D13 Modeling	O13.1 Develop models and simulations to represent information, processes, and/or objects to an appropriate level of abstraction for the intended purpose. O13.5 Create and interpret a computer model or simulation of simple objects, assemblies, or systems to inform engineering decisions and solve problems.

KNOWLEDGE and SKILLS: Students will …

KS 1.4.4 Draw valid conclusions based on supporting evidence while acknowledging the limitations, opposing views, and biases.
KS 2.1.1 Synthesize an ill-formed problem into a meaningful, well-defined problem using relevant information.
KS 2.1.3 Apply effective techniques and appropriate guidelines to generate multiple creative ideas and potential solutions to a problem.
KS 2.1.6 Identify design flaws of and potential enhancements to a proposed design solution
KS 3.1.1 Develop a testable hypothesis, experimental controls and important variables (independent and dependent) address a problem or answer a question.
KS 3.1.2 Identify best strategies and appropriate tools for data collection, documentation, and analysis.
KS 3.1.3 Summarize the objective and relevancy of an experiment.
KS 3.1.4 Read and accurately follow established protocols and instructions.
KS 3.1.5 Identify possible sources of errors, if they exist, redesign and repeat the experiment when appropriate.
KS 4.1.1 Define engineering as the creation of solutions, such as new and improved products, technologies, systems and processes), to meet the needs of people and society.
KS 6.2.1 Explain that different engineering solutions can have significantly different impacts on individuals, society, and the natural world.
KS 6.2.3 Evaluate a solution to a complex, real-world problem and identify the need for trade-offs to address a range of criteria and constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.
KS 8.1.1 According to best practices, effectively document engineering or scientific work in an organized notebook so someone unfamiliar with the work can follow and understand the process.
KS 8.1.2 Use sketches, tables, charts, and graphs when appropriate to clearly communicate information and in making arguments and claims in oral, written, and visual presentations.
KS 8.1.3 Initiate and participate in a range of open and effective interactions (one-on-one, in groups, and teacher-led) with diverse participants and across cultures, building on others' ideas and expressing one's own clearly and persuasively.
KS 8.1.4 Present information, findings, and supporting evidence clearly, concisely, and logically in writing in which the development, organization, and style are appropriate to task, purpose, and audience.
KS 8.1.6 Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence, and to add interest.
KS 8.1.7 Practice active listening.
KS 9.2.4 Describe how design quality concepts such as performance, usability, accessibility, reliability, safety, etc. impact product development.
KS 10.1.2 Describe the accuracy and precision of a measurement or measuring device and differentiate between the two.
KS 10.1.3 Use dimensional analysis and unit conversions to transform data to consistent units or to units appropriate for a particular purpose or model.
KS 10.1.4 Choose a measurement device based on the level of precision and accuracy needed.
KS 10.3.1 Describe different types of materials and their common usages in product design.
KS 10.3.2 List material properties that are important to design, including mechanical, chemical, electrical, and magnetic properties.
KS 10.3.3 Conduct non-destructive tests (e.g. hardness, flexure, conductivity) on different material types to investigate material properties.
KS 10.3.4 Explain how design criteria and constraints (e.g. cost, performance, safety, risk, aesthetics, environmental impact) often limit the material choices available for a given design.
KS 10.3.5 Select and justify the use of materials for prototyping and manufacturing products.

KS 13.1.1 Recognize that models use abstraction to represent a simplified version of a complex phenomenon and there is no guarantee that the Recognize that models use

abstraction to represent a simplified version of a complex phenomenon and there is no guarantee that the model accurately represents the real object or phenomenon. List differences (potential or real) between model behavior and the behavior of the real object, system, or process that it represents, and identify limitations of the model. (Limitations may include specific characteristics being studied, accuracy, precision, range of conditions, and so on.)

KS 13.1.2 Develop a model to accurately represent information or important characteristics of an object, data, process, or design idea for an intended purpose. [Notes on scope: the intended purpose may vary and could include organizing information to show relationships; providing a visual representation of the object/design to demonstrate how the object might "look"; a functional model to demonstrate the operation; a prototype of a specific component to test fit, performance, durability, or compatibility with other components in a system; and so on. The model could be a conceptual model, a mathematical model, a computer/virtual model, or a physical model, as appropriate for the testing scenario.]

KS 13.5.1 Create a computer model to represent an object or conceptual idea and inform design decisions.

KS 13.5.2 Correctly build and constrain a three-dimensional solid computer model to accurately represent the physical characteristics and behaviors of a design idea or real object. Scope: This could include the appropriate application of geometric (horizontal, vertical, parallel, perpendicular, tangent, concentric) and dimensional constraints, as well as modeling other physical properties (density, color, texture, and so on).

Core Instructional and Supplemental Materials

Project Lead the Way (PLTW) Curriculum
http://pltw.org

Engineering Design – An Introduction 2nd Edition
Karsnitz, O'Brien, Hutchinson, 2013 Delmar, Cengage Learning
ISBN-13: 978-1-111-64582-3 and ISBN-10: 1-111-64583-5

NEPRIS - Connecting Industry to Every Classroom
http://nepris.com.

Autodesk Inventor
http://autodesk.com

Fusion 360
http://autodesk.com

Lynda.com (Online Tutorials)
http://lynda.com

Teacher Notes:

Instructional Plan:	**Unit 2.4: Fix It**
Suggested Activities	**Resources "Project Lead The Way "**
Activities, Projects, and Problems (A P B)	**Knowledge / Skills**
2.4.1 Troubleshoot an Assembly	KS 1.1.2, KS 1.2.2, KS 1.2.3, KS 1.3.2, KS 5.1.3, KS 8.1.1, KS 8.1.2, , KS 8.1.3, , KS 8.1.5, , KS 8.1.6, , KS 8.1.7, KS 9.1.3, KS 9.1.4, KS 9.1.6, KS 9.2.1, KS 13.1.2, KS 13.3.2, KS 13.4.1, KS 13.4.2, KS 13.4.4, KS 13.5.1, KS 13.5.2, KS 13.6.1, KS 13.6.2, KS 13.6.3

Evidence of Student Learning		
Activities (A) Projects (P) Problems (B)	**Assessment FOR Learning**	**Assessment OF Learning**
2.4.1 Troubleshoot an Assembly (optional)	-- Creation of design brief -- Completion of deliverables -- creation and use of decision matrix	-- Creation of design sketches -- Creation of prototype -- Collection and interpretation of data

DOMAIN / OBJECTIVES: Students will understand that …	
D1 Engineering Mindset	O1.1 Demonstrate independent thinking and self-direction in pursuit of accomplishing a goal. O1.2 Demonstrate curiosity, creativity, flexibility, and adaptability to change. O1.3 Persevere to solve a problem or achieve a goal.
D5 Project Management	O5.1 Apply project management tools when designing and developing a solution to successfully deliver a product using available resources.
D8 Communication	O8.1 Communicate effectively with an audience based on audience characteristics.
D9 Engineering Design	O9.1 Analyze a consumer product using reverse engineering techniques to document visual, functional, and structural aspects of the design. O9.2 Optimize performance of a mechanical part or assembly. O9.2 Optimize performance of a mechanical part or assembly.
D13 Modeling	O13.1 Develop models and simulations to represent information, processes, and/or objects to an appropriate level of abstraction for the intended purpose. O13.3 Use engineering graphics to represent physical objects. O13.4 Apply appropriate engineering tolerances to specify the allowable variation, size of individual features, and orientation and location between features of an object. O13.5 Create and interpret a computer model or simulation of simple objects, assemblies, or systems to inform engineering decisions and solve problems. O13.6 Create technical drawings using 3D computer-aided design (CAD) software to document a design according to standard engineering practices.

KNOWLEDGE and SKILLS: Students will …

KS 1.1.2 Plan and use time effectively in pursuit of accomplishing a goal without direct oversight.
KS 1.2.2 Seek out and use feedback to improve work and positively influence one's personal and professional development.
KS 1.2.3 Reflect critically on past experiences to inform future progress.
KS 1.3.2 Demonstrate persistence in accomplishing a difficult challenge
KS 5.1.3 Select and use collaborative tools, such as cloud-based tools, document sharing, and video and text functions, to successfully complete a project.
KS 8.1.1 According to best practices, effectively document engineering or scientific work in an organized notebook so someone unfamiliar with the work can follow and understand the process.
KS 8.1.2 Use sketches, tables, charts, and graphs when appropriate to clearly communicate information and in making arguments and claims in oral, written, and visual presentations.
KS 8.1.3 Initiate and participate in a range of open and effective interactions (one-on-one, in groups, and teacher-led) with diverse participants and across cultures, building on others' ideas and expressing one's own clearly and persuasively.
KS 8.1.5 Present information, findings, and supporting evidence clearly, concisely, and logically, such that listeners can follow the line of reasoning and the organization, development, substance, and style are appropriate to purpose, audience, and task.
KS 8.1.6 Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence, and to add interest.
KS 8.1.7 Practice active listening.
KS 9.13 Perform a functional analysis of a product or system to determine the purpose, inputs and outputs, and operation of a product or system.
KS 9.1.4 Perform a structural analysis of a product or system to determine the materials used, the form of component parts, as well as the configuration and interaction of component parts when assembled (if applicable).
KS 9.1.6 Identify joints that allow movement between interfacing parts in an assembly and the degrees of freedom that it removes from the movement between parts (including slots, hinges, ball and socket, rotating knobs).
KS 9.2.1 Apply the principles of design for manufacturability and assembly of mechanical products.
KS 13.1.2 Develop a model to accurately represent information or important characteristics of an object, data, process, or design idea for an intended purpose. [Notes on scope: the intended purpose may vary and could include organizing information to show relationships; providing a visual representation of the object/design to demonstrate how the object might "look"; a functional model to demonstrate the operation; a prototype of a specific component to test fit, performance, durability, or compatibility with other components in a system; and so on. The model could be a conceptual model, a mathematical model, a computer/virtual model, or a physical model, as appropriate for the testing scenario.]
KS 13.3.2 Build a physical representation of an object or system based on graphical representations of the object or system. (Includes building solid objects, electrical circuits, mechanical devices, and complex systems according to technical drawings.)
KS 13.4.2 Determine the specified dimension, tolerance, upper limit, and lower limit for any given dimension and related tolerance (or any distance that is dependent on the given dimensions) show on a technical drawing.
KS 13.4.4 Identify the need for and specify appropriate dimensions to create a clearance fit or interference fit where appropriate.
KS 13.5.1 Create a computer model to represent an object or conceptual idea and inform design decisions.
KS 13.5.2 Correctly build and constrain a three-dimensional solid computer model to accurately represent the physical characteristics and behaviors of a design idea or real object. Scope: This could include the appropriate application of geometric (horizontal, vertical, parallel, perpendicular, tangent, concentric) and dimensional constraints, as well as modeling other physical properties (density, color, texture, and so on).
KS 13.6.1 Generate an annotated multiview technical drawing using CAD software to fully describe a simple part.
KS 13.6.2 Apply appropriate and sufficient annotation (including dimensioning) methods to a drawing to fully describe an object or system using accepted technical drawing techniques.
KS 13.6.3 Generate an assembly drawing using CAD software to identify component parts and show details of assembly using part identification numbers, a parts list, and other annotations, as appropriate.

Core Instructional and Supplemental Materials	
Project Lead the Way (PLTW) Curriculum http://pltw.org **Engineering Design – An Introduction** 2nd Edition Karsnitz, O'Brien, Hutchinson, 2013 Delmar, Cengage Learning ISBN-13: 978-1-111-64582-3 and ISBN-10: 1-111-64583-5 **NEPRIS -** Connecting Industry to Every Classroom http://nepris.com.	**Autodesk Inventor** http://autodesk.com **Fusion 360** http://autodesk.com **Lynda.com** (Online Tutorials) http://lynda.com
Teacher Notes:	

Unit 3: Thoughtful Product Design	**Duration:** 41 days

Standards/Learning Targets

Focus Standards (Major Standards) STL

HS-ETS1-1. - Engineering Design Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

HS.ETS1.2 - Engineering Design Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

HS.ETS1.3 - Engineering Design Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

HS.ETS1.4 - Engineering Design Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

Standards for Technological Literacy

2.9-12.Z Students will develop an understanding of the core concepts of technology.
Z. Selecting resources involves trade-offs between competing values, such as availability, cost, desirability, and waste.

2.9-12.AA Students will develop an understanding of the core concepts of technology.
AA. Requirements involve the identification of the criteria and constraints of a product or system and the determination of how they affect the final design and development.

2.9-12.BB Students will develop an understanding of the core concepts of technology.
BB. Optimization is an ongoing process or methodology of designing or making a product and is dependent on criteria and constraints.

2.9-12.DD Students will develop an understanding of the core concepts of technology.
DD. Quality control is a planned process to ensure that a product, service, or system meets established criteria.

8.9-12.H Students will develop an understanding of the attributes of design.
H. The design process includes defining a problem, brainstorming, researching and generating ideas, identifying criteria and specifying constraints, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype.

8.9-12.I Students will develop an understanding of the attributes of design.
I. Design problems are seldom presented in a clearly defined form.

8.9-12.J Students will develop an understanding of the attributes of design.
J. The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.

8.9-12.K Students will develop an understanding of the attributes of design.
K. Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other.

9.9-12.I Students will develop an understanding of engineering design.
I. Established design principles are used to evaluate existing designs, to collect data, and to guide the design process.

9.9-12.J Students will develop an understanding of engineering design.
J. Engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.

9.9-12.K Students will develop an understanding of engineering design.
K. A prototype is a working model used to test a design concept by making actual observations and necessary adjustments.

9.9-12.L Students will develop an understanding of engineering design.
L. The process of engineering design takes into account a number of factors.

11.9-12.N Students will develop the abilities to apply the design process.
N. Identify criteria and constraints and determine how these will affect the design process.

11.9-12.O Students will develop the abilities to apply the design process.
O. Refine a design by using prototypes and modeling to ensure quality, efficiency, and productivity of the final product.

11.9-12.P Students will develop the abilities to apply the design process.
P. Evaluate the design solution using conceptual, physical, and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed.

11.9-12.Q Students will develop the abilities to apply the design process.
Q. Develop and produce a product or system using a design process.

11.9-12.R Students will develop the abilities to apply the design process.
R. Evaluate final solutions and communicate observation, processes, and results of the entire design process, using verbal, graphic, quantitative, virtual, and written means, in addition to three-dimensional models.

12.9-12.L Students will develop the abilities to use and maintain technological products and systems.
L. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

12.9-12.P Students will develop the abilities to use and maintain technological products and systems.
P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

17.9-12.P Students will develop an understanding of and be able to select and use information and communication technologies.
P. There are many ways to communicate information, such as graphic and electronic means.

17.9-12.Q Students will develop an understanding of and be able to select and use information and communication technologies.
Q. Technological knowledge and processes are communicated using symbols, measurement, conventions, icons, graphic images, and languages that incorporate a variety of visual, auditory, and tactile stimuli.

The Student Learning Objectives above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Asking questions and defining problems - Evaluate a question to determine if it is testable and relevant. - Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory. - Ask and/or evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of a design. **Developing and Using Models** - Evaluate merits and limitations of two different models of the same proposed tool, process, mechanism or system in order to select or revise a model that best fits the evidence or design criteria. **Constructing Explanations and Designing Solutions** - Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. - Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. **Engaging in Argument from Evidence** - Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-	**ETS1.A: Defining and Delimiting Engineering Problems** • Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. • Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. **ETS1.B: Developing Possible Solutions** - When evaluating solutions it is important to take into account a range of constraints including cost, safety, reliability and aesthetics and to consider social, cultural and environmental impacts. (secondary to HS-LS2-7) (secondary to HS-LS4-6) (secondary to HS-ESS3-2),(secondary HS-ESS3-4) (HS-ETS1-3) - Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. (HS-ETS1-4) (secondary to HS-LS4-6)	**Cause and Effect: Mechanism and Prediction** - Systems can be designed to cause a desired effect. - Changes in systems may have various causes that may not have equal effects. **Systems and System Models** - Systems can be designed to do specific tasks.

generated evidence. Constructing Explanations and Designing Solutions **Obtaining, Evaluating, and Communicating Information** - Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. - Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem. - Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source. **Planning and Carrying Out Investigations** • Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. **Analyzing and Interpreting Data** • Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. • Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. • Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations. **Using Mathematics and Computational Thinking** • Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m3, acre-feet, etc.)	**ETS1.C: Optimizing the Design Solution** • Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (tradeoffs) may be needed. **ESS3.A - Earth and Human Activity – Natural Resources** - All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors. (HS-ESS3-2) **ESS3.C - Earth and Human Activity – Human Impacts on Earth Systems** Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. (HS-ESS3-4)	

Supporting and Additional Standards

English Language Arts

AS.R.1 – Reading: Read closely to determine what the text says explicitly and to make logical inferences from it; cite specific textual evidence when writing or speaking to support conclusions drawn from the text.

AS.R.7 – Reading: Integrate and evaluate content presented in diverse formats and media, including visually and quantitatively, as well as in words.

AS.R.10 – Reading: Read and comprehend complex literary and informational texts independently and proficiently.

AS.W.2 – Writing: Write informative/explanatory texts to examine and convey complex ideas and information clearly and accurately through the effective selection, organization, and analysis of content.

AS.W.4 – Writing: Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

AS.W.5 – Writing: Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach.

AS.W.6 – Writing: Use technology, including the Internet, to produce and publish writing and to interact and collaborate with others.

AS.W.7 – Writing: Conduct short as well as more sustained research projects based on focused questions, demonstrating understanding of the subject under investigation.

AS.W.8 – Writing: Gather relevant information from multiple print and digital sources, assess the credibility and accuracy of each source, and integrate the information while avoiding plagiarism.

AS.W.9 – Writing: Draw evidence from literary or informational texts to support analysis, reflection, and research.

AS.W.10 – Writing: Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of tasks, purposes, and audiences.

AS.SL.1 - Speaking and Listening: Prepare for and participate effectively in a range of conversations and collaborations with diverse partners, building on others' ideas and expressing their own clearly and persuasively.

AS.SL.2 - Speaking and Listening: Integrate and evaluate information presented in diverse media and formats, including visually, quantitatively, and orally.

AS.SL.4 - Speaking and Listening: Present information, findings, and supporting evidence such that listeners can follow the line of reasoning and the organization, development, and style are appropriate to task, purpose, and audience.

AS.SL.5 - Speaking and Listening: Make strategic use of digital media and visual displays of data to express information and enhance understanding of presentations.

AS.SL.6 - Speaking and Listening: Adapt speech to a variety of contexts and communicative tasks, demonstrating command of formal English when indicated or appropriate.

AS.L.1 – Language: Demonstrate command of the conventions of standard English grammar and usage when writing or speaking.

AS.L.2 – Language: Demonstrate command of the conventions of standard English capitalization, punctuation, and spelling when writing.

AS.L.6 – Language: Acquire and use accurately a range of general academic and domain-specific words and phrases sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.

9-10.W.1 – Writing: Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.

9-10.W.1.a – Writing: Introduce precise claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that establishes clear relationships among claim(s), counterclaims, reasons, and evidence.

9-10.W.1.b – Writing: Develop claim(s) and counterclaims fairly, supplying evidence for each while pointing out the strengths and limitations of both in a manner that anticipates the audience's knowledge level and concerns.

9-10.W.1.c – Writing: Use words, phrases, and clauses to link the major sections of the text, create cohesion, and clarify the relationships between claim(s) and reasons, between reasons and evidence, and between claim(s) and counterclaims.

9-10.W.1.d – Writing: Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.

9-10.W.1.e – Writing: Provide a concluding statement or section that follows from and supports the argument presented.

9-10.W.2.a – Writing: Introduce a topic; organize complex ideas, concepts, and information to make important connections and distinctions; include formatting (e.g., headings), graphics (e.g., figures, tables), and multimedia when useful to aiding comprehension.

9-10.W.2.b – Writing: Develop the topic with well-chosen, relevant, and sufficient facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic.

9-10.W.2.d – Writing: Use precise language and domain-specific vocabulary to manage the complexity of the topic.

9-10.W.2.e – Writing: Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.

9-10.W.2.f – Writing: Provide a concluding statement or section that follows from and supports the information or explanation presented (e.g., articulating implications or the significance of the topic).

9-10.W.4 – Writing: Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. (Grade-specific expectations for writing types are defined in standards 1–3 above.)

9-10.W.5 – Writing: Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience.

9-10.W.7 – Writing: Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

9-10.W.8 – Writing: Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation.

9-10.W.9 – Writing: Draw evidence from literary or informational texts to support analysis, reflection, and research.

9-10.W.10 – Writing: Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of tasks, purposes, and audiences.

9-10.SL.1 - Speaking and Listening: Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 9–10 topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.

9-10.SL.4 - Speaking and Listening: Present information, findings, and supporting evidence clearly, concisely, and logically such that listeners can follow the line of reasoning and the organization, development, substance, and style are appropriate to purpose, audience, and task.

9-10.SL.5 - Speaking and Listening - Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest.

9-10.SL.6 - Speaking and Listening - Adapt speech to a variety of contexts and tasks, demonstrating command of formal English when indicated or appropriate.

9-10.L.1 - Language - Demonstrate command of the conventions of standard English grammar and usage when writing or speaking.

9-10.L.2 - Language - Demonstrate command of the conventions of standard English capitalization, punctuation, and spelling when writing.

9-10.L.2.c - Language - Spell correctly.

9-10.L.6 - Language - Acquire and use accurately general academic and domain-specific words and phrases, sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.

9-10.RST.4 - Reading Science/Technical - Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9–10 texts and topics.

9-10.RST.8 - Reading Science/Technical - Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem.

9-10.WHST.1 - Writing HS/S/T - Write arguments focused on discipline-specific content.

9-10.WHST.1.a - Writing HS/S/T - Introduce precise claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that establishes clear relationships among the claim(s), counterclaims, reasons, and evidence.

9-10.WHST.1.b - Writing HS/S/T - Develop claim(s) and counterclaims fairly, supplying data and evidence for each while pointing out the strengths and limitations of both claim(s) and counterclaims in a discipline-appropriate form and in a manner that anticipates the audience's knowledge level and concerns.

9-10.WHST.1.c - Writing HS/S/T- Use words, phrases, and clauses to link the major sections of the text, create cohesion, and clarify the relationships between claim(s) and reasons, between reasons and evidence, and between claim(s) and counterclaims.

9-10.WHST.1.d - Writing HS/S/T- Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.

9-10.WHST.1.e - Writing HS/S/T- Provide a concluding statement or section that follows from or supports the argument presented.

9-10.WHST.2 - Writing HS/S/- Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.

9-10.WHST.2.a - Writing HS/S/T - Introduce a topic and organize ideas, concepts, and information to make important connections and distinctions; include formatting (e.g., headings), graphics (e.g., figures, tables), and multimedia when useful to aiding comprehension.

9-10.WHST.2.b - Writing HS/S/T - Develop the topic with well-chosen, relevant, and sufficient facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic.

9-10.WHST.2.d - Writing HS/S/T - Use precise language and domain-specific vocabulary to manage the complexity of the topic and convey a style appropriate to the discipline and context as well as to the expertise of likely readers.

9-10.WHST.2.e - Writing HS/S/T - Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.

9-10.WHST.2.f - Writing HS/S/T - Provide a concluding statement or section that follows from and supports the information or explanation presented (e.g., articulating implications or the significance of the topic).

9-10.WHST.4 - Writing HS/S/T: Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

9-10.WHST.5 - Writing HS/S/T: Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience.

9-10.WHST.7 - Writing HS/S/T: Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

9-10.WHST.8 - Writing HS/S/T: Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation.

9-10.WHST.9 - Writing HS/S/T: Draw evidence from informational texts to support analysis, reflection, and research.

9-10.WHST.10 - Writing HS/S/T: Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

Mathematics
MP.2 Reason abstractly and quantitatively. (HS-ETS1-1),(HS-ETS1-3),(HS-ETS1-4) **MP.4** Model with mathematics. (HS-ETS1-1),(HS-ETS1-2),(HS-ETS1-3),(HS-ETS1-4) **N.Q.1 - Quantities** - Use units as a way to understand problems and to guide the solution of multistep problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. **N.Q.2 - Quantities** - Define appropriate quantities for the purpose of descriptive modeling. **N.Q.3 - Quantities** - Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. **A.CED.3 - Creating Equations** - Represent constraints by equations or inequalities, and by systems of equations and/or inequalities, and interpret solutions as viable or non-viable options in a modeling context. For example, represent inequalities describing nutritional and cost constraints on combinations of different foods. **F.IF.7.a - Interpreting Functions** - Graph linear and quadratic functions and show intercepts, maxima, and minima. **G.MG.1 - Modeling with Geometry** - Use geometric shapes, their measures, and their properties to describe objects (e.g., modeling a tree trunk or a human torso as a cylinder). **S.ID.1 - Interpreting Categorical and Quantitative Data** - Represent data with plots on the real number line (dot plots, histograms, and box plots). **S.ID.4 - Interpreting Categorical and Quantitative Data -** Use the mean and standard deviation of a data set to fit it to a normal distribution and to estimate population percentages. Recognize that there are data sets for which such a procedure is not appropriate. Use calculators, spreadsheets, and tables to estimate areas under the normal curve. **G.MG.1 - Modeling with Geometry** Use geometric shapes, their measures, and their properties to describe objects (e.g., modeling a tree trunk or a human torso as a cylinder). **G.MG.3 - Modeling with Geometry** Apply geometric methods to solve design problems (e.g., designing an object or structure to satisfy physical constraints or minimize cost; working with typographic grid systems based on ratios).

Instructional Plan:	**Unit 3.1: Responsible Design**
Suggested Activities	**Resources "Project Lead The Way "**
Activities, Projects, and Problems (A P B)	**Knowledge / Skills**
3.1.1 Reverse Engineer a Product	KS 1.2.1, KS 1.4.1, KS 1.4.4, KS 8.1.2, KS 8.1.4, KS 8.1.6, KS 9.1.1, KS 9.1.2, KS 9.1.3, KS 9.1.4, KS 10.3.1, KS 10.3.2, KS 11.1.2, KS 12.2.2, KS 13.1.1,
3.1.2 Product Life Cycle	KS 1.4.1, KS 1.4.2, KS 4.2.2, KS 6.1.1, KS 6.2.1, KS 6.2.2, KS 6.2.3, KS 10.3.4, KS 10.3.5, KS 11.1.3, KS 13.2.1 KS 13.2.5
3.1.3 Sustainable Design	KS 1.4.3, KS 4.2.2, KS 6.1.1, KS 6.1.2, KS 6.2.1, KS 6.2.2, KS 6.2.4,KS 8.1.3, KS 8.1.4, KS 8.1.5, KS 8.1.7, KS 11.2.1, KS 10.3.5, KS 9.1.6, KS 13.5.1, KS 13.5.4
3.1.4 Design Criteria and Constraints [P]	KS 1.4.2, KS 2.1.2, KS 5.1.1, KS 6.2.3, KS 7.3.1, KS 7.3.2, KS 8.1.4, KS 9.2.4, KS 10.1.1, KS 10.3.2, KS 10.3.4,
3.1.5 Consider the Impact [B]	KS 1.1.1, KS 1.1.2, KS 1.2.1, KS 1.4.2, KS 2.1.1, KS 2.1.2, KS 2.1.3, KS 2.1.4, KS 2.1.5, KS 2.1.6, KS 5.1.1, KS 6.2.1, KS 6.2.2, KS 6.2.3, KS 6.2.4, KS 7.1.2, KS 7.1.3, KS 7.2.1, KS 7.2.2, KS 7.2.3, KS 8.1.1, KS 8.1.2, KS 9.1.2, KS 9.1.3, KS 10.3.4, KS 10.3.5, KS 11.1.3, KS 11.2.1, KS 13.1.2, KS 13.6.2

Evidence of Student Learning		
Activities (A) Projects (P) Problems (B)	**Assessment FOR Learning**	**Assessment OF Learning**
3.1.1 Reverse Engineer a Product	-- activity #1 – 3 -- activity #4 -- activity #5 -- activity #6 + 7	-- conduct a visual analysis and document -- perform functional analysis and document -- conduct a structural analysis -- Research and present findings
3.1.2 Product Life Cycle (optional)	-- activity #1 – 11 -- activity #12 - 16	-- Presentation of the team's research -- ability to communicate ideas on the modifications
3.1.3 Sustainable Design (optional)	-- Careers in Sustainable technology -- activity #3 - 9	-- research Sustainable technology -- ability to measure the environmental impact of a product.
3.1.4 Design Criteria and Constraints [P] (optional)	-- activity #1 – 3 -- activity #4 - 7	-- apply design criteria and constraints -- Evaluate a solution to a complex, real-world problem
3.1.5 Consider the Impact [B] (optional)	-- Creation of design brief -- Completion of deliverables -- creation and use of decision matrix	-- Creation of design sketches -- Creation of prototype -- Collection and interpretation of data

DOMAIN / OBJECTIVES: Students will understand that …	
D1 Engineering Mindset	O1.1 Demonstrate independent thinking and self-direction in pursuit of accomplishing a goal O1.4 Make judgments and decisions based on evidence
D2 Design Process	O2.1 Apply an iterative design process to creatively address a need or solve a problem.
D4 Career Awareness	O4.2 Analyze the role of engineering professionals in society.
D5 Project Management	O5.1 Apply project management tools when designing and developing a solution to successfully deliver a product using available resources.
D6 Professionalism and Ethics	O6.1 Apply personal and professional ethical standards as they relate to the habits and characteristics of an engineering professional. O6.2 Consider the impact of potential engineering solutions on future generations to inform the development of sustainable solutions.
D7 Collaboration	O7.1 Facilitate an effective team environment to promote successful goal attainment. O7.2 Contribute individually to overall collaborative efforts. O7.3 Analyze and evaluate the work of others to provide helpful feedback.
D8 Communication	O8.1 Communicate effectively with an audience based on audience characteristics.
D9 Engineering Design	O9.1 Analyze a consumer product using reverse engineering techniques to document visual, functional, and structural aspects of the design. O9.2 Optimize performance of a mechanical part or assembly.

D10 Engineering Science	O10.1 Using a variety of measuring devices, measure, and report quantities accurately and to a precision appropriate for the purpose. O10.3 Apply basic materials science concepts to inform a design process
D11 Systems Thinking	O11.1 Apply systems thinking to consider how an engineering problem and its solution may be thought of as containing subsystems and as being a sub-system of a larger system.
D12 Computational Thinking	O12.2 Use algorithms to create a solution with or without the use of a computer program.
D13 Modeling	O13.1 Develop models and simulations to represent information, processes, and/or objects to an appropriate level of abstraction for the intended purpose. O13.2 Apply mathematical (including graphical) models and interpret the output of models to test ideas or make predictions. O13.6 Create technical drawings using 3D computer-aided design (CAD) software to document a design according to standard engineering practices.

KNOWLEDGE and SKILLS: Students will …

KS 1.1.1 Explain the limitations of one's knowledge and skills in pursuit of accomplishing a goal.
KS 1.1.2 Plan and use time effectively in pursuit of accomplishing a goal without direct oversight.
KS 1.2.1 Ask new probing questions to expand and build upon an idea and explore personal curiosities throughout a creative process.
KS 1.4.1 Find relevant data in credible sources such as literature, databases, and policy documents.
KS 1.4.2 Collect, analyze, and interpret information relevant to the problem or opportunity at hand to support engineering decisions.
KS 1.4.3 Evaluate point of view, reasoning, and use of evidence and rhetoric, in oral or written communication and identify deficiencies, limitations and biases.
KS 1.4.4 Draw valid conclusions based on supporting evidence while acknowledging the limitations, opposing views, and biases.
KS 2.1.1 Synthesize an ill-formed problem into a meaningful, well-defined problem using relevant information.

KS 2.1.2 Define measurable visual, functional, and structural design requirements (criteria) and realistic constraints against which solution alternatives can be evaluated and optimized. [Note that criteria and constraints should include considerations of cost, safety, reliability, manufacturability, and aesthetics, as well as possible social, cultural, and environmental impacts.]
KS 2.1.3 Apply effective techniques and appropriate guidelines to generate multiple creative ideas and potential solutions to a problem.
KS 2.1.4 Carry out a plan to compare competing solution ideas and justify the selection of a solution path with respect to design requirements and constraints.
KS 2.1.5, Develop a potential solution and implement a plan to test and evaluate the solution with respect to design criteria and constraints.
KS 2.1.6 Explain that engineers have a responsibility to serve the public interest, their clients, and the profession with a high degree of honesty, integrity, and accountability. This responsibility is defined in professional codes of ethics.
KS 4.2.2 Identify and describe contemporary engineering issues of local, global and cultural significance.
KS 5.1.1 Define the project deliverables and constraints, such as scope, time, cost, quality, resources, and risk.
KS 6.1.1 Explain that engineers have a responsibility to serve the public interest, their clients, and the profession with a high degree of honesty, integrity, and accountability. This responsibility is defined in professional codes of ethics.
KS 6.1.2 Acknowledge and respect the local, national and international perspectives and ideas of others. Demonstrate respect and empathy for teammates, mentors, employers/teachers, clients and other professional contacts, and those impacted by engineering decision
KS 6.2.1 Explain that different engineering solutions can have significantly different impacts on individuals, society, and the natural world.
KS 6.2.2 Describe the life cycle of a product or service.
KS 6.2.3 Evaluate a solution to a complex, real-world problem and identify the need for trade-offs to address a range of criteria and constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.
KS 6.2.4 Take action for collective well-being and sustainable development using an ethical decision-making process. (This includes using natural resources effectively and efficiently, and considering the safety of those affected by a product and the potential effects on individual and public health.)
KS 7.1.2 Monitor, solicit, negotiate, and balance diverse views and beliefs to reach shared understanding, common ground and workable solutions. Identify basic resolution strategies and employ those strategies as necessary and appropriate
KS 7.1.3 Develop ideas and create products through positive interdependence among all teammates.
KS 7.2.1 Describe one's individual role and expectations of performance within the team, including communication protocol and rules of engagement per the team norms.

KS 7.2.2 Support other team members, prompting and offering assistance, if needed, to meet team goals.
KS 7.2.3 Present all work to be/being done individually in a timely manner to the team to gather feedback, inform revision, and gain consensus.
KS 7.3.1 Describe the purpose and positive outcomes of a peer review process.
KS 7.3.2 Provide effective feedback to peers.
KS 8.1.1 According to best practices, effectively document engineering or scientific work in an organized notebook so someone unfamiliar with the work can follow and understand the process.
KS 8.1.2 Use sketches, tables, charts, and graphs when appropriate to clearly communicate information and in making arguments and claims in oral, written, and visual presentations.
KS 8.1.3 Initiate and participate in a range of open and effective interactions (one-on-one, in groups, and teacher-led) with diverse participants and across cultures, building on others' ideas and expressing one's own clearly and persuasively.
KS 8.1.4 Present information, findings, and supporting evidence clearly, concisely, and logically in writing in which the development, organization, and style are appropriate to task, purpose, and audience.
KS 8.1.5 Present information, findings, and supporting evidence clearly, concisely, and logically, such that listeners can follow the line of reasoning and the organization, development, substance, and style are appropriate to purpose, audience, and task.
KS 8.1.6 Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence, and to add interest.
KS 8.1.7 Practice active listening.
KS 9.1.1 Describe the processes and purposes of reverse engineering**.**
KS 9.1.2 Perform a visual analysis of a natural or man-made object and describe the apparent visual principles and elements of design.
KS 9.1.3 Perform a functional analysis of a product or system to determine the purpose, inputs and outputs, and operation of a product or system.
KS 9.1.4 Perform a structural analysis of a product or system to determine the materials used, the form of component parts, as well as the configuration and interaction of component parts when assembled (if applicable).
KS 9.2.4 Describe how design quality concepts such as performance, usability, accessibility, reliability, safety, etc. impact product development.
KS 10.1.1 Explain that all measurements are an approximation of the true value of a quantity.
KS 10.3.1 Describe different types of materials and their common usages in product design.
KS 10.3.2 List material properties that are important to design, including mechanical, chemical, electrical, and magnetic properties.
KS 10.3.4 Explain how design criteria and constraints (e.g. cost, performance, safety, risk, aesthetics, environmental impact) often limit the material choices available for a given design.
KS 10.3.5 Select and justify the use of materials for prototyping and manufacturing products.
KS 11.1.2 Describe a system using a black box model indicating inputs and outputs, boundaries
KS 11.1.3 Predict the local and global risks and impacts of an engineering decision/solution (e.g., society, the economy, the environment), including some that were not anticipated.
KS 11.2.1 Define sustainability, and identify principles that help guide development of sustainable solutions (e.g. generative design and life cycle assessment)
KS 12.2.2 Write a set of ordered instructions (with or without a computer) involving multiple discrete steps to accomplish a complex task or achieve a desired result.
KS 13.1.1 Recognize that models use abstraction to represent a simplified version of a complex phenomenon and there is no guarantee that the Recognize that models use abstraction to represent a simplified version of a complex phenomenon and there is no guarantee that the model accurately represents the real object or phenomenon. List differences (potential or real) between model behavior and the behavior of the real object, system, or process that it represents, and identify limitations of the model. (Limitations may include specific characteristics being studied, accuracy, precision, range of conditions, and so on.)
KS 13.1.2 Develop a model to accurately represent information or important characteristics of an object, data, process, or design idea for an intended purpose. [Notes on scope: the intended purpose may vary and could include organizing information to show relationships; providing a visual representation of the object/design to demonstrate how the object might “look”; a functional model to demonstrate the operation; a prototype of a specific component to test fit, performance, durability, or compatibility with other components in a system; and so on. The model could be a conceptual model, a mathematical model, a computer/virtual model, or a physical model, as appropriate for the testing scenario.]
KS 13.2.1 Build and/or use a mathematical model (algorithm, table of values, equation, graph) to represent data, describe relationships, describe processes, and to make predictions in the context of the problem. For example: create displacement/time graphs (Cartesian); create polar graphs to describe displacement caused by a cam (and cam shape).
KS 13.2.5 Use mathematical modeling to optimize design criteria.
KS 13.6.2 Apply appropriate and sufficient annotation (including dimensioning) methods to a drawing to fully describe an object or system using accepted technical drawing techniques.

Core Instructional and Supplemental Materials	
Project Lead the Way (PLTW) Curriculum http://pltw.org **Engineering Design – An Introduction** 2nd Edition Karsnitz, O'Brien, Hutchinson, 2013 Delmar, Cengage Learning ISBN-13: 978-1-111-64582-3 and ISBN-10: 1-111-64583-5 **NEPRIS -** Connecting Industry to Every Classroom http://nepris.com.	**Autodesk Inventor** http://autodesk.com **Fusion 360** http://autodesk.com **Lynda.com** (Online Tutorials) http://lynda.com
Teacher Notes:	

Instructional Plan:	**Unit 3.2: More Than Parts**
Suggested Activities	**Resources "Project Lead The Way "**
Activities, Projects, and Problems (A P B)	**Knowledge / Skills**
3.2.1 Human-Centered Design	KS 1.1.3, KS 1.2.1, KS 1.2.2, KS 1.4.1, KS 2.1.2, KS 2.1.3, KS 3.2.3, KS 4.1.1, KS 6.1.1, KS 6.1.2, KS 6.2.1, KS 6.2.3, KS 7.1.3, KS 8.1.2, KS 8.1.3, KS 9.2.4, KS 11.2.2, KS 13.2.5, KS 13.5.4
3.2.2 Whole-systems Thinking	KS 1.4.1, KS 1.4.2, KS 1.4.3, KS 1.4.4, KS 6.1.2, KS 6.2.1, KS 6.2.3, KS 6.2.4, KS 7.1.3, KS 8.1.3, KS 8.1.5, KS 8.1.7, KS 9.1.3, KS 9.2.4, KS 11.1.1, KS 11.1.3, KS 11.2.2,
3.2.3 Generative Design	KS 1.4.2, KS 2.1.2, KS 2.1.3, KS 2.1.6, KS 3.1.1, KS 3.2.4, KS 6.1.1, KS 9.2.2, KS 9.2.3, KS 10.3.2, KS 12.1.1, KS 12.2.2, KS 13.1.2, KS 13.2.5, KS 13.5.1, KS 13.5.2
3.2.4 When Is "Good" Good Enough?	KS 1.4.4, KS 3.2.3, KS 8.1.2, KS 8.1.3, KS 8.1.4, KS 9.2.3, KS 12.1.1, KS 12.4.1, KS 12.4.2, KS 13.2.1, KS 13.2.5
3.2.5 Gadget Design [B]	KS 1.2.1, KS 1.4.1, KS 1.4.2, KS 2.1.1, KS 2.1.2, KS 2.1.3, KS 2.1.4, KS 2.1.5, KS 2.1.6, KS 2.1.7, KS 4.1.1, KS 6.2.2, KS 6.2.3, KS 7.1.3, KS 7.2.2, KS 7.2.4, KS 8.1.1, KS 8.1.2, KS 8.1.3, KS 8.1.5, KS 8.1.6, KS 8.1.7, KS 9.2.3, KS 9.2.4, KS 10.3.5, KS 11.1.1, KS 11.1.3, KS 11.2.1, KS 11.2.2, KS 13.1.2, KS 13.2.5, KS 13.5.1, KS 13.5.2

Evidence of Student Learning		
Activities (A) Projects (P) Problems (B)	**Assessment FOR Learning**	**Assessment OF Learning**
3.2.1 Human-Centered Design (optional)	-- activity #1 – 4 -- activity #5 - 13	-- The design must meet people's needs -- proper use ideation and implementation of a concept
3.2.2 Whole-systems Thinking (optional)	-- activity #1 – 9 -- career connection	-- Predict what the effect of making a change to a component of a system will have on the system as a whole. -- Biomedical engineering
3.2.3 Generative Design	-- activity #1 – 4 -- activity #5 - 10	-- Apply effective techniques and appropriate guidelines to generate multiple creative ideas and potential solutions to a problem. -- Use computer-aided engineering tools to optimize design performance
3.2.4 When Is "Good" Good Enough? (optional)	-- activity #1 – 6 -- career connection	-- Draw valid conclusions based on supporting evidence while acknowledging the limitations, opposing views, and biases. -- Supply Chain Manager
3.2.5 Gadget Design [B] (optional)	-- Creation of design brief -- Completion of deliverables -- creation and use of decision matrix	-- Creation of design sketches -- Creation of prototype -- Collection and interpretation of data

DOMAIN / OBJECTIVES: Students will understand that …	
D1 Engineering Mindset	O1.1 Demonstrate independent thinking and self-direction in pursuit of accomplishing a goal O1.2 Demonstrate curiosity, creativity, flexibility, and adaptability to change. O1.4 Make judgments and decisions based on evidence
D2 Design Process	O2.1 Apply an iterative design process to creatively address a need or solve a problem
D3 Experimental Design	O3.1 Design and perform an experimental protocol to investigate a phenomenon and/or gain knowledge. O3.2 Use appropriate statistical methods and visualization techniques to justify claims based on evidence.
D4 Career Awareness	O4.1 Demonstrate awareness of the education and skills required for professional practice in an engineering field.
D6 Professionalism and Ethics	O6.1 Apply personal and professional ethical standards as they relate to the habits and characteristics of an engineering professional. O6.2 Consider the impact of potential engineering solutions on future generations to inform the development of sustainable solutions.
D7 Collaboration	O7.1 Facilitate an effective team environment to promote successful goal attainment. O7.2 Contribute individually to overall collaborative efforts.
D8 Communication	O8.1 Communicate effectively with an audience based on audience characteristics.
D9 Engineering Design	O9.1 Analyze a consumer product using reverse engineering techniques to document visual, functional, and structural aspects of the design. O9.2 Optimize performance of a mechanical part or assembly.
D10 Engineering Science	O10.3 Apply basic materials science concepts to inform a design process
D11 Systems Thinking	O11.1 Apply systems thinking to consider how an engineering problem and its solution may be thought of as containing subsystems and as being a sub-system of a larger system. O11.2 Assess the sustainability of an engineering solution based on the impacts (within the system or interrelated systems) that result from implementation of the solution.
D12 Computational Thinking	O12.1 Apply problem decomposition skills to break down data, problems, and processes into manageable parts. O12.2 Use algorithms to create a solution with or without the use of a computer program. O12.4 Collect, organize, and analyze data to help define and/or solve a problem.
D13 Modeling	O13.1 Develop models and simulations to represent information, processes, and/or objects to an appropriate level of abstraction for the intended purpose. O13.2 Apply mathematical (including graphical) models and interpret the output of models to test ideas or make predictions. O13.5 Create and interpret a computer model or simulation of simple objects, assemblies, or systems to inform engineering decisions and solve problems.

KNOWLEDGE and SKILLS: Students will …

KS 1.1.3 Make and execute a plan to gain additional knowledge and learning to accomplish a goal.
KS 1.2.1 Ask new probing questions to expand and build upon an idea and explore personal curiosities throughout a creative process.
KS 1.2.2 Seek out and use feedback to improve work and positively influence one's personal and professional development.
KS 1.4.1 Find relevant data in credible sources such as literature, databases, and policy documents.
KS 1.4.2 Collect, analyze, and interpret information relevant to the problem or opportunity at hand to support engineering decisions.

KS 1.4.3 Evaluate point of view, reasoning, and use of evidence and rhetoric, in oral or written communication and identify deficiencies, limitations and biases.
KS 1.4.4 Draw valid conclusions based on supporting evidence while acknowledging the limitations, opposing views, and biases.
KS 2.1.1 Synthesize an ill-formed problem into a meaningful, well-defined problem using relevant information.
KS 2.1.2 Define measurable visual, functional, and structural design requirements (criteria) and realistic constraints against which solution alternatives can be evaluated and optimized. [Note that criteria and constraints should include considerations of cost, safety, reliability, manufacturability, and aesthetics, as well as possible social, cultural, and environmental impacts.]
KS 2.1.3 Apply effective techniques and appropriate guidelines to generate multiple creative ideas and potential solutions to a problem.
KS 2.1.4 Carry out a plan to compare competing solution ideas and justify the selection of a solution path with respect to design requirements and constraints.
KS 2.1.5, Develop a potential solution and implement a plan to test and evaluate the solution with respect to design criteria and constraints.
KS 2.1.6 Identify design flaws of and potential enhancements to a proposed design solution
KS 2.1.7 Strategically iterate steps of the design process to improve and optimize a solution.
KS 3.1.1 Develop a testable hypothesis, experimental controls and important variables (independent and dependent) address a problem or answer a question.
KS 3.2.3 Apply inferential reasoning to make and/or support claims about populations based on data.
KS 3.2.4 Draw conclusions related to the hypothesis and support conclusions using experimental data.
KS 4.1.1 Define engineering as the creation of solutions, such as new and improved products, technologies, systems and processes), to meet the needs of people and society.
KS 4.1.2 Identify technical and nontechnical skills common to all engineering disciplines that are gained from specialized and intense education, training, and experience, including problem solving, the design process, data processing and interpretation, handling uncertainty, systems thinking, and modeling.
KS 4.2.1 Describe the discipline of mechanical engineering and a variety of sub-disciplines and technical roles related to mechanical engineering
KS 6.1.1 Explain that engineers have a responsibility to serve the public interest, their clients, and the profession with a high degree of honesty, integrity, and accountability. This responsibility is defined in professional codes of ethics.
KS 6.1.2 Acknowledge and respect the local, national, and international perspectives and ideas of others. Demonstrate respect and empathy for teammates, mentors, employers/teachers, clients and other professional contacts, and those impacted by engineering decision
KS 6.2.1 Explain that different engineering solutions can have significantly different impacts on individuals, society, and the natural world.
KS 6.2.2 Describe the life cycle of a product or service.
KS 6.2.3 Evaluate a solution to a complex, real-world problem and identify the need for trade-offs to address a range of criteria and constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.
KS 6.2.4 Take action for collective well-being and sustainable development using an ethical decision-making process. (This includes using natural resources effectively and efficiently, and considering the safety of those affected by a product and the potential effects on individual and public health.)
KS 7.1.3 Develop ideas and create products through positive interdependence among all teammates.
KS 7.2.2 Support other team members, prompting and offering assistance, if needed, to meet team goals.
KS 7.2.4 Critically and realistically self-evaluate personal contributions and collaboration effectiveness within a team. [ongoing]
KS 8.1.1 According to best practices, effectively document engineering or scientific work in an organized notebook so someone unfamiliar with the work can follow and understand the process.
KS 8.1.2 Use sketches, tables, charts, and graphs when appropriate to clearly communicate information and in making arguments and claims in oral, written, and visual presentations.
KS 8.1.3 Initiate and participate in a range of open and effective interactions (one-on-one, in groups, and teacher-led) with diverse participants and across cultures, building on others' ideas and expressing one's own clearly and persuasively.
KS 8.1.4 Present information, findings, and supporting evidence clearly, concisely, and logically in writing in which the development, organization, and style are appropriate to task, purpose, and audience.
KS 8.1.5 Present information, findings, and supporting evidence clearly, concisely, and logically, such that listeners can follow the line of reasoning and the organization, development, substance, and style are appropriate to purpose, audience, and task.
KS 8.1.6 Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence, and to add interest.
KS 8.1.7 Practice active listening.
KS 9.1.3 Perform a functional analysis of a product or system to determine the purpose, inputs and outputs, and operation of a product or system.
KS 9.2.2 Define basic fabrication processes and analyze if a product can be built as designed.
KS 9.2.3 Use computer-aided engineering tools (e.g. generative design and shape optimization) to optimize design performance of a mechanical part or assembly.
KS 9.2.4 Describe how design quality concepts such as performance, usability, accessibility, reliability, safety, etc. impact product development.
KS 10.3.2 List material properties that are important to design, including mechanical, chemical, electrical, and magnetic properties.
KS 10.3.5 Select and justify the use of materials for prototyping and manufacturing products.
KS 11.1.1 Describe a system in terms of its components and/or subsystems and their interactions. For example, describe the components of an electronic circuit, including source,

path, and load; describe how an electronic circuit provides power to a larger system to produce mechanical motion; describe the subsystems of a building, including power system, communication system, lighting system, ventilation system, water system, sewer system, safety system, social system, transportation system, structural system, and so on; describe how the water system and sewer system interact in your home. Predict what the effect of making a change to a component of a system will have on the system as a whole.

KS 11.1.3 Predict the local and global risks and impacts of an engineering decision/solution (e.g., society, the economy, the environment), including some that were not anticipated.

KS 11.2.1 Define sustainability, and identify principles that help guide development of sustainable solutions (e.g. generative design and life cycle assessment)

KS 11.2.2 Explain the benefits of human-centered design and apply principles to align product design with intended use.

KS 12.1.1 Separate a complex process into multiple subprocesses that can be implemented in an organized way to complete the larger process.

KS 12.2.2 Write a set of ordered instructions (with or without a computer) involving multiple discrete steps to accomplish a complex task or achieve a desired result.

KS 12.4.1 Populate a spreadsheet application with data and organize the data to be useful in accomplishing a specific goal.

KS 12.4.2 Use the functions and tools within a spreadsheet application to manipulate, analyze, and present data in a useful way, including graphs, regression analyses, and descriptive statistical analyses.

KS 13.1.2 Develop a model to accurately represent information or important characteristics of an object, data, process, or design idea for an intended purpose. [Notes on scope: the intended purpose may vary and could include organizing information to show relationships; providing a visual representation of the object/design to demonstrate how the object might "look"; a functional model to demonstrate the operation; a prototype of a specific component to test fit, performance, durability, or compatibility with other components in a system; and so on. The model could be a conceptual model, a mathematical model, a computer/virtual model, or a physical model, as appropriate for the testing scenario.]

KS 13.2.1 Build and/or use a mathematical model (algorithm, table of values, equation, graph) to represent data, describe relationships, describe processes, and to make predictions in the context of the problem. For example: create displacement/time graphs (Cartesian); create polar graphs to describe displacement caused by a cam (and cam shape).

KS 13.2.5 Use mathematical modeling to optimize design criteria.

KS 13.5.1 Create a computer model to represent an object or conceptual idea and inform design decisions.

KS 13.5.2 Correctly build and constrain a three-dimensional solid computer model to accurately represent the physical characteristics and behaviors of a design idea or real object. Scope: This could include the appropriate application of geometric (horizontal, vertical, parallel, perpendicular, tangent, concentric) and dimensional constraints, as well as modeling other physical properties (density, color, texture, and so on).

KS 13.5.4 Correctly apply joints to constrain multi-component models and/or simulate realistic relative motion of the component parts.

Core Instructional and Supplemental Materials

Project Lead the Way (PLTW) Curriculum
http://pltw.org

Engineering Design – An Introduction 2nd Edition
Karsnitz, O'Brien, Hutchinson, 2013 Delmar, Cengage Learning
ISBN-13: 978-1-111-64582-3 and ISBN-10: 1-111-64583-5

NEPRIS - Connecting Industry to Every Classroom
http://nepris.com.

Autodesk Inventor
http://autodesk.com

Fusion 360
http://autodesk.com

Lynda.com (Online Tutorials)
http://lynda.com

Teacher Notes:

Instructional Plan:	**Unit 3.3: Solve a Problem**
Suggested Activities	**Resources "Project Lead The Way "**
Activities, Projects, and Problems (A P B)	**Knowledge / Skills**
3.3.1 Establishing a Team	KS 1.2.1, KS 5.1,3, KS 7.1.1, KS 7.1.2, KS 7.2.1,
3.3.2 Project Scheduling	KS 5.1.1, KS 5.1.2, KS 5.1.3,
3.3.3 The Engineering Consultant	KS 1.1,2, KS 1.1,3, KS 1.2.1, KS 1.2.2, KS 1.2.4, KS 1.31, KS 1.3.2, KS 1.4.2, KS 1.4.4, KS 2.1.4, KS 2.1.5 KS 3.2.4, KS4.2.2, KS 5.1.1, KS 5.1.2, KS 6.1.1, KS 6.1.2, KS 6.2.2, KS 6.2.3, KS 7.1.1, KS 7.1.3, KS 7.2.1, KS 7.2.2, KS 7.3.2, KS 8.1.1, KS 8.1.5, KS 8.1.6, KS 9.1.3, KS 10.1.1, KS 10.1.2, KS 10.1.3, KS 10.1.4, KS 10.3.4, KS 11.1.1, KS 11.1.3, KS 11.2.1, KS 12.1.1, KS 12.2.1, KS 12.2.2, KS 12.5.1, KS 13.1.2, KS 13.2.1, KS 13.5.1, KS 13.5.2, KS 13.6.1, KS 13.6.2

Evidence of Student Learning		
Activities (A) Projects (P) Problems (B)	**Assessment FOR Learning**	**Assessment OF Learning**
3.3.1 Establishing a Team	-- activity #1 – 5 -- activity #6 – 9 -- career as engineering consultant	-- Ability to develop and follow team norms. -- able to develop a plan and method for collaboration.
3.3.2 Project Scheduling	-- activity #1 – 6 -- activity #7 - 11	-- Ability to Define the project deliverables and constraints -- Develop a project schedule and Gnatt Chart of duties
3.3.3 The Engineering Consultant (optional)	-- Creation of design brief -- Completion of deliverables -- creation and use of decision matrix	-- Creation of design sketches -- Creation of prototype -- Collection and interpretation of data
DOMAIN / OBJECTIVES: Students will understand that …		
D1 Engineering Mindset	O1.1 Demonstrate independent thinking and self-direction in pursuit of accomplishing a goal O1.2 Demonstrate curiosity, creativity, flexibility, and adaptability to change. O1.3 Persevere to solve a problem or achieve a goal. O1.4 Make judgments and decisions based on evidence	
D2 Design Process	O2.1 Apply an iterative design process to creatively address a need or solve a problem	
D3 Experimental Design	O3.2 Use appropriate statistical methods and visualization techniques to justify claims based on evidence.	
D4 Career Awareness	O4.2 Analyze the role of engineering professionals in society.	
D5 Project Management	O5.1 Apply project management tools when designing and developing a solution to successfully deliver a product using available resources.	
D6 Professionalism and Ethics	O6.1 Apply personal and professional ethical standards as they relate to the habits and characteristics of an engineering professional. O6.2 Consider the impact of potential engineering solutions on future generations to inform the development of sustainable solutions.	

D7 Collaboration	O7.1 Facilitate an effective team environment to promote successful goal attainment. O7.2 Contribute individually to overall collaborative efforts. O7.3 Analyze and evaluate the work of others to provide helpful feedback.
D8 Communication	O8.1 Communicate effectively with an audience based on audience characteristics.
D9 Engineering Design	O9.1 Analyze a consumer product using reverse engineering techniques to document visual, functional, and structural aspects of the design.
D10 Engineering Science	O10.1 Using a variety of measuring devices, measure and report quantities accurately and to a precision appropriate for the purpose O10.3 Apply basic materials science concepts to inform a design process
D11 Systems Thinking	O11.1 Apply systems thinking to consider how an engineering problem and its solution may be thought of as containing subsystems and as being a sub-system of a larger system. O11.2 Assess the sustainability of an engineering solution based on the impacts (within the system or interrelated systems) that result from implementation of the solution.
D12 Computational Thinking	O12.1 Apply problem decomposition skills to break down data, problems, and processes into manageable parts. O12.2 Use algorithms to create a solution with or without the use of a computer program. O12.5 Identify what has been made more general by an abstraction and what details have been hidden or removed.
D13 Modeling	O13.1 Develop models and simulations to represent information, processes, and/or objects to an appropriate level of abstraction for the intended purpose. O13.2 Apply mathematical (including graphical) models and interpret the output of models to test ideas or make predictions. O13.5 Create and interpret a computer model or simulation of simple objects, assemblies, or systems to inform engineering decisions and solve problems. O13.6 Create technical drawings using 3D computer-aided design (CAD) software to document a design according to standard engineering practices.

KNOWLEDGE and SKILLS: Students will …

KS 1.1.2 Plan and use time effectively in pursuit of accomplishing a goal without direct oversight.
KS 1.1.3 Make and execute a plan to gain additional knowledge and learning to accomplish a goal.
KS 1.2.1 Ask new probing questions to expand and build upon an idea and explore personal curiosities throughout a creative process.
KS 1.2.2 Seek out and use feedback to improve work and positively influence one's personal and professional development.
KS 1.2.4 Successfully adjust to changes that impact work. Adapt to varied roles, job responsibilities, and schedules.
KS 1.3.1 Demonstrate risk taking in engineering, scientific, or computational processes.
KS 1.3.2 Demonstrate persistence in accomplishing a difficult challenge.
KS 1.4.2 Collect, analyze, and interpret information relevant to the problem or opportunity at hand to support engineering decisions.
KS 1.4.4 Draw valid conclusions based on supporting evidence while acknowledging the limitations, opposing views, and biases.
KS 2.1.4 Carry out a plan to compare competing solution ideas and justify the selection of a solution path with respect to design requirements and constraints.
KS 2.1.5 Develop a potential solution and implement a plan to test and evaluate the solution with respect to design criteria and constraints.
KS 3.2.4 Draw conclusions related to the hypothesis and support conclusions using experimental data.
KS 4.2.2 Identify and describe contemporary engineering issues of local, global and cultural significance.
KS 5.1.1 Define the project deliverables and constraints, such as scope, time, cost, quality, resources, and risk.
KS 5.1.2 Develop a project schedule (with the critical path identified when appropriate), allocate tasks among team members, and track progress for successful completion of the project.
KS 5.1.3 Select and use collaborative tools, such as cloud-based tools, document sharing, and video and text functions, to successfully complete a project.
KS 6.1.1 Explain that engineers have a responsibility to serve the public interest, their clients, and the profession with a high degree of honesty, integrity, and accountability. This responsibility is defined in professional codes of ethics.

KS 6.1.2 Acknowledge and respect the local, national, and international perspectives and ideas of others. Demonstrate respect and empathy for teammates, mentors, employers/teachers, clients and other professional contacts, and those impacted by engineering decision

KS 6.2.2 Describe the life cycle of a product or service.

KS 6.2.3 Evaluate a solution to a complex, real-world problem and identify the need for trade-offs to address a range of criteria and constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

KS 7.1.1 Develop and follow team norms.

KS 7.1.2 Monitor, solicit, negotiate, and balance diverse views and beliefs to reach shared understanding, common ground and workable solutions. Identify basic resolution strategies and employ those strategies as necessary and appropriate.

KS 7.1.3 Develop ideas and create products through positive interdependence among all teammates.

KS 7.2.1 Describe one's individual role and expectations of performance within the team, including communication protocol and rules of engagement per the team norms.

KS 7.2.2 Support other team members, prompting and offering assistance, if needed, to meet team goals.

KS 7.3.2 Provide effective feedback to peers.

KS 8.1.1 According to best practices, effectively document engineering or scientific work in an organized notebook so someone unfamiliar with the work can follow and understand the process.

KS 8.1.5 Present information, findings, and supporting evidence clearly, concisely, and logically, such that listeners can follow the line of reasoning and the organization, development, substance, and style are appropriate to purpose, audience, and task.

KS 8.1.6 Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence, and to add interest.

KS 9.1.3 Perform a functional analysis of a product or system to determine the purpose, inputs and outputs, and operation of a product or system.

KS 10.1.1 Explain that all measurements are an approximation of the true value of a quantity.

KS 10.1.2 Describe the accuracy and precision of a measurement or measuring device and differentiate between the two.

KS 10.1.3 Use dimensional analysis and unit conversions to transform data to consistent units or to units appropriate for a particular purpose or model.

KS 10.1.4 Choose a measurement device based on the level of precision and accuracy needed.

KS 10.3.4 Explain how design criteria and constraints (e.g. cost, performance, safety, risk, aesthetics, environmental impact) often limit the material choices available for a given design.

KS 11.1.1 Describe a system in terms of its components and/or subsystems and their interactions. For example, describe the components of an electronic circuit, including source, path, and load; describe how an electronic circuit provides power to a larger system to produce mechanical motion; describe the subsystems of a building, including power system, communication system, lighting system, ventilation system, water system, sewer system, safety system, social system, transportation system, structural system, and so on; describe how the water system and sewer system interact in your home. Predict what the effect of making a change to a component of a system will have on the system as a whole.

KS 11.1.3 Predict the local and global risks and impacts of an engineering decision/solution (e.g., society, the economy, the environment), including some that were not anticipated.

KS 11.2.1 Define sustainability, and identify principles that help guide development of sustainable solutions (e.g. generative design and life cycle assessment)

KS 12.1.1 Separate a complex process into multiple subprocesses that can be implemented in an organized way to complete the larger process.

KS 12.2.1 Use existing correct algorithms as building blocks for constructing a new algorithm to help ensure the new algorithm is correct.

KS 12.2.2 Write a set of ordered instructions (with or without a computer) involving multiple discrete steps to accomplish a complex task or achieve a desired result.

KS 12.5.1 Identify what has been made more general by an abstraction and what details have been hidden or removed.

KS 13.1.2 Develop a model to accurately represent information or important characteristics of an object, data, process, or design idea for an intended purpose. [Notes on scope: the intended purpose may vary and could include organizing information to show relationships; providing a visual representation of the object/design to demonstrate how the object might "look"; a functional model to demonstrate the operation; a prototype of a specific component to test fit, performance, durability, or compatibility with other components in a system; and so on. The model could be a conceptual model, a mathematical model, a computer/virtual model, or a physical model, as appropriate for the testing scenario.]

KS 13.2.1 Build and/or use a mathematical model (algorithm, table of values, equation, graph) to represent data, describe relationships, describe processes, and to make predictions in the context of the problem. For example: create displacement/time graphs (Cartesian); create polar graphs to describe displacement caused by a cam (and cam shape).

KS 13.5.1 Create a computer model to represent an object or conceptual idea and inform design decisions.

KS 13.5.2 Correctly build and constrain a three-dimensional solid computer model to accurately represent the physical characteristics and behaviors of a design idea or real object. Scope: This could include the appropriate application of geometric (horizontal, vertical, parallel, perpendicular, tangent, concentric) and dimensional constraints, as well as modeling other physical properties (density, color, texture, and so on).

KS 13.6.1 Generate an annotated multiview technical drawing using CAD software to fully describe a simple part.

KS 13.6.2 Apply appropriate and sufficient annotation (including dimensioning) methods to a drawing to fully describe an object or system using accepted technical drawing techniques.

Core Instructional and Supplemental Materials	
Project Lead the Way (PLTW) Curriculum http://pltw.org **Engineering Design – An Introduction** 2nd Edition Karsnitz, O'Brien, Hutchinson, 2013 Delmar, Cengage Learning ISBN-13: 978-1-111-64582-3 and ISBN-10: 1-111-64583-5 **NEPRIS -** Connecting Industry to Every Classroom http://nepris.com.	**Autodesk Inventor** http://autodesk.com **Fusion 360** http://autodesk.com **Lynda.com** (Online Tutorials) http://lynda.com
Teacher Notes:	

Unit 4: Making Things Move	**Duration:** 41 days

Standards/Learning Targets

Focus Standards (Major Standards) STL

HS-ETS1.1. - Engineering Design Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

HS.ETS1.2 - Engineering Design Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

HS.ETS1.3 - Engineering Design Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

HS.ETS1.4 - Engineering Design Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

The Student Learning Objectives above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Asking Questions and Defining Problems - Evaluate a question to determine if it is testable and relevant. Ask questions • that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information. • that arise from examining models or a theory, to clarify and/or seek additional information and relationships. • to determine relationships, including quantitative relationships, between independent and dependent variables. • to clarify and refine a model, an explanation, or an engineering problem. - Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical, and/or environmental considerations. - that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory. **Developing and Using Models** - Evaluate merits and limitations of two different models of the same proposed tool, process, mechanism or system in order to select or revise a model that best fits the evidence or design criteria. - Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. - Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and	**ETS1.A: Defining and Delimiting Engineering Problems** • Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. **ETS1.B: Developing Possible Solutions** • When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. • Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. (HS-ETS1-4) (secondary to HS-LS4-6) **ETS1.C: Optimizing the Design Solution** • Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (tradeoffs) may be needed.	**Scale, Proportion, and Quantity** - Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth). **Systems and System Models** - Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. **Structure and Function** - The way an object is shaped or structured determines many of its properties and functions.

move flexibly between model types based on merits and limitations. - Develop a complex model that allows for manipulation and testing of a proposed process or system. **Planning and Carrying Out Investigations** - Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled. - Select appropriate tools to collect, record, analyze, and evaluate data. Make directional hypotheses that specify what happens to a dependent variable when an independent variable is manipulated. **Analyzing and Interpreting Data** - Analyze data to identify design features or characteristics of the components of a proposed process or system to optimize it relative to criteria for success. **Using Mathematics and Computational Thinking** - Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. **Constructing Explanations and Designing Solutions** - Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. **Engaging in Argument from Evidence** - Compare and evaluate competing arguments or design solutions in light of currently accepted explanations, new evidence, limitations (e.g., trade-offs), constraints, and ethical issues. - Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence. - Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and/or logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations).		

Supporting and Additional Standards

English Language Arts

AS.L.6 – Language: Acquire and use accurately a range of general academic and domain-specific words and phrases sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.

9-10.SL.1 - Speaking and Listening: Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 9–10 topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.

9-10.L.6 – Language: Acquire and use accurately general academic and domain-specific words and phrases, sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.

9-10.RST.4 - Reading Science/Technical: Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9–10 texts and topics.

WHST.11-12.8 Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation.

RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-ETS1-1),(HS-ETS1-3)

RST.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (HS-ETS1-1),(HS-ETS1-3)

RST.11-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. (HS-ETS1-1),(HS-ETS1-3)

Mathematics

G.MG.1 - Modeling with Geometry: Use geometric shapes, their measures, and their properties to describe objects (e.g., modeling a tree trunk or a human torso as a cylinder).

MP.4 Model with mathematics. (HS-ETS1-1),(HS-ETS1-2),(HS-ETS1-3),(HS-ETS1-4)

N.Q.1 – Quantities Use units as a way to understand problems and to guide the solution of multistep problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.

N.Q.2 – Quantities Define appropriate quantities for the purpose of descriptive modeling.

N.Q.3 – Quantities Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

A.SSE.1 - Seeing Structure in Expressions Interpret expressions that represent a quantity in terms of its context.

A.SSE.1.a - Seeing Structure in Expressions Interpret parts of an expression, such as terms, factors, and coefficients.

A.CED.1 - Creating Equations Create equations and inequalities in one variable and use them to solve problems. Include equations arising from linear and quadratic functions, and simple rational and exponential functions.

A.CED.2 - Creating Equations Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.

A.CED.3 - Creating Equations Represent constraints by equations or inequalities, and by systems of equations and/or inequalities, and interpret solutions as viable or non- viable options in a modeling context. For example, represent inequalities describing nutritional and cost constraints on combinations of different foods.

A.REI.3 - Reasoning with Equations and Inequalities Solve linear equations and inequalities in one variable, including equations with coefficients represented by letters.

A.REI.10 - Reasoning with Equations and Inequalities Understand that the graph of an equation in two variables is the set of all its solutions plotted in the coordinate plane, often forming a curve (which could be a line).

F.IF.1 - Interpreting Functions Understand that a function from one set (called the domain) to another set (called the range) assigns to each element of the domain exactly one element of the range. If f is a function and x is an element of its domain, then f(x) denotes the output of f corresponding to the input x. the graph of f is the graph of the equation y = f(x).

F.IF.2 - Interpreting Functions Use function notation, evaluate functions for inputs in their domains, and interpret statements that use function notation in terms of a context.

F.IF.5 - Interpreting Functions Relate the domain of a function to its graph and, where applicable, to the quantitative relationship it describes. For example, if the function h(n) gives the number of person-hours it takes to assemble n engines in a factory, then the positive integers would be an appropriate domain for the function.

F.IF.6 - Interpreting Functions Calculate and interpret the average rate of change of a function (presented symbolically or as a table) over a specified interval. Estimate the rate of change from a graph.

F.IF.7.a - Interpreting Functions Graph linear and quadratic functions and show intercepts, maxima, and minima.

F.BF.1 - Building Functions Write a function that describes a relationship between two quantities.

F.LE.5 - Linear, Quadratic, and Exponential Models Interpret the parameters in a linear or exponential function in terms of a context.

G.MG.1 - Modeling with Geometry Use geometric shapes, their measures, and their properties to describe objects (e.g., modeling a tree trunk or a human torso as a cylinder).

G.MG.3 - Modeling with Geometry Apply geometric methods to solve design problems (e.g., designing an object or structure to satisfy physical constraints or minimize cost; working with typographic grid systems based on ratios).

S.ID.6 - Interpreting Categorical and Quantitative Data Represent data on two quantitative variables on a scatter plot, and describe how the variables are related.

S.ID.6.a - Interpreting Categorical and Quantitative Data Fit a function to the data; use functions fitted to data to solve problems in the context of the data. Use given functions or choose a function suggested by the context. Emphasize linear, quadratic, and exponential models.

S.ID.6.c - Interpreting Categorical and Quantitative Data Fit a linear function for a scatter plot that suggests a linear association.

S.ID.7 - Interpreting Categorical and Quantitative Data Interpret the slope (rate of change) and the intercept (constant term) of a linear model in the context of the data.

S.ID.8 - Interpreting Categorical and Quantitative Data Compute (using technology) and interpret the correlation coefficient of a linear fit.

S.IC.1 - Making Inferences and Justifying Conclusions Understand statistics as a process for making inferences about population parameters based on a random sample from that population.

Instructional Plan:	**Unit 4.1: You've Got to Move It**
Suggested Activities	**Resources "Project Lead The Way "**
Activities, Projects, and Problems (A P B)	**Knowledge / Skills**
4.1.1 Reverse Engineer a Mechanism	KS 8.1.2, KS 9.1.2, KS 9.1.3, KS 9.1.4, KS 10.1.1, KS 10.4.1, KS 11.1.1, KS 11.1.2,
4.1.2 Cams Make the World Go Round	KS 10.4.2, KS 13.1.2, KS 13.2.1, KS 13.2.5, KS 13.3.4, KS 13.4.2, KS 13.4.4, KS 13.5.1, KS 13.5.2, KS 13.5.3
4.1.3 Mechanisms of Motion	KS 9.1.3, KS 10.4.1, KS 10.4.3, KS 10.4.4, KS 13.1.2, KS 13.2.1,
4.1.4 Modeling Mechanical Motion [P]	KS 10.4.1 KS 13.1.2, KS 13.2.1, KS 13.5.1, KS 13.5.2, KS 13.5.3, KS 13.5.4,
4.1.5 Cams in Motion [B]	KS 1.4.2, KS 3.1.1, KS 3.1.2, KS 3.2.1, KS 3.2.4, KS 7.1.3, KS 7.2.3, KS 8.1.2, KS 8.1.5, KS 8.1.6, KS 10.1.4, KS 10.4.2, KS 12.4.1, KS 12.4.2, KS 13.1.2, KS 13.2.1, KS 13.2.2, KS 13.2.3, KS 13.2.4,
4.1.6 Design a Cam	KS 1.2.2, KS 10.4.2, KS 10.4.3, KS 13.1.2, KS 13.2.1, KS 13.2.2, KS 13.2.3, KS 13.4.4, KS 13.5.1, KS 13.5.2, KS 13.6.1
4.1.7 Simulating Cam Motion	KS 13.1.2, KS 13.1.2, KS 13.2.1, KS 13.5.1, KS 13.5.2, KS 13.5.4,
4.1.8 Shoebox Automaton	KS 1.1.2, KS 1.2.1, KS 1.4.2, KS 2.1.3, KS 2.1.4, KS 2.1.5, KS 2.1.6, KS 2.1.7, KS 7.1.3, KS 7.3.2, KS 8.1.2, KS 8.1.3, KS 8.1.5, KS 10.3.5, KS 10.4.1, KS 10.4.2, KS 10.4.3, KS 10.4.4, KS 12.1.1, KS 13.1.2, KS 13.2.1, KS 13.2.2, KS 13.3.2,

Evidence of Student Learning		
Activities (A) Projects (P) Problems (B)	**Assessment FOR Learning**	**Assessment OF Learning**
4.1.1 Reverse Engineer a Mechanism	-- activity #1 - 7 -- problem activity	-- Ability to describe different types of motion. -- Ability to Separate a complex process into multiple sub processes that can be implemented in an organized way to complete the larger process.
4.1.2 Cams Make the World Go Round	-- activity #1 - 3 -- activity #4 - 7	-- To create a 3D solid model of a cam using parametric modeling. -- Use mathematical modeling to optimize design criteria.
4.1.3 Mechanisms of Motion	-- activity #1 - 7	-- To perform a functional analysis of a product or system to determine the purpose, inputs and outputs, and operation of a product or system. -- Select and use simple mechanisms to create and control motion to solve a problem.
4.1.4 Modeling Mechanical Motion [P]	-- activity #1 - 7	-- Use a mathematical model to describe the relationship between the motion of objects. -- Correctly apply constraints to a multi-component model and/or simulate realistic relative motion of the component parts.
4.1.5 Cams in Motion [B]	-- activity #7 - 10 -- activity #11 - 21	-- Ability to explain how cams and followers can be used to move objects in periodic motion. -- Represent data for two quantitative variables on a scatter plot and describe how the variables are related.
4.1.6 Design a Cam (optional)	-- activity #1 - 6 -- activity #7 - 14	-- Build and use a mathematical model to represent data, describe relationships, describe processes, or to make predictions in the context of a problem. -- To build and constrain a three-dimensional solid computer model to accurately represent the physical characteristics and behaviors
4.1.7 Simulating Cam Motion	-- activity #1 - 7	-- Develop a model to accurately represent the motion of a system with a series of cams. -- Correctly apply joints to constrain a multi-component model to simulate realistic relative motion.
4.1.8 Shoebox Automaton	-- Creation of design brief -- Completion of deliverables -- creation and use of decision matrix	-- Creation of design sketches -- Creation of prototype -- Collection and interpretation of data

DOMAIN / OBJECTIVES: Students will understand that …	
D1 Engineering Mindset	O1.1 Demonstrate independent thinking and self-direction in pursuit of accomplishing a goal O1.2 Demonstrate curiosity, creativity, flexibility, and adaptability to change. O1.4 Make judgments and decisions based on evidence
D2 Design Process	O2.1 Apply an iterative design process to creatively address a need or solve a problem
D3 Experimental Design	O3.1 Design and perform an experimental protocol to investigate a phenomenon and/or gain knowledge. O3.2 Use appropriate statistical methods and visualization techniques to justify claims based on evidence
D7 Collaboration	O7.1 Facilitate an effective team environment to promote successful goal attainment. O7.2 Contribute individually to overall collaborative efforts. O7.3 Analyze and evaluate the work of others to provide helpful feedback.
D8 Communication	O8.1 Communicate effectively with an audience based on audience characteristics.
D9 Engineering Design	O9.1 Analyze a consumer product using reverse engineering techniques to document visual, functional, and structural aspects of the design.
D10 Engineering Science	O10.1 Using a variety of measuring devices, measure and report quantities accurately and to a precision appropriate for the purpose O10.3 Apply basic materials science concepts to inform a design process O10.4 Understand how different machine elements influence motion of a mechanical system.
D11 Systems Thinking	O11.1 Apply systems thinking to consider how an engineering problem and its solution may be thought of as containing subsystems and as being a sub-system of a larger system.
D12 Computational Thinking	O12.1 Apply problem decomposition skills to break down data, problems, and processes into manageable parts. O12.4 Collect, organize, and analyze data to help define and/or solve a problem.
D13 Modeling	O13.1 Develop models and simulations to represent information, processes, and/or objects to an appropriate level of abstraction for the intended purpose. O13.2 Apply mathematical (including graphical) models and interpret the output of models to test ideas or make predictions. O13.3 Use engineering graphics to represent physical objects. O13.4 Apply appropriate engineering tolerances to specify the allowable variation, size of individual features, and orientation and location between features of an object. O13.5 Create and interpret a computer model or simulation of simple objects, assemblies, or systems to inform engineering decisions and solve problems. O13.6 Create technical drawings using 3D computer-aided design (CAD) software to document a design according to standard engineering practices.

KNOWLEDGE and SKILLS: Students will …

KS 1.1.2 Plan and use time effectively in pursuit of accomplishing a goal without direct oversight.
KS 1.2.1 Ask new probing questions to expand and build upon an idea and explore personal curiosities throughout a creative process.
KS 1.2.2 Seek out and use feedback to improve work and positively influence one's personal and professional development.
KS 1.4.2 Collect, analyze, and interpret information relevant to the problem or opportunity at hand to support engineering decisions.
KS 2.1.3 Apply effective techniques and appropriate guidelines to generate multiple creative ideas and potential solutions to a problem.
KS 2.1.4 Carry out a plan to compare competing solution ideas and justify the selection of a solution path with respect to design requirements and constraints.
KS 2.1.5 Develop a potential solution and implement a plan to test and evaluate the solution with respect to design criteria and constraints.
KS 2.1.6 Identify design flaws of and potential enhancements to a proposed design solution

KS 2.1.7 Strategically iterate steps of the design process to improve and optimize a solution.
KS 3.1.1 Develop a testable hypothesis, experimental controls and important variables (independent and dependent) address a problem or answer a question.
KS 3.1.2 Identify best strategies and appropriate tools for data collection, documentation, and analysis.
KS 3.2.1 Graphically represent experimental data for a single count or measurement with charts and/or plots on the real number line, such as dot plots, box plots and histograms.
KS 3.2.4 Draw conclusions related to the hypothesis and support conclusions using experimental data.
KS 7.1.3 Develop ideas and create products through positive interdependence among all teammates.
KS 7.2.2 Support other team members, prompting and offering assistance, if needed, to meet team goals.
KS 7.2.3 Present all work to be/being done individually in a timely manner to the team to gather feedback, inform revision, and gain consensus.
KS 7.3.2 Provide effective feedback to peers.
KS 8.1.1 According to best practices, effectively document engineering or scientific work in an organized notebook so someone unfamiliar with the work can follow and understand the process.
KS 8.1.2 Use sketches, tables, charts, and graphs when appropriate to clearly communicate information and in making arguments and claims in oral, written, and visual presentations.
KS 8.1.3 Initiate and participate in a range of open and effective interactions (one-on-one, in groups, and teacher-led) with diverse participants and across cultures, building on others' ideas and expressing one's own clearly and persuasively.
KS 8.1.5 Present information, findings, and supporting evidence clearly, concisely, and logically, such that listeners can follow the line of reasoning and the organization, development, substance, and style are appropriate to purpose, audience, and task.
KS 8.1.6 Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence, and to add interest.
KS 9.1.2 Perform a visual analysis of a natural or man-made object and describe the apparent visual principles and elements of design.
KS 9.1.3 Perform a functional analysis of a product or system to determine the purpose, inputs and outputs, and operation of a product or system.
KS 9.1.4 Perform a structural analysis of a product or system to determine the materials used, the form of component parts, as well as the configuration and interaction of component parts when assembled (if applicable).
KS 10.1.1 Explain that all measurements are an approximation of the true value of a quantity.
KS 10.1.4 Choose a measurement device based on the level of precision and accuracy needed.
KS 10.3.5 Select and justify the use of materials for prototyping and manufacturing products.
KS 10.4.1 Describe different types of motion (e.g. rotary, oscillating, linear, reciprocating, intermittent, and irregular).
KS 10.4.2 Explain how cams and followers can be used to move objects in periodic or irregular motion.
KS 10.4.3 Select and use simple mechanisms (e.g. cams, gears, pulleys and belts, sprockets and chains, springs, levers) to create and control motion to solve a problem.
KS 10.4.4 Use mechanisms in a design to transform a motion without changing its type (e.g. slow to fast rotary motion, magnifying linear movement, or changing axis of motion)
KS 11.1.1 Describe a system in terms of its components and/or subsystems and their interactions. For example, describe the components of an electronic circuit, including source, path, and load; describe how an electronic circuit provides power to a larger system to produce mechanical motion; describe the subsystems of a building, including power system, communication system, lighting system, ventilation system, water system, sewer system, safety system, social system, transportation system, structural system, and so on; describe how the water system and sewer system interact in your home. Predict what the effect of making a change to a component of a system will have on the system as a whole.
KS 11.1.2 Describe a system using a black box model indicating inputs and outputs, boundaries
KS 12.1.1 Separate a complex process into multiple subprocesses that can be implemented in an organized way to complete the larger process.
KS 12.4.1 Populate a spreadsheet application with data and organize the data to be useful in accomplishing a specific goal.
KS 12.4.2 Use the functions and tools within a spreadsheet application to manipulate, analyze, and present data in a useful way, including graphs, regression analyses, and descriptive statistical analyses.
KS 13.1.2 Develop a model to accurately represent information or important characteristics of an object, data, process, or design idea for an intended purpose. [Notes on scope: the intended purpose may vary and could include organizing information to show relationships; providing a visual representation of the object/design to demonstrate how the object might “look”; a functional model to demonstrate the operation; a prototype of a specific component to test fit, performance, durability, or compatibility with other components in a system; and so on. The model could be a conceptual model, a mathematical model, a computer/virtual model, or a physical model, as appropriate for the testing scenario.]
KS 13.2.1 Build and/or use a mathematical model (algorithm, table of values, equation, graph) to represent data, describe relationships, describe processes, and to make predictions in the context of the problem. For example: create displacement/time graphs (Cartesian); create polar graphs to describe displacement caused by a cam (and cam shape).
KS 13.2.2 Represent data for two quantitative variables on a scatter plot, and describe how the variables are related.
KS 13.2.3 Fit a function to the data and use the function to solve problems and/or make predictions in the context of the data.
KS 13.2.4 In mathematical models, interpret the rate of change (slope) and the y-intercept (constant term) in the context of the data.
KS 13.2.5 Use mathematical modeling to optimize design criteria.

KS 13.3.2 Build a physical representation of an object or system based on graphical representations of the object or system. (Includes building solid objects, electrical circuits, mechanical devices, and complex systems according to technical drawings.)

KS 13.3.4 Identify errors and omissions in orthographic projections and multiview drawings (including errors in line locations, line types, Identify errors and ommissions in orthographic projections and multiview drawings (including errors in line locations, line types, number of views, scale, dimensioning, and view orientation) to fully detail an object or part using the actual object, a detailed verbal description of the object, or a pictorial and isometric view of the object.

KS 13.4.2 Determine the specified dimension, tolerance, upper limit, and lower limit for any given dimension and related tolerance (or any distance that is dependent on the given dimensions) show on a technical drawing.

KS 13.4.4 Identify the need for and specify appropriate dimensions to create a clearance fit or interference fit where appropriate.

KS 13.5.1 Create a computer model to represent an object or conceptual idea and inform design decisions.

KS 13.5.2 Correctly build and constrain a three-dimensional solid computer model to accurately represent the physical characteristics and behaviors of a design idea or real object. Scope: This could include the appropriate application of geometric (horizontal, vertical, parallel, perpendicular, tangent, concentric) and dimensional constraints, as well as modeling other physical properties (density, color, texture, and so on).

KS 13.5.3 Create relationships among part features and dimensions using parametric formulas

KS 13.5.4 Correctly apply joints to constrain multi-component models and/or simulate realistic relative motion of the component parts.

KS 13.6.1 Generate an annotated multiview technical drawing using CAD software to fully describe a simple part.

Core Instructional and Supplemental Materials

Project Lead the Way (PLTW) Curriculum
http://pltw.org

Engineering Design – An Introduction 2nd Edition
Karsnitz, O'Brien, Hutchinson, 2013 Delmar, Cengage Learning
ISBN-13: 978-1-111-64582-3 and ISBN-10: 1-111-64583-5

NEPRIS - Connecting Industry to Every Classroom
http://nepris.com.

Autodesk Inventor
http://autodesk.com

Fusion 360
http://autodesk.com

Lynda.com (Online Tutorials)
http://lynda.com

Teacher Notes:

- Students should build cams, then get cams to work
- Several sections can be combined.
- Students will complete the digital model before doing the physical model.

Instructional Plan:	**Unit 4.2: May the Force Be With You**
Suggested Activities	**Resources "Project Lead The Way "**
Activities, Projects, and Problems (A P B)	**Knowledge / Skills**
4.2.1 Force Springs Eternal	KS 1.4.1, KS 1.4.2, KS 1.4.4, KS 3.1.1, KS 3.1.2, KS 3.1.3, KS 3.1.4, KS 3.2.4, KS 10.4.3, KS 12.2.2, KS 12.4.1, KS 13.1.2, KS 13.2.1, KS 13.2.2, KS 13.2.3, KS 13.2.4
4.2.2 Friction Is a Real Drag	KS 1.4.1, KS 1.4.2, KS 1.4.4, KS 3.1.1, KS 3.1.4, KS 3.1.5, KS 3.2.4, KS 10.2.1, KS 10.2.2, KS 10.3.3, KS 13.1.1, KS 13.1.2, KS 13.2.1, KS 13.2.4
4.2.3 Fighting Friction	KS 1.4.2, KS 2.1.2, KS 2.1.3, KS 2.1.4, KS 2.1.5, KS 10.1.4, KS 10.2.1, KS 10.2.3, KS 10.3.2, KS 10.3.5, KS 13.1.2, KS 13.3.2, KS 13.3.3, KS 13.3.6, KS 13.4.3, KS 13.4.4, KS 13.5.1, KS 13.5.2, KS 13.6.1, KS 13.6.2,
4.2.4 Friction: Design Friend or Foe	KS 1.3.1, KS 2.1.3, KS 2.1.4, KS 2.1.5, KS 2.1.6, KS 8.1.5, KS 10.2.3, KS 10.3.5, KS 10.4.3, KS 10.4.4, KS 13.1.2,
4.2.5 Automata Design Challenge	KS 1.1.2, KS 1.2.2, KS 1.2.3, KS 2.1.3, KS 2.1.4, KS 2.1.5, KS 2.1.7, KS 5.1.2, KS 7.3.2, KS 8.1.1, KS 8.1.2, KS 10.2.3, KS 10.3.5, KS 10.4.1, KS 10.4.2, KS 10.4.3, KS 10.4.4, KS 12.1.1, KS 13.1.2, KS 13.2.1, KS 13.3.2, KS 13.3.6, KS 13.4.4, KS 13.5.1, KS 13.5.2, KS 13.5.3, KS 13.5.4, KS 13.6.1, KS 13.6.2, KS 13.6.3

Evidence of Student Learning		
Activities (A) Projects (P) Problems (B)	**Assessment FOR Learning**	**Assessment OF Learning**
4.2.1 Force Springs Eternal (optional)	-- activity #1 - 13 -- activity #14 - 31	-- Select and use simple mechanisms, such as springs, to create and control motion to solve a problem. -- Fit a function to the data and use the function to solve problems and make predictions in the context of the data.
4.2.2 Friction Is a Real Drag (optional)	-- activity #1 - 8 -- activity #9 - 16	-- Collect, analyze, and interpret information relevant to the problem or opportunity at hand to support engineering decisions. -- Explain that friction is a force that opposes motion. -- Determine the coefficient of friction between two surfaces.
4.2.3 Fighting Friction (optional)	-- activity #1 - 6 -- activity #7 - 14	-- Explain that friction is a force that opposes motion. -- Identify the force of friction between two interacting components in a mechanism, explain how the frictional force impacts the function and efficiency of the mechanism, and recommend design revisions to improve performance.
4.2.4 Friction: Design Friend or Foe (optional)	-- activity #1 - 6 -- activity #7 - 8	-- Explain how frictional force impacts the function and efficiency of a mechanism and recommend design revisions to improve performance.
4.2.5 Automata Design Challenge (merge concepts)	-- Creation of design brief -- Completion of deliverables -- creation and use of decision matrix	-- Creation of design sketches -- Creation of prototype -- Collection and interpretation of data

DOMAIN / OBJECTIVES: Students will understand that …	
D1 Engineering Mindset	O1.1 Demonstrate independent thinking and self-direction in pursuit of accomplishing a goal O1.2 Demonstrate curiosity, creativity, flexibility, and adaptability to change. O1.3 Persevere to solve a problem or achieve a goal. O1.4 Make judgments and decisions based on evidence
D2 Design Process	O2.1 Apply an iterative design process to creatively address a need or solve a problem
D3 Experimental Design	O3.1 Design and perform an experimental protocol to investigate a phenomenon and/or gain knowledge. O3.2 Use appropriate statistical methods and visualization techniques to justify claims based on evidence
D5 Project Management	O5.1 Apply project management tools when designing and developing a solution to successfully deliver a product using available resources.
D7 Collaboration	O7.3 Analyze and evaluate the work of others to provide helpful feedback.
D8 Communication	O8.1 Communicate effectively with an audience based on audience characteristics.
D10 Engineering Science	O10.1 Using a variety of measuring devices, measure and report quantities accurately and to a precision appropriate for the purpose O10.2 Apply scientific knowledge related to frictional forces, to solve a problem or design a physical system. O10.3 Apply basic materials science concepts to inform a design process O10.4 Understand how different machine elements influence motion of a mechanical system.
D12 Computational Thinking	O12.1 Apply problem decomposition skills to break down data, problems, and processes into manageable parts. O12.2 Use algorithms to create a solution with or without the use of a computer program. O12.4 Collect, organize, and analyze data to help define and/or solve a problem.
D13 Modeling	O13.1 Develop models and simulations to represent information, processes, and/or objects to an appropriate level of abstraction for the intended purpose. O13.2 Apply mathematical (including graphical) models and interpret the output of models to test ideas or make predictions. O13.3 Use engineering graphics to represent physical objects. O13.4 Apply appropriate engineering tolerances to specify the allowable variation, size of individual features, and orientation and location between features of an object. O13.5 Create and interpret a computer model or simulation of simple objects, assemblies, or systems to inform engineering decisions and solve problems. O13.6 Create technical drawings using 3D computer-aided design (CAD) software to document a design according to standard engineering practices.

KNOWLEDGE and SKILLS: Students will …

KS 1.1.2 Plan and use time effectively in pursuit of accomplishing a goal without direct oversight.
KS 1.2.1 Ask new probing questions to expand and build upon an idea and explore personal curiosities throughout a creative process.
KS 1.2.2 Seek out and use feedback to improve work and positively influence one's personal and professional development.
KS 1.2.3 Reflect critically on past experiences to inform future progress.
KS 1.3.1 Demonstrate risk taking in engineering, scientific, or computational processes.
KS 1.4.1 Find relevant data in credible sources such as literature, databases, and policy documents.
KS 1.4.2 Collect, analyze, and interpret information relevant to the problem or opportunity at hand to support engineering decisions.
KS 1.4.4 Draw valid conclusions based on supporting evidence while acknowledging the limitations, opposing views, and biases.
KS 2.1.2 Define measurable visual, functional, and structural design requirements (criteria) and realistic constraints against which solution alternatives can be evaluated and optimized. [Note that criteria and constraints should include considerations of cost, safety, reliability, manufacturability, and aesthetics, as well as possible social, cultural, and

environmental impacts.]

KS 2.1.3 Apply effective techniques and appropriate guidelines to generate multiple creative ideas and potential solutions to a problem.

KS 2.1.4 Carry out a plan to compare competing solution ideas and justify the selection of a solution path with respect to design requirements and constraints.

KS 2.1.5 Develop a potential solution and implement a plan to test and evaluate the solution with respect to design criteria and constraints.

KS 2.1.6 Identify design flaws of and potential enhancements to a proposed design solution

KS 2.1.7 Strategically iterate steps of the design process to improve and optimize a solution.

KS 3.1.1 Develop a testable hypothesis, experimental controls and important variables (independent and dependent) address a problem or answer a question.

KS 3.1.2 Identify best strategies and appropriate tools for data collection, documentation, and analysis.

KS 3.1.3 Summarize the objective and relevancy of an experiment.

KS 3.1.4 Read and accurately follow established protocols and instructions.

KS 3.1.5 Identify possible sources of errors, if they exist, redesign and repeat the experiment when appropriate.

KS 3.2.4 Draw conclusions related to the hypothesis and support conclusions using experimental data.

KS 5.1.2 Develop a project schedule (with the critical path identified when appropriate), allocate tasks among team members, and track progress for successful completion of the project.

KS 7.3.2 Provide effective feedback to peers.

KS 8.1.1 According to best practices, effectively document engineering or scientific work in an organized notebook so someone unfamiliar with the work can follow and understand the process.

KS 8.1.2 Use sketches, tables, charts, and graphs when appropriate to clearly communicate information and in making arguments and claims in oral, written, and visual presentations.

KS 8.1.5 Present information, findings, and supporting evidence clearly, concisely, and logically, such that listeners can follow the line of reasoning and the organization, development, substance, and style are appropriate to purpose, audience, and task.

KS 10.1.1 Explain that all measurements are an approximation of the true value of a quantity.

KS 10.1.4 Choose a measurement device based on the level of precision and accuracy needed.

KS 10.2.1 Explain that friction is a force that opposes motion.

KS 10.2.2 Determine the coefficient of friction between two surfaces.

KS 10.2.3 Identify the force of friction between two interacting components in a mechanism, explain how the frictional force impacts the function and efficiency of the mechanism, and recommend design revisions to improve performance.

KS 10.3.2 List material properties that are important to design, including mechanical, chemical, electrical, and magnetic properties.

KS 10.3.3 Conduct non-destructive tests (e.g. hardness, flexure, conductivity) on different material types to investigate material properties.

KS 10.3.5 Select and justify the use of materials for prototyping and manufacturing products.

KS 10.4.1 Describe different types of motion (e.g. rotary, oscillating, linear, reciprocating, intermittent, and irregular).

KS 10.4.2 Explain how cams and followers can be used to move objects in periodic or irregular motion.

KS 10.4.3 Select and use simple mechanisms (e.g. cams, gears, pulleys and belts, sprockets and chains, springs, levers) to create and control motion to solve a problem.

KS 10.4.4 Use mechanisms in a design to transform a motion without changing its type (e.g. slow to fast rotary motion, magnifying linear movement, or changing axis of motion)

KS 12.1.1 Separate a complex process into multiple subprocesses that can be implemented in an organized way to complete the larger process.

KS 12.2.2 Write a set of ordered instructions (with or without a computer) involving multiple discrete steps to accomplish a complex task or achieve a desired result.

KS 12.4.1 Populate a spreadsheet application with data and organize the data to be useful in accomplishing a specific goal.

KS 12.4.2 Use the functions and tools within a spreadsheet application to manipulate, analyze, and present data in a useful way, including graphs, regression analyses, and descriptive statistical analyses.

KS 13.1.1 Recognize that models use abstraction to represent a simplified version of a complex phenomenon and there is no guarantee that the Recognize that models use abstraction to represent a simplified version of a complex phenomenon and there is no guarantee that the model accurately represents the real object or phenomenon. List differences (potential or real) between model behavior and the behavior of the real object, system, or process that it represents, and identify limitations of the model. (Limitations may include specific characteristics being studied, accuracy, precision, range of conditions, and so on.)

KS 13.1.2 Develop a model to accurately represent information or important characteristics of an object, data, process, or design idea for an intended purpose. [Notes on scope: the intended purpose may vary and could include organizing information to show relationships; providing a visual representation of the object/design to demonstrate how the object might “look”; a functional model to demonstrate the operation; a prototype of a specific component to test fit, performance, durability, or compatibility with other components in a system; and so on. The model could be a conceptual model, a mathematical model, a computer/virtual model, or a physical model, as appropriate for the testing scenario.]

KS 13.2.1 Build and/or use a mathematical model (algorithm, table of values, equation, graph) to represent data, describe relationships, describe processes, and to make predictions in the context of the problem. For example: create displacement/time graphs (Cartesian); create polar graphs to describe displacement caused by a cam (and cam shape).

KS 13.2.2 Represent data for two quantitative variables on a scatter plot, and describe how the variables are related.
KS 13.2.3 Fit a function to the data and use the function to solve problems and/or make predictions in the context of the data.
KS 13.2.4 In mathematical models, interpret the rate of change (slope) and the y-intercept (constant term) in the context of the data.
KS 13.3.2 Build a physical representation of an object or system based on graphical representations of the object or system. (Includes building solid objects, electrical circuits, mechanical devices, and complex systems according to technical drawings.)
KS 13.3.3 Hand sketch isometric views of a simple object or part at a given scale using the actual object, a detailed verbal description of the object, pictorial view of the object, or set of orthographic projections.
KS 13.3.6 Identify necessary/appropriate views to fully detail a part or assembly.
KS 13.4.3 Determine the allowance between two mating parts of an assembly based on dimensions given on a technical drawing
KS 13.4.4 Identify the need for and specify appropriate dimensions to create a clearance fit or interference fit where appropriate.
KS 13.5.1 Create a computer model to represent an object or conceptual idea and inform design decisions.
KS 13.5.2 Correctly build and constrain a three-dimensional solid computer model to accurately represent the physical characteristics and behaviors of a design idea or real object. Scope: This could include the appropriate application of geometric (horizontal, vertical, parallel, perpendicular, tangent, concentric) and dimensional constraints, as well as modeling other physical properties (density, color, texture, and so on).
KS 13.5.3 Create relationships among part features and dimensions using parametric formulas
KS 13.5.4 Correctly apply joints to constrain multi-component models and/or simulate realistic relative motion of the component parts.
KS 13.6.1 Generate an annotated multiview technical drawing using CAD software to fully describe a simple part.
KS 13.6.2 Apply appropriate and sufficient annotation (including dimensioning) methods to a drawing to fully describe an object or system using accepted technical drawing techniques.
KS 13.6.3 Generate an assembly drawing using CAD software to identify component parts and show details of assembly using part identification numbers, a parts list, and other annotations, as appropriate.

Core Instructional and Supplemental Materials

Project Lead the Way (PLTW) Curriculum
http://pltw.org

Engineering Design – An Introduction 2nd Edition
Karsnitz, O'Brien, Hutchinson, 2013 Delmar, Cengage Learning
ISBN-13: 978-1-111-64582-3 and ISBN-10: 1-111-64583-5

NEPRIS - Connecting Industry to Every Classroom
http://nepris.com.

Autodesk Inventor
http://autodesk.com

Fusion 360
http://autodesk.com

Lynda.com (Online Tutorials)
http://lynda.com

Teacher Notes:

• Most of this can be skipped, since the CAD design is the major goal of the class

Instructional Plan:	**Unit 4.3: Automating Motion**
Suggested Activities	**Resources "Project Lead The Way "**
Activities, Projects, and Problems (A P B)	**Knowledge / Skills**
4.3.1 Circuit Basics	KS 1.2.4, KS 1.3.1, KS 10.1.4, KS 10.3.5, KS 10.4.4, 10.5.1, KS 10.5.2, KS 13.1.2, KS 13.3.2,
4.3.2 Fun with Motors	KS 1.2.4, KS 1.3.1, KS 3.2.1, 10.5.1, KS 10.5.2, KS 12.4.1, KS 12.4.2, KS 13.1.2, KS 13.2.1 KS 13.2.2, KS 13.2.3 KS 13.2.4
4.3.3 Automata Redesign	KS 1.1.2, KS 1.2.3, KS 1.3.2, KS 8.1.2, KS 8.1.4, KS 8.1.5, KS 8.1.6, 10.5.1, KS 10.5.2, KS 11.1.1, KS 12.3.1, KS 13.3.2,

Evidence of Student Learning		
Activities (A) Projects (P) Problems (B)	**Assessment FOR Learning**	**Assessment OF Learning**
4.3.1 Circuit Basics (optional)	-- activity #1 - 8 -- activity #9 - 13	-- Design and build an electrical circuit that includes a DC power source, a motor, and a switch. -- Calculate and measure the resistance, current, and voltage of a circuit.
4.3.2 Fun with Motors (optional)	-- activity #1 - 4 -- activity #5 - 9	-- Design and build an electrical circuit that includes a variable resistance to control the speed of a mechanism. -- Organize and analyze data to make information usable.
4.3.3 Automata Redesign (optional)	-- Creation of design brief -- Completion of deliverables -- creation and use of decision matrix	-- Creation of design sketches -- Creation of prototype -- Collection and interpretation of data

DOMAIN / OBJECTIVES: Students will understand that …	
D1 Engineering Mindset	O1.1 Demonstrate independent thinking and self-direction in pursuit of accomplishing a goal O1.2 Demonstrate curiosity, creativity, flexibility, and adaptability to change. O1.3 Persevere to solve a problem or achieve a goal.
D3 Experimental Design	O3.2 Use appropriate statistical methods and visualization techniques to justify claims based on evidence
D8 Communication	O8.1 Communicate effectively with an audience based on audience characteristics.
D10 Engineering Science	O10.1 Using a variety of measuring devices, measure and report quantities accurately and to a precision appropriate for the purpose. O10.3 Apply basic materials science concepts to inform a design process O10.4 Understand how different machine elements influence motion of a mechanical system. O10.5 Integrate an electrical circuit with a machine to solve a problem.
D11 Systems Thinking	O11.1 Apply systems thinking to consider how an engineering problem and its solution may be thought of as containing subsystems and as being a sub-system of a larger system.

D12 Computational Thinking	O12.3 Formulate solutions that use automation to solve a problem. O12.4 Collect, organize, and analyze data to help define and/or solve a problem.
D13 Modeling	O13.1 Develop models and simulations to represent information, processes, and/or objects to an appropriate level of abstraction for the intended purpose. O13.2 Apply mathematical (including graphical) models and interpret the output of models to test ideas or make predictions O13.3 Use engineering graphics to represent physical objects.

KNOWLEDGE and SKILLS: Students will …

KS 1.1.2 Plan and use time effectively in pursuit of accomplishing a goal without direct oversight.
KS 1.2.3 Reflect critically on past experiences to inform future progress.
KS 1.2.4 Successfully adjust to changes that impact work. Adapt to varied roles, job responsibilities, and schedules.
KS 1.3.1 Demonstrate risk taking in engineering, scientific, or computational processes.
KS 1.3.2 Demonstrate persistence in accomplishing a difficult challenge.
KS 3.2.1 Graphically represent experimental data for a single count or measurement with charts and/or plots on the real number line, such as dot plots, box plots and histograms.
KS 8.1.2 Use sketches, tables, charts, and graphs when appropriate to clearly communicate information and in making arguments and claims in oral, written, and visual presentations.
KS 8.1.4 Present information, findings, and supporting evidence clearly, concisely, and logically in writing in which the development, organization, and style are appropriate to task, purpose, and audience.
KS 8.1.5 Present information, findings, and supporting evidence clearly, concisely, and logically, such that listeners can follow the line of reasoning and the organization, development, substance, and style are appropriate to purpose, audience, and task.
KS 8.1.6 Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence, and to add interest.
KS 10.1.4 Choose a measurement device based on the level of precision and accuracy needed.
KS 10.3.5 Select and justify the use of materials for prototyping and manufacturing products.
KS 10.4.4 Use mechanisms in a design to transform a motion without changing its type (e.g. slow to fast rotary motion, magnifying linear movement, or changing axis of motion)
KS 10.5.1 Calculate circuit resistance, current, and voltage within a circuit.
KS 10.5.2 Design and build an electrical circuit that includes a motor, a switch and variable resistance to power and control the speed of a mechanism.
KS 11.1.1 Describe a system in terms of its components and/or subsystems and their interactions. For example, describe the components of an electronic circuit, including source, path, and load; describe how an electronic circuit provides power to a larger system to produce mechanical motion; describe the subsystems of a building, including power system, communication system, lighting system, ventilation system, water system, sewer system, safety system, social system, transportation system, structural system, and so on; describe how the water system and sewer system interact in your home. Predict what the effect of making a change to a component of a system will have on the system as a whole.
KS 12.3.1 Automate a human-powered device using a mechanical and/or electrical system.
KS 12.4.1 Populate a spreadsheet application with data and organize the data to be useful in accomplishing a specific goal.
KS 12.4.2 Use the functions and tools within a spreadsheet application to manipulate, analyze, and present data in a useful way, including graphs, regression analyses, and descriptive statistical analyses.
KS 13.1.2 Develop a model to accurately represent information or important characteristics of an object, data, process, or design idea for an intended purpose. [Notes on scope: the intended purpose may vary and could include organizing information to show relationships; providing a visual representation of the object/design to demonstrate how the object might “look”; a functional model to demonstrate the operation; a prototype of a specific component to test fit, performance, durability, or compatibility with other components in a system; and so on. The model could be a conceptual model, a mathematical model, a computer/virtual model, or a physical model, as appropriate for the testing scenario.]
KS 13.2.1 Build and/or use a mathematical model (algorithm, table of values, equation, graph) to represent data, describe relationships, describe processes, and to make predictions in the context of the problem. For example: create displacement/time graphs (Cartesian); create polar graphs to describe displacement caused by a cam (and cam shape).
KS 13.2.2 Represent data for two quantitative variables on a scatter plot, and describe how the variables are related.
KS 13.2.3 Fit a function to the data and use the function to solve problems and/or make predictions in the context of the data.
KS 13.2.4 In mathematical models, interpret the rate of change (slope) and the y-intercept (constant term) in the context of the data.
KS 13.3.2 Build a physical representation of an object or system based on graphical representations of the object or system. (Includes building solid objects, electrical circuits, mechanical devices, and complex systems according to technical drawings.)

Core Instructional and Supplemental Materials	
Project Lead the Way (PLTW) Curriculum http://pltw.org **Engineering Design – An Introduction** 2nd Edition Karsnitz, O'Brien, Hutchinson, 2013 Delmar, Cengage Learning ISBN-13: 978-1-111-64582-3 and ISBN-10: 1-111-64583-5 **NEPRIS -** Connecting Industry to Every Classroom http://nepris.com.	**Autodesk Inventor** http://autodesk.com **Fusion 360** http://autodesk.com **Lynda.com** (Online Tutorials) http://lynda.com
Teacher Notes: • There will not be much time to complete this section • This section is a topic that we cover in POE	

Instructional Plan:	**Unit 4.4: Make it Move**
Suggested Activities	**Resources "Project Lead The Way "**
Activities, Projects, and Problems (A P B)	**Knowledge / Skills**
4.4.1 All Together Now	KS 1.1.2, KS 1.1.3, KS 1.2.3, KS 1.2.4, KS 1.3.1, KS 2.1.1, KS 2.1.2, KS 2.1.3, KS 2.1.4, KS 2.1.5, KS 2.1.6, KS 5.1.1, KS 5.1.3, KS 7.1.3, KS 7.2.3, KS 7.2.4, KS 7.3.2, KS 8.1.1, KS 8.1.5, KS 8.1.6, KS 9.1.6, KS 10.2.3, KS 10.4.3, KS 10.4.4, KS 10.5.2, KS 11.1.1, KS 13.1.2, KS 13.3.2, KS 13.5.1, KS 13.5.2, KS 13.5.3, KS 13.5.4 KS 13.6.2, KS 13.6.3
4.4.1 Move with a Purpose [alternate]	KS 1.1.2, KS 1.1.3, KS 1.2.3, KS 1.2.4, KS 1.3.1, KS 2.1.1, KS 2.1.2, KS 2.1.3, KS 2.1.4, KS 2.1.5, KS 2.1.6, KS 5.1.1, KS 5.1.3, KS 7.1.3, KS 7.2.3, KS 7.2.4, KS 7.3.2, KS 8.1.1, KS 8.1.5, KS 8.1.6, KS 9.1.6, KS 10.2.3, KS 10.4.3, KS 10.4.4, KS 10.5.2, KS 11.1.1, KS 13.1.2, KS 13.3.2, KS 13.5.1, KS 13.5.2, KS 13.5.3, KS 13.5.4 KS 13.6.2, KS 13.6.3
4.4.2 Engineering for Change [optional]	KS 1.1.2, KS 1.1.3, KS 1.2.3, KS 1.2.4, KS 1.3.1, KS 1.4.2, KS 2.1.1, KS 2.1.2, KS 2.1.3, KS 2.1.4, KS 2.1.5, KS 2.1.6, KS 4.2.2, KS 5.1.1, KS 5.1.3, KS 7.1.3, KS 7.2.3, KS 7.2.4, KS 7.3.2, KS 8.1.1, KS 8.1.5, KS 8.1.6, KS 11.1.1, KS 13.1.2, KS 13.3.2, KS 13.6.2, KS 13.6.3

Evidence of Student Learning		
Activities (A) Projects (P) Problems (B)	**Assessment FOR Learning**	**Assessment OF Learning**
4.4.1 All Together Now (optional)	-- activity #1 - 11 -- activity #12 - 16	-- Apply systems thinking to consider how an engineering problem and its solution may be thought of as containing a subsystem and as being a subsystem of a larger system. -- Understand how different machine elements influence motion of a mechanical system. -- Integrate an electrical circuit with a machine to solve a problem.
4.4.1 Move with a Purpose [alternate]	-- activity #1 - 11 -- activity #12 - 16	-- Apply systems thinking to consider how an engineering problem and its solution may be thought of as containing a subsystem and as being a subsystem of a larger system. -- Understand how different machine elements influence motion of a mechanical system. -- Integrate an electrical circuit with a machine to solve a problem.
4.4.2 Engineering for Change (optional)	-- Creation of design brief -- Completion of deliverables -- creation and use of decision matrix	-- Creation of design sketches -- Creation of prototype -- Collection and interpretation of data

DOMAIN / OBJECTIVES: Students will understand that …	
D1 Engineering Mindset	O1.1 Demonstrate independent thinking and self-direction in pursuit of accomplishing a goal O1.2 Demonstrate curiosity, creativity, flexibility, and adaptability to change. O1.3 Persevere to solve a problem or achieve a goal.
D2 Design Process	O2.1 Apply an iterative design process to creatively address a need or solve a problem
D5 Project Management	O5.1 Apply project management tools when designing and developing a solution to successfully deliver a product using available resources.
D7 Collaboration	O7.1 Facilitate an effective team environment to promote successful goal attainment. O7.2 Contribute individually to overall collaborative efforts. O7.3 Analyze and evaluate the work of others to provide helpful feedback.
D8 Communication	O8.1 Communicate effectively with an audience based on audience characteristics.
D9 Engineering Design	O9.1 Analyze a consumer product using reverse engineering techniques to document visual, functional, and structural aspects of the design.
D10 Engineering Science	O10.2 Apply scientific knowledge related to frictional forces, to solve a problem or design a physical system. O10.4 Understand how different machine elements influence motion of a mechanical system. O10.5 Integrate an electrical circuit with a machine to solve a problem.

D11 Systems Thinking	O11.1 Apply systems thinking to consider how an engineering problem and its solution may be thought of as containing subsystems and as being a sub-system of a larger system.
D13 Modeling	O13.1 Develop models and simulations to represent information, processes, and/or objects to an appropriate level of abstraction for the intended purpose. O13.3 Use engineering graphics to represent physical objects. O13.5 Create and interpret a computer model or simulation of simple objects, assemblies, or systems to inform engineering decisions and solve problems. O13.6 Create technical drawings using 3D computer-aided design (CAD) software to document a design according to standard engineering practices.

KNOWLEDGE and SKILLS: Students will …

KS 1.1.2 Plan and use time effectively in pursuit of accomplishing a goal without direct oversight.
KS 1.1.3 Make and execute a plan to gain additional knowledge and learning to accomplish a goal.
KS 1.2.3 Reflect critically on past experiences to inform future progress.
KS 1.2.4 Successfully adjust to changes that impact work. Adapt to varied roles, job responsibilities, and schedules.
KS 1.3.1 Demonstrate risk taking in engineering, scientific, or computational processes.
KS 2.1.1 Synthesize an ill-formed problem into a meaningful, well-defined problem using relevant information
KS 2.1.2 Define measurable visual, functional, and structural design requirements (criteria) and realistic constraints against which solution alternatives can be evaluated and optimized. [Note that criteria and constraints should include considerations of cost, safety, reliability, manufacturability, and aesthetics, as well as possible social, cultural, and environmental impacts.]
KS 2.1.3 Apply effective techniques and appropriate guidelines to generate multiple creative ideas and potential solutions to a problem.
KS 2.1.4 Carry out a plan to compare competing solution ideas and justify the selection of a solution path with respect to design requirements and constraints.
KS 2.1.5 Develop a potential solution and implement a plan to test and evaluate the solution with respect to design criteria and constraints.
KS 2.1.6 Identify design flaws of and potential enhancements to a proposed design solution
KS 5.1.1 Define the project deliverables and constraints, such as scope, time, cost, quality, resources, and risk.
KS 5.1.3 Select and use collaborative tools, such as cloud-based tools, document sharing, and video and text functions, to successfully complete a project.
KS 7.1.3 Develop ideas and create products through positive interdependence among all teammates.
KS 7.2.3 Present all work to be/being done individually in a timely manner to the team to gather feedback, inform revision, and gain consensus.
KS 7.2.4 Critically and realistically self-evaluate personal contributions and collaboration effectiveness within a team. [ongoing]
KS 7.3.2 Provide effective feedback to peers.
KS 8.1.1 According to best practices, effectively document engineering or scientific work in an organized notebook so someone unfamiliar with the work can follow and understand the process.
KS 8.1.5 Present information, findings, and supporting evidence clearly, concisely, and logically, such that listeners can follow the line of reasoning and the organization, development, substance, and style are appropriate to purpose, audience, and task.
KS 8.1.6 Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence, and to add interest.
KS 9.1.6 Identify joints that allow movement between interfacing parts in an assembly and the degrees of freedom that it removes from the movement between parts (including slots, hinges, ball and socket, rotating knobs).
KS 10.2.3 Identify the force of friction between two interacting components in a mechanism, explain how the frictional force impacts the function and efficiency of the mechanism, and recommend design revisions to improve performance.
KS 10.4.3 Select and use simple mechanisms (e.g. cams, gears, pulleys and belts, sprockets and chains, springs, levers) to create and control motion to solve a problem.
KS 10.4.4 Use mechanisms in a design to transform a motion without changing its type (e.g. slow to fast rotary motion, magnifying linear movement, or changing axis of motion)
KS 10.5.2 Design and build an electrical circuit that includes a motor, a switch and variable resistance to power and control the speed of a mechanism.
KS 11.1.1 Describe a system in terms of its components and/or subsystems and their interactions. For example, describe the components of an electronic circuit, including source, path, and load; describe how an electronic circuit provides power to a larger system to produce mechanical motion; describe the subsystems of a building, including power system, communication system, lighting system, ventilation system, water system, sewer system, safety system, social system, transportation system, structural system, and so on; describe how the water system and sewer system interact in your home. Predict what the effect of making a change to a component of a system will have on the system as a whole.

KS 12.3.1 Automate a human-powered device using a mechanical and/or electrical system.
KS 13.1.2 Develop a model to accurately represent information or important characteristics of an object, data, process, or design idea for an intended purpose. [Notes on scope: the intended purpose may vary and could include organizing information to show relationships; providing a visual representation of the object/design to demonstrate how the object might "look"; a functional model to demonstrate the operation; a prototype of a specific component to test fit, performance, durability, or compatibility with other components in a system; and so on. The model could be a conceptual model, a mathematical model, a computer/virtual model, or a physical model, as appropriate for the testing scenario.]
KS 13.2.1 Build and/or use a mathematical model (algorithm, table of values, equation, graph) to represent data, describe relationships, describe processes, and to make predictions in the context of the problem. For example: create displacement/time graphs (Cartesian); create polar graphs to describe displacement caused by a cam (and cam shape).
KS 13.3.2 Build a physical representation of an object or system based on graphical representations of the object or system. (Includes building solid objects, electrical circuits, mechanical devices, and complex systems according to technical drawings.)
KS 13.5.1 Create a computer model to represent an object or conceptual idea and inform design decisions.
KS 13.5.2 Correctly build and constrain a three-dimensional solid computer model to accurately represent the physical characteristics and behaviors of a design idea or real object. Scope: This could include the appropriate application of geometric (horizontal, vertical, parallel, perpendicular, tangent, concentric) and dimensional constraints, as well as modeling other physical properties (density, color, texture, and so on).
KS 13.5.3 Create relationships among part features and dimensions using parametric formulas
KS 13.5.4 Correctly apply joints to constrain multi-component models and/or simulate realistic relative motion of the component parts.
KS 13.6.1 Generate an annotated multiview technical drawing using CAD software to fully describe a simple part.
KS 13.6.2 Apply appropriate and sufficient annotation (including dimensioning) methods to a drawing to fully describe an object or system using accepted technical drawing techniques.
KS 13.6.3 Generate an assembly drawing using CAD software to identify component parts and show details of assembly using part identification numbers, a parts list, and other annotations, as appropriate.

Core Instructional and Supplemental Materials

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http://pltw.org

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NEPRIS - Connecting Industry to Every Classroom
http://nepris.com.

Autodesk Inventor
http://autodesk.com

Fusion 360
http://autodesk.com

Lynda.com (Online Tutorials)
http://lynda.com

Teacher Notes:

- There will not be much time to complete this section
- This section is a topic that we cover in POE