Lakewood High School

Department of Engineering Technology

Engineering Design and Development
Curriculum [EDD]
(2022 update)

Original Adoption:	September 20, 2019
Created by:	PLTW – Project Lead the Way
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Engineering Design and Development-21 Curriculum	
Content Area: Engineering	
Course Title: Engineering Design and Development	**Grade Level:** 12
Component 0: Project Management	1 week
Component 1: Researching a Problem [A] Identification and Justification of the Problem [B] Documentation and Analysis of Prior Solution Attempts [C] Presentation and Justification of Solution Requirements	 2 weeks
Component 2: Designing a Solution [D] Design Concept Generation, Analysis, and Selection [E] Application of STEM Principles and Practices [F] Consideration of Design Viability	 2 weeks 2 – 3 days 1 week
Component 3: Creating a Prototype and Testing Plan [G] Construction of a Testable Prototype [H] Prototype Testing and Data Collection Plan [I] Testing, Data Collection, and Analysis	 3 – 4 weeks 1 – 2 weeks 1 – 2 weeks
Component 4: Evaluation and Reflection on the Design Process [J] Documentation of External Evaluation [K] Reflection on the Design Project [L] Presentation of Designer's Recommendations	 2 weeks 1 week 1 week
Component 5: Presentation of the Design Process [M] Presentation of the Project and Project Portfolio [N] Writing Like an Engineer	 2 weeks 2 weeks
Component 6: Going Beyond Engineering Design and Development (EDD)	2 – 3 weeks
Component 7: Mini projects	1 – 2 weeks each

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.

Engineering Design and Development (EDD) is the capstone course in the PLTW high school engineering program. It is an open-ended engineering research course in which students work in teams to design and develop an original solution to a well-defined and justified open-ended problem by applying an engineering design process.

Students will perform research to select, define, and justify a problem. After carefully defining the design requirements and creating multiple solution approaches, teams of students select an approach, create, and test their solution prototype. Student teams will present and defend their original solution to an outside panel. While progressing through the engineering design process, students will work closely with experts and will continually hone their organizational, communication and interpersonal skills, their creative and problem solving abilities, and their understanding of the design process.

Engineering Design and Development is a high school level course that is appropriate for 12th grade students. Since the projects on which students work can vary with student interest and the curriculum focuses on problem solving, EDD is appropriate for students who are interested in any technical career path. EDD should be taken as the final capstone PLTW course since it requires application of the knowledge and skills introduced during the PLTW foundation courses.

Students taking this course will complete their SLE by going out to a business. These students will have a few options to complete this career component, such as doing a PAL placement during their senior year or being assigned to Ocean County College (OCC), to be placed into one of their programs.

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.

Number Standard	**Statement**
	ARCHITECTURE & CONSTRUCTION CAREER CLUSTER®
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.
MARKETING CAREER CLUSTER®	
CAREER CLUSTER®:	**MARKETING (MK)**
9.3.MK.2	Implement marketing research to obtain and evaluate information for the creation of a marketing plan.
PATHWAY:	**MARKETING RESEARCH (MK-RES)**
9.3.MK-RES.2	Design and conduct research activities to facilitate marketing business decisions.
9.3.MK-RES.3	Use information systems and tools to make marketing research decisions.
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

Core Instructional and Supplemental Materials

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

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

VEX® Robotics platform
https://www.vexrobotics.com/

Logger Pro® - Data collection and analysis software
https://www.vernier.com/

ROBOTC® - Robot programming language
http://www.robotc.net/

Principles of Engineering
Brett Handley, Craig Coon, and David M. Marshall
Developed specifically for the PLTW POE course to support lesson concepts.© 2002

Mini Projects:
- Clawbot Coding Search
- Water Purification Project
- School Beautification Project [optional]
- Disney Research Assignment [individual]
- "As seen on TV" Project

Videos:
- Deep Dive [an ABC news report on IDEO]
- Flash of Genius [intermittent wiper creator]
- Ted Talks
  - -- 13 must see Ted Talks for engineers [element A]
  - -- Nikolai Begg [element C]
  - -- Design for an outcome [element F]
  - -- Primer on 3D printing – Lisa Harouni [element G]

Component 0	Project Management	Duration: 15 days

Standards/Learning Targets

Focus Standards (Major Standards)

HS.ESS3.2 - Earth and Human Activity - Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.

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.

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. **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 - 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. - Plan and conduct an investigation or test a design solution in a safe and ethical manner including considerations of environmental, social, and personal impacts.	**DCI - ETS1.A** - Engineering Design - 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. (secondary to HS-PS2-3) **DCI - ETS1.A** - Engineering Design - Defining and Delimiting Engineering Problems - 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. (HS-ETS1-1)	**Systems and System Models** - Systems can be designed to do specific tasks.

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. - Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. - 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 contradictions. - Construct, use, and/or present an oral and written argument or counter-arguments based on data and 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. - 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.R.1 - 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.2 -** Determine central ideas or themes of a text and analyze their development; summarize the key supporting details and ideas.

AS.R.4 - Interpret words and phrases as they are used in a text, including determining technical, connotative, and figurative meanings, and analyze how specific word choices shape meaning or tone.
AS.R.10 - Read and comprehend complex literary and informational texts independently and proficiently.
AS.W.1 - Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.
AS.W.2 - 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 - Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
AS.W.5 - Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach.
AS.W.6 –Use technology, including the Internet, to produce and publish writing and to interact and collaborate with others.
AS.W.7 - Conduct short as well as more sustained research projects based on focused questions, demonstrating understanding of the subject under investigation.
AS.W.8 - 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 - Draw evidence from literary or informational texts to support analysis, reflection, and research.
AS.W.10 - 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 - 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 - Integrate and evaluate information presented in diverse media and formats, including visually, quantitatively, and orally.
AS.SL.3 - Evaluate a speaker's point of view, reasoning, and use of evidence and rhetoric.
AS.SL.4 - 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 - Make strategic use of digital media and visual displays of data to express information and enhance understanding of presentations.
AS.SL.6 - Adapt speech to a variety of contexts and communicative tasks, demonstrating command of formal English when indicated or appropriate.
AS.L.1 –Demonstrate command of the conventions of standard English grammar and usage when writing or speaking.
AS.L.2 - Demonstrate command of the conventions of standard English capitalization, punctuation, and spelling when writing.
AS.L.3 - Apply knowledge of language to understand how language functions in different contexts, to make effective choices for meaning or style, and to comprehend more fully when reading or listening.
AS.L.4 - Determine or clarify the meaning of unknown and multiple-meaning words and phrases by using context clues, analyzing meaningful word parts, and consulting general and specialized reference materials, as appropriate.
AS.L.5 - Demonstrate understanding of word relationships and nuances in word meanings.
AS.L.6 - 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.

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.

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.

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

S.ID.2 - Use statistics appropriate to the shape of the data distribution to compare center (median, mean) and spread (interquartile range, standard deviation) of two or more different data sets.

S.ID.3 - Interpret differences in shape, center, and spread in the context of the data sets, accounting for possible effects of extreme data points (outliers).

S.ID.4 - 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.

S.ID.5 - Interpreting Categorical and Quantitative Data - Summarize categorical data for two categories in two-way frequency tables. Interpret relative frequencies in the context of the data (including joint, marginal, and conditional relative frequencies). Recognize possible associations and trends in the data.

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.b - Interpreting Categorical and Quantitative Data - Informally assess the fit of a function by plotting and analyzing residuals.

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.ID.9 - Interpreting Categorical and Quantitative Data - Distinguish between correlation and causation.

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.

S.IC.2 - Making Inferences and Justifying Conclusions - Decide if a specified model is consistent with results from a given data-generating process, e.g., using simulation. For example, a model says a spinning coin falls heads up with probability 0.5. Would a result of 5 tails in a row cause you to question the model?

S.IC.3 - Making Inferences and Justifying Conclusions - Recognize the purposes of and differences among sample surveys, experiments, and observational studies; explain how randomization relates to each.

S.IC.5 - Making Inferences and Justifying Conclusions - Use data from a randomized experiment to compare two treatments; use simulations to decide if differences between parameters are significant.

S.IC.6 - Making Inferences and Justifying Conclusions - Evaluate reports based on data.

Instructional Plan – Component 0: Project Management

Suggested Activities	Resources "Project Lead The Way "
Activities (A) Projects (P) Problems (B)	**UNDERSTANDINGS: Students will understand that …**
Component 0 is the only component not defined in the EDPPSR evaluation tool. It is meant to be a guide and a toolbox that will help you and your students manage the project. Five resource areas are found in Component 0: • **Resource (α) Alpha –** The EDD Design Process and Project Management • **Resource (β) Beta –** Documenting the Engineering Design Process • **Resource (γ) Gamma –** Teams, Timelines, and Contacting Experts • **Resource (δ) Delta –** Project Evaluations and Classroom Management • **Resource (ε) Epsilon –** Intellectual Property You will address many of these resources in the beginning and continue to refer back to Component 0 throughout the year.	D1 Engineering Mindset: Successful engineers typically exhibit specific personal and professional characteristics that lend themselves to the creative, collaborative, and solution-driven nature of the profession. D2 Design Process: An engineering design process is an iterative, systematic approach to problem solving. D4 Collaboration: Demonstrate an ability to function on multidisciplinary teams. D5 Communication: Engineering practice requires effective communication with a variety of audiences using multiple modalities

ESSENTIAL QUESTIONS: Students will keep considering …	
C0.1 Why do companies advertise the positive ecological and sustainable design attributes of products? C0.2 How do you decide what key points are most important when given limited time to present findings? C0.3 Why is it crucial to use a design process when trying to solve complex problems? C0.4 What are attributes of successful project planning and management? C0.5 Why is it important for engineers and designers to utilize known scientific and mathematical principles? C0.6 What negative issues does successful project planning and management potentially prevent? C0.7 Why is teaming often more effective than individuals working alone when solving a complex problem? C0.8 Why is it crucial to use a design process when trying to solve complex problems?	C0.9 What are the roles and responsibilities of engineering in society? C0.10 What justifies expenditure of resources to try and solve a problem? C0.11 What are the critical checkpoints in a design process?

KNOWLEDGE / Skills: Students will …

O1.1 Demonstrate independent thinking and self-direction in pursuit of accomplishing a goal.
- **KS1.1.1** List and prioritize goals with tangible success criteria.
- **KS1.1.2** Plan and use time in pursuit of accomplishing a goal without direct oversight.
- **KS1.1.3** Plan how to gain additional knowledge and learning to accomplish a goal.

O1.2 Demonstrate flexibility and adaptability to change.

KS1.2.1 Adapt to varied roles, job responsibilities, schedules, and contexts.

O1.3 Persevere to solve a problem or achieve a goal..

KS1.3.1 Describe why persistence is important when identifying a problem and/or pursuing solutions.

KS1.3.2 Accept failure as part of an evolution of individual growth and necessary to the expansion of the engineering profession

KS1.3.3 Reflect critically on past experiences to inform future progress.

O2.1 Explain and justify an engineering design process.

KS2.1.1 Explain that there are many versions of a design process that describe essentially the same process

KS2.1.2 Describe major steps of a design process and identify typical tasks involved in each step.

KS2.1.3 Identify the step in which an engineering task would fit in a design process.

KS2.1.4 Outline how iterative processes inform engineering decisions, improve solutions, and inspire new ideas.

KS2.1.5 Document a design process in an engineering notebook according to best practices.

O2.2 Collect, analyze, and interpret information relevant to the problem or opportunity at hand to support engineering decisions.

KS2.2.1 Explain the role of research in the process of design.

KS2.2.2 Find relevant data in credible sources such as literature, databases, and policy documents.

KS2.2.3 Explain the role of stakeholders and subject matter experts in the design process.

KS2.2.4 Describe criteria for determining the reliability and credibility of information.

O2.3 Synthesize an ill-formed problem into a meaningful, well-defined problem.

KS2.3.1 . Explain the importance of carefully and specifically defining a problem or opportunity, design criteria, and constraints, to develop successful design solutions.

KS2.3.3 List potential constraints that may impact the success of a design solution. Examples include economic (cost), environmental, social, political, ethical, health and safety, manufacturability, technical feasibility, and sustainability

O2.4 Generate multiple potential solution concepts.

KS2.4.1 Describe multiple techniques and appropriate guidelines used to generate ideas.

O2.5 Develop models to represent design alternatives and generate data to inform decision making, test alternatives, and demonstrate solutions.

KS2.5.1 Describe the use of a model to accurately represent the key aspects of a physical system. Include the identification of constraints, such as cost, time, or expertise that may influence the selection of a model.

KS2.5.2 Define various types of models that can be used to represent products, processes, or designs, such as physical prototypes, mathematical models, and virtual representations. Explain the purpose and appropriate use of each.

O2.6 Select a solution path from many options to successfully address a problem or opportunity.

KS2.6.1 Explain that there are often multiple viable solutions and no obvious best solution. Trade-offs must be considered and evaluated consistently throughout an engineering design process.

KS2.6.2 Develop and carry out a justifiable scheme to compare and evaluate competing solutions paths. A decision matrix is one tool used to compare and evaluate competing solutions based on design criteria.

O2.7 Make judgments and decisions based on evidence.

KS2.7.2 Evaluate evidence and arguments to identify deficiencies, limitations, and biases or appropriate next steps in the pursuit of a better solution.

O4.1 Facilitate an effective team environment to promote successful goal attainment.

KS4.1.1 Describe the various individual roles and interdependencies of a collaborative team.

O4.2 Contribute individually to overall collaborative efforts.

KS4.2.1 Critically and realistically self-evaluate personal contributions and collaboration effectiveness within a team.

O4.3 Analyze and evaluate the work of others to provide helpful and effective feedback.

KS4.3.2 Describe the characteristics of effective feedback.

O4.4 Manage project timelines and resources as part of an engineering design process.

KS4.4.3 Select and use a system of collaborative tools, such as cloud-based tools, document sharing, and video and text functions, to successfully complete a project.

O5.1 Communicate effectively with an audience based on audience characteristics.

KS5.1.1 Adhere to established conventions of written, oral and electronic communications (grammar, spelling, usage, and mechanics).

KS5.1.2 Follow acceptable formats for technical writing and professional presentations.

KS5.1.3 Describe how the size and characteristics of an audience will affect communication.

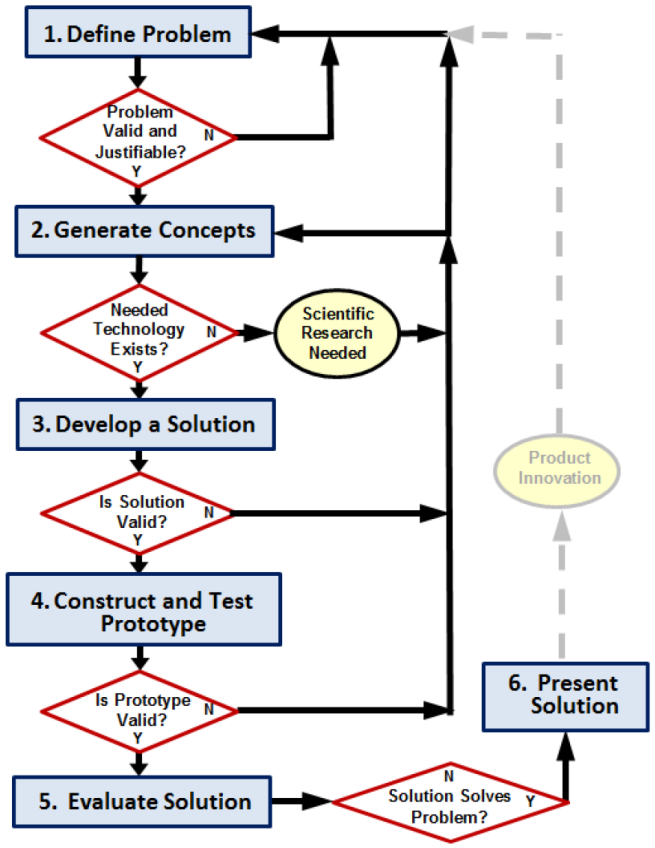
KS5.1.4 Modify the content, format, level of technical detail, and length of communications to meet the needs of the audience.

KS5.1.5 Properly cite references for all communication in an accepted format. Clearly label tables and figures with units and explain the information presented in context.
KS5.1.6 Describe characteristics important to oral delivery of information (volume, tempo, eye contact, articulation, and energy). Vary these elements of delivery to convey and emphasize information and engage the audience.
KS5.1.7 Describe characteristics important to oral delivery of information (volume, tempo, eye contact, articulation, and energy). Vary these elements of delivery to convey and emphasize information and engage the audience.

Evidence of Student Learning		
Activities (A) Projects (P) Problems (B)	**Assessment FOR Learning**	**Assessment OF Learning**
(α) Alpha – The EDD Design Process and Project Management	• EDPPSR evaluation tool. • Engineering Book Check	• Deliverable
What is EDD	• Engineering Book Check	• Deliverable
Design Process	• Engineering Book Check	• Deliverable
(β) Beta – Documenting the Engineering Design Process	• EDPPSR evaluation tool. • Engineering Book Check	• Deliverable
Innovation Portal / Journal	• EDPPSR evaluation tool.	• Deliverable
(γ) Gamma – Teams, Timelines, and Contacting Experts	• EDPPSR evaluation tool. • Engineering Book Check	• Deliverable
Choosing Teams / Team Norms	• EDPPSR evaluation tool.	• Deliverable
Time Management	• EDPPSR evaluation tool.	• Gantt Chart
Contacts	• APC format	• Deliverable
(δ) Delta – Project Evaluations and Classroom Management	• EDPPSR evaluation tool. • Engineering Book Check	• Deliverable
Proposal		• Deliverable
(ε) Epsilon – Intellectual Property	• EDPPSR evaluation tool. • Engineering Book Check	• Deliverable
Intellectual Property		• Deliverable
Unit Assessment Items Summative – EoC	-- All items	-- All items

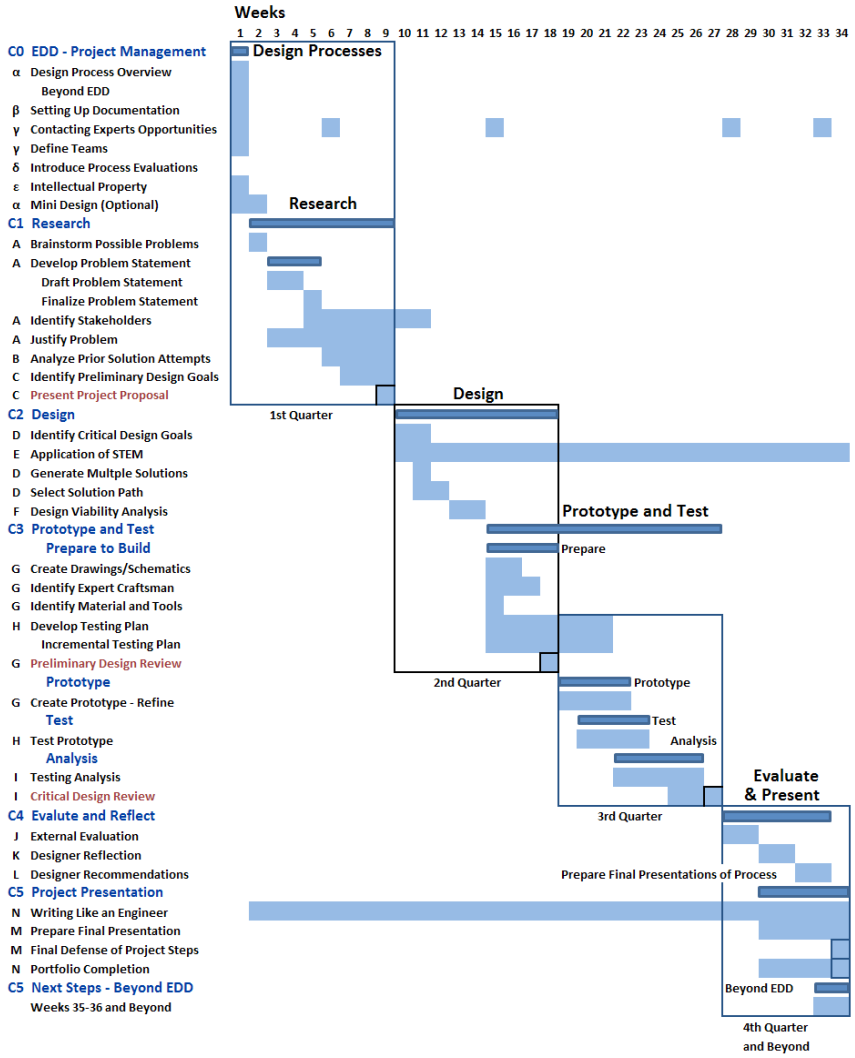
PLTW | Engineering

Design Process



Planning and Project Timeline
Engineering Design and Development

PLTW



Core Instructional, References and Supplemental Materials
Abts, Leigh. (2011). *Analysis of the barriers, constraints and issues for dual credit and/or an Advanced Placement pathway for introduction to engineering*. American Society for Engineering Education. **Foreman, L. J., & Welytok, J. G. (2009).** *The independent inventor's handbook*. New York, NY: Workman Publishing Company, Inc. **Grissom, F. E., & Pressman, D. (2008).** *Inventor's notebook*: *A patent it yourself companion*. (5th ed.). Berkely, CA: Nolo. **Industrial Designers Society of America. (2009). Okala:** *Learning ecological design*. Phoenix, AZ. **International Technology Education Association. (2000).** Reston, VA: ITEA. **InvestorWords.com. (n.d.).** Retrieved from **http://www.investorwords.com/** **Pressman, D. (2009).** *Patent it yourself*. (14th ed.). Berkely, CA: Nolo **Ulrich, K. T., & Eppinger, S. D. (2008).** *Product design and development*. New York, NY: McGraw Hill. **Williams, M. (2008).** *The principles of project management*. Victoria, Australia: SitePoint Pty. Ltd.
Teacher Notes:

Component 1	Researching a Problem	**Duration:** 30 days

Standards/Learning Targets

Focus Standards (Major Standards)

HS.ESS3.1 - Earth and Human Activity - Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.
HS.ESS3.2 - Earth and Human Activity - Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.
HS.ESS3.5 - Earth and Human Activity - Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.
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 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. - 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. **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. - Design a test of a model to ascertain its reliability. - Develop, revise, and/or use a model based on	**DCI - ETS1.A** - Engineering Design - 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. (secondary to HS-PS2-3) **DCI - ETS1.A** - Engineering Design - Defining and Delimiting Engineering Problems - 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. (HS-ETS1-1)	**Patterns** - Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them. - 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. - Classifications or explanations used at one scale may fail or need revision when information from smaller or larger scales is introduced; thus requiring improved investigations and experiments. - Patterns of performance of designed systems can be analyzed and interpreted to reengineer and improve the system. - Mathematical representations are needed to identify some patterns. - Empirical evidence is needed to identify patterns. **Cause and Effect: Mechanism and Prediction** - Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. - Cause and effect relationships can be suggested

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. - Develop a complex model that allows for manipulation and testing of a proposed process or system. - Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems. **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 - 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. - Plan and conduct an investigation or test a design solution in a safe and ethical manner including considerations of environmental, social, and personal impacts. - 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. **Constructing Explanations and Designing Solutions** - Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories		and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. - 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. **Stability and Change** - Much of science deals with constructing explanations of how things change and how they remain stable.

and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. - Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. - Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. - 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. - Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. - 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 contradictions. - Construct, use, and/or present an oral and written argument or counter-arguments based on data and 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. - 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). **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. - Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible. Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (i.e., orally, graphically, textually, mathematically).		

Supporting and Additional Standards
English Language Arts
S.R.1 - 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.2 -** Determine central ideas or themes of a text and analyze their development; summarize the key supporting details and ideas. **AS.R.4 -** Interpret words and phrases as they are used in a text, including determining technical, connotative, and figurative meanings, and analyze how specific word choices shape meaning or tone. **AS.R.6** - Assess how point of view or purpose shapes the content and style of a text. **AS.R.7** - Integrate and evaluate content presented in diverse formats and media, including visually and quantitatively, as well as in words. **AS.R.8** - Delineate and evaluate the argument and specific claims in a text, including the validity of the reasoning as well as the relevance and sufficiency of the evidence. **AS.R.9** - Analyze how two or more texts address similar themes or topics in order to build knowledge or to compare the approaches the authors take. **AS.R.10 -** Read and comprehend complex literary and informational texts independently and proficiently. **AS.W.1 -** Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence. **AS.W.2 -** 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.3** - Write narratives to develop real or imagined experiences or events using effective technique, well-chosen details, and well-structured event sequences. **AS.W.4 -** Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. **AS.W.5 -** Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach. **AS.W.6 –Use technology, including the Internet, to produce and publish writing and to interact and collaborate with others.** **AS.W.7 -** Conduct short as well as more sustained research projects based on focused questions, demonstrating understanding of the subject under investigation.

AS.W.8 - 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 - Draw evidence from literary or informational texts to support analysis, reflection, and research.
AS.W.10 - 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 - 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 - Integrate and evaluate information presented in diverse media and formats, including visually, quantitatively, and orally.
AS.SL.3 - Evaluate a speaker's point of view, reasoning, and use of evidence and rhetoric.
AS.SL.4 - 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 - Make strategic use of digital media and visual displays of data to express information and enhance understanding of presentations.
AS.SL.6 - Adapt speech to a variety of contexts and communicative tasks, demonstrating command of formal English when indicated or appropriate.
AS.L.1 –Demonstrate command of the conventions of standard English grammar and usage when writing or speaking.
AS.L.2 - Demonstrate command of the conventions of standard English capitalization, punctuation, and spelling when writing.
AS.L.3 - Apply knowledge of language to understand how language functions in different contexts, to make effective choices for meaning or style, and to comprehend more fully when reading or listening.
AS.L.4 - Determine or clarify the meaning of unknown and multiple-meaning words and phrases by using context clues, analyzing meaningful word parts, and consulting general and specialized reference materials, as appropriate.
AS.L.5 - Demonstrate understanding of word relationships and nuances in word meanings.
AS.L.6 - 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.

Mathematics

N.Q.1 - 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 - Define appropriate quantities for the purpose of descriptive modeling.

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

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

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

A.REI.10 - 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.4 - For a function that models a relationship between two quantities, interpret key features of graphs and tables in terms of the quantities, and sketch graphs showing key features given a verbal description of the relationship. Key features include: intercepts; intervals where the function is increasing, decreasing, positive, or negative; relative maximums and minimums; symmetries; end behavior; and periodicity.

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.LE.1 - Linear, Quadratic, and Exponential Models Distinguish between situations that can be modeled with linear functions and with exponential functions.

F.LE.1.b - Recognize situations in which one quantity changes at a constant rate per unit interval relative to another.

F.LE.1.c - Recognize situations in which a quantity grows or decays by a constant percent rate per unit interval relative to another.

F.LE.3 - Observe using graphs and tables that a quantity increasing exponentially eventually exceeds a quantity increasing linearly, quadratically, or (more generally) as a polynomial function.

F.LE.5 - Interpret the parameters in a linear or exponential function in terms of a context.

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

S.ID.2 - Use statistics appropriate to the shape of the data distribution to compare center (median, mean) and spread (interquartile range, standard deviation) of two or more different data sets.

S.ID.3 - Interpret differences in shape, center, and spread in the context of the data sets, accounting for possible effects of extreme data points (outliers).

S.ID.4 - 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.

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

S.ID.6.b - Informally assess the fit of a function by plotting and analyzing residuals.

S.ID.6.c - Fit a linear function for a scatter plot that suggests a linear association.

S.ID.9 - Distinguish between correlation and causation.

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

S.IC.3 - Recognize the purposes of and differences among sample surveys, experiments, and observational studies; explain how randomization relates to each.

S.IC.4 - Use data from a sample survey to estimate a population mean or proportion; develop a margin of error through the use of simulation models for random sampling.

S.IC.6 - Evaluate reports based on data.

S.MD.5 - (+) Weigh the possible outcomes of a decision by assigning probabilities to payoff values and finding expected values.

S.MD.5.b - Evaluate and compare strategies on the basis of expected values. For example, compare a high-deductible versus a low-deductible automobile insurance policy using various, but reasonable, chances of having a minor or a major accident.

S.MD.6 - (+) Use probabilities to make fair decisions (e.g., drawing by lots, using a random number generator).

S.MD.7 - (+) Analyze decisions and strategies using probability concepts (e.g., product testing, medical testing, pulling a hockey goalie at the end of a game).

Instructional Plan – Component 1: Researching a Problem	
Suggested Activities	
Activities (A) Projects (P) Problems (B)	**UNDERSTANDINGS: Students will understand that …**

Element A – Identification and Justification of the Problem **Problem Statement** **Surveys** **Element B –** Documentation and Analysis of Prior Solution Attempts **Patent Research** **Market Research** **Element C –** Presentation and Justification of Solution Requirements **Customer Requirements** **Design / Product Specifications** **Similar Solution Matrix**	**D1 Engineering Mindset** Successful engineers typically exhibit specific personal and professional characteristics that lend themselves to the creative, collaborative, and solution-driven nature of the profession. **D2 Design Process** An engineering design process is an iterative, systematic approach to problem solving. **D4 Collaboration** Demonstrate an ability to function on multidisciplinary teams. **D5 Communication** Engineering practice requires effective communication with a variety of audiences using multiple modalities.

ESSENTIAL QUESTIONS: Students will keep considering …	
C1.1 How can one establish the validity of a problem? **C1.2** Why is it important to begin a design project with a valid problem statement? **C1.3** How are experts and mentors valuable to the design process? **C1.4** How can valuable and credible research be identified for use? **C1.5** Why should an individual or company be concerned with justification of the problem? **C1.6** How is market research used to aid research and development? **C1.7** What exactly is the problem? How do I phrase it as an objective problem statement? **C1.8** What is the background, context, or setting of the problem? **C1.9** Who says that this is a problem worth solving, and why should anyone believe them? **C1.10** What are all of the methods, products, or actions that are being used or have been developed to try to solve this problem? Exactly why doesn't each of them actually solve the problem? **C1.11** How do I/we prove to others that I/we have done an extensive search for possible current solution attempts?	**C1.12** Who has helped me/us identify and state the shortcomings of the solution attempts found and why should anyone believe them? **C1.13** Now that I know what the problem statement is and why current solutions are not solving the problem well enough, what are the measurable things a new design would have to accomplish (in order of importance) to be seen as a real solution? **C1.14** How did I/we determine each of these design requirements?

KNOWLEDGE / Skills: Students will …

O1.1 Demonstrate independent thinking and self-direction in pursuit of accomplishing a goal.
- **KS1.1.1** List and prioritize goals with tangible success criteria.
- **KS1.1.2** Plan and use time in pursuit of accomplishing a goal without direct oversight.

O1.3 Persevere to solve a problem or achieve a goal..
- **KS1.3.2** Accept failure as part of an evolution of individual growth and necessary to the expansion of the engineering profession
- **KS1.3.3** Reflect critically on past experiences to inform future progress.

O2.1 Explain and justify an engineering design process.
- **KS2.1.4** Outline how iterative processes inform engineering decisions, improve solutions, and inspire new ideas.
- **KS2.1.5** Document a design process in an engineering notebook according to best practices.

O2.2 Collect, analyze, and interpret information relevant to the problem or opportunity at hand to support engineering decisions.
- **KS2.2.1** Explain the role of research in the process of design.

KS2.2.2 Find relevant data in credible sources such as literature, databases, and policy documents.
KS2.2.4 Describe criteria for determining the reliability and credibility of information.
O2.3 Synthesize an ill-formed problem into a meaningful, well-defined problem.
KS2.3.1 . Explain the importance of carefully and specifically defining a problem or opportunity, design criteria, and constraints, to develop successful design solutions.
KS2.3.3 List potential constraints that may impact the success of a design solution. Examples include economic (cost), environmental, social, political, ethical, health and safety, manufacturability, technical feasibility, and sustainability
O2.4 Generate multiple potential solution concepts.
KS2.4.2 Represent concepts using a variety of visual tools, such as sketches, graphs, and charts, to communicate details of an idea.
O2.5 Develop models to represent design alternatives and generate data to inform decision making, test alternatives, and demonstrate solutions.
KS2.5.1 Describe the use of a model to accurately represent the key aspects of a physical system. Include the identification of constraints, such as cost, time, or expertise that may influence the selection of a model.
KS2.5.2 Define various types of models that can be used to represent products, processes, or designs, such as physical prototypes, mathematical models, and virtual representations. Explain the purpose and appropriate use of each.
O2.6 Select a solution path from many options to successfully address a problem or opportunity.
KS2.6.1 Explain that there are often multiple viable solutions and no obvious best solution. Trade-offs must be considered and evaluated consistently throughout an engineering design process.
KS2.6.2 Develop and carry out a justifiable scheme to compare and evaluate competing solutions paths. A decision matrix is one tool used to compare and evaluate competing solutions based on design criteria.
O4.4 Manage project timelines and resources as part of an engineering design process.
KS4.4.3 Select and use a system of collaborative tools, such as cloud-based tools, document sharing, and video and text functions, to successfully complete a project.
O5.1 Communicate effectively with an audience based on audience characteristics.
KS5.1.1 Adhere to established conventions of written, oral and electronic communications (grammar, spelling, usage, and mechanics).
KS5.1.2 Follow acceptable formats for technical writing and professional presentations.
KS5.1.3 Describe how the size and characteristics of an audience will affect communication.
KS5.1.4 Modify the content, format, level of technical detail, and length of communications to meet the needs of the audience.
KS5.1.5 Properly cite references for all communication in an accepted format. Clearly label tables and figures with units and explain the information presented in context.
KS5.1.6 Describe characteristics important to oral delivery of information (volume, tempo, eye contact, articulation, and energy). Vary these elements of delivery to convey and emphasize information and engage the audience.

Evidence of Student Learning		
Activities (A) Projects (P) Problems (B)	**Assessment FOR Learning**	**Assessment OF Learning**
Element A – Identification and Justification of the Problem	• EDPPSR evaluation tool. • Engineering Book Check	• Deliverable
Problem Statement	• EDPPSR evaluation tool.	• Deliverable
Surveys	• EDPPSR evaluation tool.	• Deliverable
Element B – Documentation and Analysis of Prior Solution Attempts	• EDPPSR evaluation tool. • Engineering Book Check	• Deliverable
Patent Research	• EDPPSR evaluation tool.•	• Deliverable
Market Research	• EDPPSR evaluation tool.•	• Deliverable
Element C – Presentation and Justification of Solution	• EDPPSR evaluation tool.	• Deliverable

Requirements	• Engineering Book Check	
Customer Requirements	• EDPPSR evaluation tool. • Engineering Book Check	• Deliverable
Design / Product Specifications	• EDPPSR evaluation tool. • Engineering Book Check	• Deliverable
Similar Solution Matrix	• EDPPSR evaluation tool. • Engineering Book Check	• Deliverable
Component 1 – Research: The Project Proposal	• EDPPSR evaluation tool. • Engineering Book Check	• Deliverable
Unit Assessment Items Summative – EoC	-- All items	-- All items

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ε1.3 Patent Summary Sheet

Instructions

In your engineering notebook or on this form, document each patent you find related to the major project problem you have identified. Your instructor may want you to print or partially print the related patent.

Source (APA format):

Patent Number:

Patent Summary:

Summarize the patent in your own words. Highlight the key pieces of information, including features and benefits.

Patent Critique:

How does the patented item solve or attempt to solve your problem or a similar one? What are some good and bad attributes of the item? What unique aspect does the patent add to your overall research?

Images/sketches:

Attach images or sketches related to the patent that help describe the solution.

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Research Summary Sheet

Instructions:

Complete the following form for each artifact that validates your problem statement.

Source (APA format):

Click here to enter text.

Artifact Summary:

Summarize in your own words. Highlight the key pieces, including features and benefits.

Click here to enter text.

Artifact Critique:

How does the artifact provide validity, conflict, or the need for further research? What unique aspect does the artifact add to your overall research?

Click here to enter text.

Core Instructional, References and Supplemental Materials
Abts, Leigh. (2011). *Analysis of the barriers, constraints and issues for dual credit and/or an Advanced Placement pathway for introduction to engineering*. American Society for Engineering Education. **Foreman, L. J., & Welytok, J. G. (2009).** *The independent inventor's handbook*. New York, NY: Workman Publishing Company, Inc. **Grissom, F. E., & Pressman, D. (2008).** *Inventor's notebook*: *A patent it yourself companion*. (5th ed.). Berkely, CA: Nolo. **Industrial Designers Society of America. (2009). Okala:** *Learning ecological design*. Phoenix, AZ. **International Technology Education Association. (2000).** Reston, VA: ITEA. **InvestorWords.com. (n.d.).** Retrieved from **http://www.investorwords.com/** **Pressman, D. (2009).** *Patent it yourself*. (14th ed.). Berkely, CA: Nolo **Ulrich, K. T., & Eppinger, S. D. (2008).** *Product design and development*. New York, NY: McGraw Hill. **Williams, M. (2008).** *The principles of project management*. Victoria, Australia: SitePoint Pty. Ltd.
Teacher Notes:

Component 2	Designing a Solution	**Duration:** 60 days

Standards/Learning Targets

Focus Standards (Major Standards)

HS.ESS3.3 - Earth and Human Activity - Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.
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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.
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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. - 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. **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. - Design a test of a model to ascertain its reliability. - 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. - Develop a complex model that allows for manipulation	**DCI - ETS1.A** - Engineering Design - 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. (secondary to HS-PS2-3) **DCI - ETS1.A** - Engineering Design - Defining and Delimiting Engineering Problems - 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. (HS-ETS1-1)	**Patterns** - Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them. - 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. - Classifications or explanations used at one scale may fail or need revision when information from smaller or larger scales is introduced; thus requiring improved investigations and experiments. - Patterns of performance of designed systems can be analyzed and interpreted to reengineer and improve the system. - Mathematical representations are needed to identify some patterns. - Empirical evidence is needed to identify patterns. **Cause and Effect: Mechanism and Prediction** - Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. - Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. - Systems can be designed to cause a desired effect. - Changes in systems may have various causes that may not have equal effects.

and testing of a proposed process or system. - Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems. **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 - 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. - Plan and conduct an investigation or test a design solution in a safe and ethical manner including considerations of environmental, social, and personal impacts. - 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. - Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data. - Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations. - Evaluate the impact of new data on a working explanation and/or model of a proposed process or system. - 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**		**Scale, Proportion, and Quantity** - In considering phenomena, it is critical to recognize what is relevant at different size, time, and energy scales, and to recognize proportional relationships between different quantities as scales change. - The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. - Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly. - Patterns observable at one scale may not be observable or exist at other scales. - Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale. - 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** - Systems can be designed to do specific tasks. **Energy and Matter: Flows, Cycles, and Conservation** - Tracking energy and matter flows, into, out of, and within systems helps one understand their system's behavior. - The total amount of energy and matter in closed systems is conserved. - Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. - Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems. - Energy drives the cycling of matter within and between systems. **Structure and Function** - The way an object is shaped or structured determines many of its properties and functions. - 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. **Stability and Change** - For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand.

- Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system. - Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. - Apply techniques of algebra and functions to represent and solve scientific and engineering problems. - Use simple limit cases to test mathematical expressions, computer programs, algorithms, or simulations of a process or system to see if a model "makes sense" by comparing the outcomes with what is known about the real world. - 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** - Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables. - Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. - Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. - Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. - 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. - Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments.		- Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. - Feedback (negative or positive) can stabilize or destabilize a system. - Systems can be designed for greater or lesser stability.

- 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 contradictions. - Construct, use, and/or present an oral and written argument or counter-arguments based on data and 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. - 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). **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. - Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible.		

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.2 -** Determine central ideas or themes of a text and analyze their development; summarize the key supporting details and ideas. **AS.R.4 -** Interpret words and phrases as they are used in a text, including determining technical, connotative, and figurative meanings, and analyze how specific word choices shape meaning or tone. **AS.R.6** - Assess how point of view or purpose shapes the content and style of a text. **AS.R.7** - Integrate and evaluate content presented in diverse formats and media, including visually and quantitatively, as well as in words. **AS.R.8** - Delineate and evaluate the argument and specific claims in a text, including the validity of the reasoning as well as the relevance and sufficiency of the evidence. **AS.R.9** - Analyze how two or more texts address similar themes or topics in order to build knowledge or to compare the approaches the authors take. **AS.R.10 -** Read and comprehend complex literary and informational texts independently and proficiently. **AS.W.1 -** Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence. **AS.W.2 -** 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.3 - Write narratives to develop real or imagined experiences or events using effective technique, well-chosen details, and well-structured event sequences.

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

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

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

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

AS.W.8 - 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 - Draw evidence from literary or informational texts to support analysis, reflection, and research.

AS.W.10 - 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 - 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 - Integrate and evaluate information presented in diverse media and formats, including visually, quantitatively, and orally.

AS.SL.3 - Evaluate a speaker's point of view, reasoning, and use of evidence and rhetoric.

AS.SL.4 - 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 - Make strategic use of digital media and visual displays of data to express information and enhance understanding of presentations.

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

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

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

AS.L.3 - Apply knowledge of language to understand how language functions in different contexts, to make effective choices for meaning or style, and to comprehend more fully when reading or listening.

AS.L.4 - Determine or clarify the meaning of unknown and multiple-meaning words and phrases by using context clues, analyzing meaningful word parts, and consulting general and specialized reference materials, as appropriate.

AS.L.5 - Demonstrate understanding of word relationships and nuances in word meanings.

AS.L.6 - 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.

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.

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.SSE.3 - Seeing Structure in Expressions - Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression.

A.APR.1 - Arithmetic with Polynomials and Rational Expressions - Understand that polynomials form a system analogous to the integers, namely, they are closed under the operations of addition, subtraction, and multiplication; add, subtract, and multiply polynomials.

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.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.

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 - Reasoning with Equations and Inequalities - Solve quadratic equations in one variable.

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).

A.REI.11 - Reasoning with Equations and Inequalities - Explain why the x-coordinates of the points where the graphs of the equations y = f(x) and y = g(x) intersect are the

solutions of the equation f(x) = g(x); find the solutions approximately, e.g., using technology to graph the functions, make tables of values, or find successive approximations. Include cases where f(x) and/or g(x) are linear, polynomial, rational, absolute value, exponential, and logarithmic functions.

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.7 - Interpreting Functions - Graph functions expressed symbolically and show key features of the graph, by hand in simple cases and using technology for more complicated cases.

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

F.IF.8 - Interpreting Functions - Write a function defined by an expression in different but equivalent forms to reveal and explain different properties of the function.

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

F.BF.1.b - Building Functions - Combine standard function types using arithmetic operations. For example, build a function that models the temperature of a cooling body by adding a constant function to a decaying exponential, and relate these functions to the model.

F.BF.1.c - Building Functions - (+) Compose functions. For example, if T(y) is the temperature in the atmosphere as a function of height, and h(t) is the height of a weather balloon as a function of time, then T(h(t)) is the temperature at the location of the weather balloon as a function of time.

F.LE.1 - Linear, Quadratic, and Exponential Models Distinguish between situations that can be modeled with linear functions and with exponential functions.

F.LE.1.b - Linear, Quadratic, and Exponential Models Recognize situations in which one quantity changes at a constant rate per unit interval relative to another.

F.LE.1.c - Linear, Quadratic, and Exponential Models Recognize situations in which a quantity grows or decays by a constant percent rate per unit interval relative to another.

F.LE.3 - Linear, Quadratic, and Exponential Models Observe using graphs and tables that a quantity increasing exponentially eventually exceeds a quantity increasing linearly, quadratically, or (more generally) as a polynomial function.

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

G.CO.1 – Congruence Know precise definitions of angle, circle, perpendicular line, parallel line, and line segment, based on the undefined notions of point, line, distance along a line, and distance around a circular arc.

G.CO.4 - Congruence

Develop definitions of rotations, reflections, and translations in terms of angles, circles, perpendicular lines, parallel lines, and line segments.

G.CO.5 – Congruence Given a geometric figure and a rotation, reflection, or translation, draw the transformed figure using, e.g., graph paper, tracing paper, or geometry software. Specify a sequence of transformations that will carry a given figure onto another.

G.CO.12 – Congruence Make formal geometric constructions with a variety of tools and methods (compass and straightedge, string, reflective devices, paper folding, dynamic geometric software, etc.). Copying a segment; copying an angle; bisecting a perpendicular bisector of a line segment; and constructing a line parallel to a given line through a point not on the line.

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).

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.

Instructional Plan – Component 2	
Suggested Activities	**Resources "Project Lead The Way "**
Activities (A) Projects (P) Problems (B)	**UNDERSTANDINGS: Students will understand that …**
Element D – Design Concepts Generation, Analysis, and Selection Brainstorming Thumbnail Sketches Mechanical Drawings	**D1 Engineering Mindset** Successful engineers typically exhibit specific personal and professional characteristics that lend themselves to the creative, collaborative, and solution-driven nature of the profession. **D2 Design Process** An engineering design process is an iterative, systematic approach

Decision Matrix **Element E –** Application of STEM Principles and Practices How STEM was used **Element F** – Consideration of Design Viability Questions on all outcomes	to problem solving. **D4 Collaboration** Demonstrate an ability to function on multidisciplinary teams. **D5 Communication** Engineering practice requires effective communication with a variety of audiences using multiple modalities.

ESSENTIAL QUESTIONS: Students will keep considering …	
C2.1 Why would an engineer need to identify the criteria and constraints required for a design solution? C2.2 How would you explain the following statement? "Finding a good solution is an iterative process." C2.3 Why is it important to take the time to thoroughly explore many potential solutions before selecting a solution path? C2.4 What benefit does optimization provide at this point in the design process? C2.5 What are advantages of using virtual solutions before and sometimes in place of physical prototypes? C2.6 What brainstorming or idea generation techniques did I/we use to help define possible solutions? How can we show that I/we kept all of the design requirements in mind throughout the entire process? C2.7 What was the best solution to try and why was it the best solution to try?	C2.8 How do we show that our design ideas were not just guesses and that my/our ideas and each of the proposed design attributes really is based on sound logic and subject-related knowledge? C2.9 How do I/we show evidence that the proposed design has merit beyond the classroom or lab as a real solution? C2.10 How can I/we show evidence that the design could realistically get into the hands of the people the design is trying to help in a sustainable way? C2.11 What evidence would I/we have to offer to honestly ask a family to invest their life savings in this idea?

KNOWLEDGE / Skills: Students will …

O1.1 Demonstrate independent thinking and self-direction in pursuit of accomplishing a goal.
- **KS1.1.1** List and prioritize goals with tangible success criteria.
- **KS1.1.2** Plan and use time in pursuit of accomplishing a goal without direct oversight.

O1.3 Persevere to solve a problem or achieve a goal..
- **KS1.3.3** Reflect critically on past experiences to inform future progress.

O2.1 Explain and justify an engineering design process.
- **KS2.1.4** Outline how iterative processes inform engineering decisions, improve solutions, and inspire new ideas.
- **KS2.1.5** Document a design process in an engineering notebook according to best practices.

O2.3 Synthesize an ill-formed problem into a meaningful, well-defined problem.
- **KS2.3.1** . Explain the importance of carefully and specifically defining a problem or opportunity, design criteria, and constraints, to develop successful design solutions.
- **KS2.3.2** Identify and define visual, functional, and structural design requirements with realistic constraints, against which solution alternatives can be evaluated.

O2.4 Generate multiple potential solution concepts.
- **KS2.4.2** Represent concepts using a variety of visual tools, such as sketches, graphs, and charts, to communicate details of an idea.

O2.5 Develop models to represent design alternatives and generate data to inform decision making, test alternatives, and demonstrate solutions.
- **KS2.5.1** Describe the use of a model to accurately represent the key aspects of a physical system. Include the identification of constraints, such as cost, time, or expertise that may influence the selection of a model.
- **KS2.5.2** Define various types of models that can be used to represent products, processes, or designs, such as physical prototypes, mathematical models, and virtual representations. Explain the purpose and appropriate use of each.

O2.6 Select a solution path from many options to successfully address a problem or opportunity.
- **KS2.6.2** Develop and carry out a justifiable scheme to compare and evaluate competing solutions paths. A decision matrix is one tool used to compare and evaluate competing solutions based on design criteria.

O4.4 Manage project timelines and resources as part of an engineering design process.
KS4.4.3 Select and use a system of collaborative tools, such as cloud-based tools, document sharing, and video and text functions, to successfully complete a project.
O5.1 Communicate effectively with an audience based on audience characteristics.
KS5.1.1 Adhere to established conventions of written, oral and electronic communications (grammar, spelling, usage, and mechanics).
KS5.1.2 Follow acceptable formats for technical writing and professional presentations.
KS5.1.3 Describe how the size and characteristics of an audience will affect communication.
KS5.1.4 Modify the content, format, level of technical detail, and length of communications to meet the needs of the audience.
KS5.1.5 Properly cite references for all communication in an accepted format. Clearly label tables and figures with units and explain the information presented in context.
KS5.1.6 Describe characteristics important to oral delivery of information (volume, tempo, eye contact, articulation, and energy). Vary these elements of delivery to convey and emphasize information and engage the audience.
KS5.1.7 Describe characteristics important to oral delivery of information (volume, tempo, eye contact, articulation, and energy). Vary these elements of delivery to convey and emphasize information and engage the audience.

Evidence of Student Learning		
Activities (A) Projects (P) Problems (B)	**Assessment FOR Learning**	**Assessment OF Learning**
Element D – Design Concepts Generation, Analysis, and Selection	• EDPPSR evaluation tool. • Engineering Book Check	• Deliverable
Brainstorming	• Engineering Book Check	• Engineering Book Check
Thumbnail Sketches	• Engineering Book Check	• Engineering Book Check
Mechanical Drawings	• Engineering Book Check • Inventor File	• Deliverable • Inventor File
Decision Matrix	• EDPPSR evaluation tool. • Engineering Book Check	• Deliverable
Element E – Application of STEM Principles and Practices	• EDPPSR evaluation tool. • Engineering Book Check	• Deliverable
How STEM was used	• EDPPSR evaluation tool. • Engineering Book Check	• Deliverable • Engineering Book Check
Element F – Consideration of Design Viability	• EDPPSR evaluation tool. • Engineering Book Check	• Deliverable
Questions on all outcomes	• Benefits/risks • Engineering Book Check	• Deliverable • Engineering Book Check
Unit Assessment Items Summative – EoC	-- All items	-- All items

PLTW | Engineering

Decision Matrix Rubric

Topics	4 points	3 points	2 points	1 point
Matrix	Matrix is designed in a manner that displays all possibilities along one axis. Specifications and constraints are displayed along the other axis. Relative weightings of specifications or constraints are stated with their relative importance in making the decision.	Matrix is designed in a manner that displays most possibilities along one axis. Most specifications and constraints are displayed along the other axis. Minor omissions exist or parts have been disproportionately weighted.	Matrix is designed in a manner that displays some possibilities along one axis. Some specifications and constraints are displayed along the other axis. Major omissions exist or weighting has been ignored.	An attempt was made to create a matrix, but serious misunderstandings regarding what a possible solution is and how it differs from a specification or constraint are obvious.
Assignment of Values	A logical, well-explained method of evaluating each specification or constraint for each of the listed possibilities is presented to the reader of the matrix.	A method of evaluating each specification or constraint for each of the listed possibilities is used. An attempt to explain it is made but is unclear to the reader of the matrix.	Each specification or constraint for each of the listed possibilities is assigned an evaluation, but no attempt is made to present it to the reader of the matrix.	Each specification or constraint for each of the listed possibilities is either assigned an apparently random value or is not evaluated at all.
Conclusions Drawn	Based on the results of the matrix evaluation, a clear choice is made and defended on a technical basis.	Based on the results of the matrix evaluation, a choice is made but does not stand up to technical challenge.	A choice from the list of possible solutions is made but is not supported by the decision making matrix.	No choice is made, even though the matrix shows one possibility to be superior, or a choice was not obvious due to misuse or misinterpretation of the matrix.

Core Instructional, References and Supplemental Materials
Abts, Leigh. (2011). *Analysis of the barriers, constraints and issues for dual credit and/or an Advanced Placement pathway for introduction to engineering*. American Society for Engineering Education. **Foreman, L. J., & Welytok, J. G. (2009).** *The independent inventor's handbook*. New York, NY: Workman Publishing Company, Inc. **Grissom, F. E., & Pressman, D. (2008).** *Inventor's notebook*: *A patent it yourself companion*. (5th ed.). Berkely, CA: Nolo. **Industrial Designers Society of America. (2009). Okala:** *Learning ecological design*. Phoenix, AZ. **International Technology Education Association. (2000).** Reston, VA: ITEA. **InvestorWords.com. (n.d.).** Retrieved from **http://www.investorwords.com/** **Pressman, D. (2009).** *Patent it yourself*. (14th ed.). Berkely, CA: Nolo **Ulrich, K. T., & Eppinger, S. D. (2008).** *Product design and development*. New York, NY: McGraw Hill. **Williams, M. (2008).** *The principles of project management*. Victoria, Australia: SitePoint Pty. Ltd.
Teacher Notes:

Component 3	Creating a Prototype and Testing Plan	**Duration:** 75 days

Standards/Learning Targets

Focus Standards (Major Standards)

HS.PS3.3 – Energy - Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.
HS.ESS3.3 - Earth and Human Activity - Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.
HS.ESS3.4 - Earth and Human Activity - Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.
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 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. - 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. **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. - Design a test of a model to ascertain its reliability. - Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between	**DCI - ETS1.A** - Engineering Design - 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. (secondary to HS-PS2-3) **DCI - ETS1.A** - Engineering Design - Defining and Delimiting Engineering Problems - 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. (HS-ETS1-1)	**Patterns** - Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them. - 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. - Classifications or explanations used at one scale may fail or need revision when information from smaller or larger scales is introduced; thus requiring improved investigations and experiments. - Patterns of performance of designed systems can be analyzed and interpreted to reengineer and improve the system. - Mathematical representations are needed to identify some patterns. - Empirical evidence is needed to identify patterns. **Cause and Effect: Mechanism and Prediction** - Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major

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. - Develop a complex model that allows for manipulation and testing of a proposed process or system. - Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems. **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 - 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. - Plan and conduct an investigation or test a design solution in a safe and ethical manner including considerations of environmental, social, and personal impacts. - 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. - Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing		activity of science and engineering. - Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. - Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. - Systems can be designed to cause a desired effect. - Changes in systems may have various causes that may not have equal effects. **Scale, Proportion, and Quantity** - In considering phenomena, it is critical to recognize what is relevant at different size, time, and energy scales, and to recognize proportional relationships between different quantities as scales change. - The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. - Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly. - Patterns observable at one scale may not be observable or exist at other scales. - Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale. - 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** - A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems. - Systems can be designed to do specific tasks. - When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using 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. - Models can be used to predict the behavior of a system, but these predictions have limited precision

and interpreting data. - Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations. - Evaluate the impact of new data on a working explanation and/or model of a proposed process or system. - 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** - Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system. - Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. - Apply techniques of algebra and functions to represent and solve scientific and engineering problems. - Use simple limit cases to test mathematical expressions, computer programs, algorithms, or simulations of a process or system to see if a model "makes sense" by comparing the outcomes with what is known about the real world. - 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** - Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables. - Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. - Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. - Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which		and reliability due to the assumptions and approximations inherent in models.

the reasoning and data support the explanation or conclusion. - 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. - Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. - 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 contradictions. - Construct, use, and/or present an oral and written argument or counter-arguments based on data and 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. - 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). **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. - Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible. Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (i.e., orally, graphically, textually, mathematically).		

Supporting and Additional Standards
English Language Arts
AS.R.1 - 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.4 -** Interpret words and phrases as they are used in a text, including determining technical, connotative, and figurative meanings, and analyze how specific word choices shape meaning or tone. **AS.R.7** - Integrate and evaluate content presented in diverse formats and media, including visually and quantitatively, as well as in words. **AS.R.10 -** Read and comprehend complex literary and informational texts independently and proficiently. **AS.W.1 -** Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence. **AS.W.2 -** 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.3** - Write narratives to develop real or imagined experiences or events using effective technique, well-chosen details, and well-structured event sequences. **AS.W.4 -** Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. **AS.W.5 -** Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach. **AS.W.6 –Use technology, including the Internet, to produce and publish writing and to interact and collaborate with others.** **AS.W.7 -** Conduct short as well as more sustained research projects based on focused questions, demonstrating understanding of the subject under investigation. **AS.W.8 -** 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 -** Draw evidence from literary or informational texts to support analysis, reflection, and research. **AS.W.10 -** 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 -** 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 -** Integrate and evaluate information presented in diverse media and formats, including visually, quantitatively, and orally. **AS.SL.3 -** Evaluate a speaker's point of view, reasoning, and use of evidence and rhetoric. **AS.SL.4 -** 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 -** Make strategic use of digital media and visual displays of data to express information and enhance understanding of presentations. **AS.SL.6 -** Adapt speech to a variety of contexts and communicative tasks, demonstrating command of formal English when indicated or appropriate. **AS.L.1 –**Demonstrate command of the conventions of standard English grammar and usage when writing or speaking. **AS.L.2 -** Demonstrate command of the conventions of standard English capitalization, punctuation, and spelling when writing. **AS.L.3 -** Apply knowledge of language to understand how language functions in different contexts, to make effective choices for meaning or style, and to comprehend more fully when reading or listening. **AS.L.4 -** Determine or clarify the meaning of unknown and multiple-meaning words and phrases by using context clues, analyzing meaningful word parts, and consulting general and specialized reference materials, as appropriate. **AS.L.5 -** Demonstrate understanding of word relationships and nuances in word meanings. **AS.L.6 -** 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.

Mathematics

N.Q.1 - 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 - Define appropriate quantities for the purpose of descriptive modeling.

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

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

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

A.SSE.3 - Seeing Structure in Expressions Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression.

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.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.

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.6 - Reasoning with Equations and Inequalities Solve systems of linear equations exactly and approximately (e.g., with graphs), focusing on pairs of linear equations in two variables.

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).

A.REI.12 - Reasoning with Equations and Inequalities Graph the solutions to a linear inequality in two variables as a half- plane (excluding the boundary in the case of a strict inequality), and graph the solution set to a system of linear inequalities in two variables as the intersection of the corresponding half-planes.

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.4 - For a function that models a relationship between two quantities, interpret key features of graphs and tables in terms of the quantities, and sketch graphs showing key features given a verbal description of the relationship. Key features include: intercepts; intervals where the function is increasing, decreasing, positive, or negative; relative maximums and minimums; symmetries; end behavior; and periodicity.

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.LE.1 - Linear, Quadratic, and Exponential Models Distinguish between situations that can be modeled with linear functions and with exponential functions.

F.LE.1.b - Recognize situations in which one quantity changes at a constant rate per unit interval relative to another.

F.LE.1.c - Recognize situations in which a quantity grows or decays by a constant percent rate per unit interval relative to another.

F.LE.2 - Linear, Quadratic, and Exponential Models Construct linear and exponential functions, including arithmetic and geometric sequences, given a graph, a description of a relationship, or two input-output pairs (include reading these from a table).

F.LE.3 - Linear, Quadratic, and Exponential Models Observe using graphs and tables that a quantity increasing exponentially eventually exceeds a quantity increasing linearly, quadratically, or (more generally) as a polynomial function.

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

S.ID.2 - Use statistics appropriate to the shape of the data distribution to compare center (median, mean) and spread (interquartile range, standard deviation) of two or more different data sets.

S.ID.3 - Interpret differences in shape, center, and spread in the context of the data sets, accounting for possible effects of extreme data points (outliers).

S.ID.4 - 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.

S.ID.6 - 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.b - Informally assess the fit of a function by plotting and analyzing residuals.

S.ID.6.c - 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.ID.9 - Distinguish between correlation and causation.

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

S.IC.3 - Recognize the purposes of and differences among sample surveys, experiments, and observational studies; explain how randomization relates to each.

S.IC.4 - Use data from a sample survey to estimate a population mean or proportion; develop a margin of error through the use of simulation models for random sampling.

S.IC.5 - Making Inferences and Justifying Conclusions Use data from a randomized experiment to compare two treatments; use simulations to decide if differences between parameters are significant.

S.IC.6 - Evaluate reports based on data.

S.MD.5 - (+) Weigh the possible outcomes of a decision by assigning probabilities to payoff values and finding expected values.

S.MD.5.b - Evaluate and compare strategies on the basis of expected values. For example, compare a high-deductible versus a low-deductible automobile insurance policy using various, but reasonable, chances of having a minor or a major accident.

S.MD.6 - (+) Use probabilities to make fair decisions (e.g., drawing by lots, using a random number generator).

S.MD.7 - (+) Analyze decisions and strategies using probability concepts (e.g., product testing, medical testing, pulling a hockey goalie at the end of a game).

Instructional Plan – Component 3	
Suggested Activities	**Resources "Project Lead The Way "**
Activities (A) Projects (P) Problems (B)	**UNDERSTANDINGS: Students will understand that …**
Element G – Creation of a Testable Prototype Inventor Drawings Materials List/ Bill of Materials Construction Documentation **Element H –** Prototype Testing and Data Collection Plan List of Tests Purpose for Each Test **Element I** – Data Results and Testing Analysis Data Analysis Documentation	**D1 Engineering Mindset** Successful engineers typically exhibit specific personal and professional characteristics that lend themselves to the creative, collaborative, and solution-driven nature of the profession. **D2 Design Process** An engineering design process is an iterative, systematic approach to problem solving. **D4 Collaboration** Demonstrate an ability to function on multidisciplinary teams. **D5 Communication** Engineering practice requires effective communication with a variety of audiences using multiple modalities.

ESSENTIAL QUESTIONS: Students will keep considering …	
C3.1 What are the subsystems of products or systems that you are familiar with? Which subsystems are essential to system function and which are enhancements? **C3.2** What are advantages of using virtual solutions before and sometimes in place of physical prototypes? **C3.3** How does having a highly functional prototype relate to testing? **C3.4** What steps can be taken to lower the cost of your prototype? **C3.5** Why are test criteria important in test design? **C3.6** How do you know that you have enough step-by-step detail in your test procedure? **C3.7** What measurement practices are used to analyze your test results? **C3.8** What is the significance of seeking input from experts or non-team members?	**C3.9** What is the plan to test the prototype design? How can I show others that the testing plan for each design requirement is a well thought out test and would yield believable data? **C3.10** What did I/we learn from testing about how well this design met the stated design requirements? **C3.11** Why should others believe my/our analysis of the data? **C3.12** What do end users and experts, who are directly related to this project and problem statement, think of the testing results and my/our conclusions about the effectiveness of this idea?

KNOWLEDGE / Skills: Students will …

O1.1 Demonstrate independent thinking and self-direction in pursuit of accomplishing a goal.
- **KS1.1.2** Plan and use time in pursuit of accomplishing a goal without direct oversight.

O1.2 Demonstrate flexibility and adaptability to change.
- **KS1.2.1** Adapt to varied roles, job responsibilities, schedules, and contexts.

O1.3 Persevere to solve a problem or achieve a goal..
- **KS1.3.2** Accept failure as part of an evolution of individual growth and necessary to the expansion of the engineering profession
- **KS1.3.3** Reflect critically on past experiences to inform future progress.

O2.1 Explain and justify an engineering design process.
- **KS2.1.4** Outline how iterative processes inform engineering decisions, improve solutions, and inspire new ideas.
- **KS2.1.5** Document a design process in an engineering notebook according to best practices.

O2.2 Collect, analyze, and interpret information relevant to the problem or opportunity at hand to support engineering decisions.
- **KS2.2.1** Explain the role of research in the process of design.
- **KS2.2.2** Find relevant data in credible sources such as literature, databases, and policy documents.
- **KS2.2.4** Describe criteria for determining the reliability and credibility of information.

O2.3 Synthesize an ill-formed problem into a meaningful, well-defined problem.
- **KS2.3.1** . Explain the importance of carefully and specifically defining a problem or opportunity, design criteria, and constraints, to develop successful design solutions.
- **KS2.3.3**List potential constraints that may impact the success of a design solution. Examples include economic (cost), environmental, social, political, ethical, health and safety, manufacturability, technical feasibility, and sustainability

O2.4 Generate multiple potential solution concepts.
- **KS2.4.2** Represent concepts using a variety of visual tools, such as sketches, graphs, and charts, to communicate details of an idea.

O2.5 Develop models to represent design alternatives and generate data to inform decision making, test alternatives, and demonstrate solutions.
- **KS2.5.1** Describe the use of a model to accurately represent the key aspects of a physical system. Include the identification of constraints, such as cost, time, or expertise that may influence the selection of a model.
- **KS2.5.2** Define various types of models that can be used to represent products, processes, or designs, such as physical prototypes, mathematical models, and virtual representations. Explain the purpose and appropriate use of each.

O3.1 Using a variety of measuring devices, measure and report quantities accurately and to a precision appropriate for the purpose.
- **KS3.1.1** Explain that all measurements are an approximation of the true value of a quantity.
- **KS3.1.2** Explain and differentiate between the accuracy and precision of a measurement or measuring device.
- **KS3.1.3** Use dimensional analysis and unit conversions to transform data to consistent units or to units appropriate for a particular purpose or model.

O3.2 Interpret and analyze data for a single count or measurement variable.
- **KS3.2.1** Represent data for a single count or measurement with plots on the real number line, for example dot plots, histograms, and box plots.
- **KS3.2.2** Use statistics appropriate to the shape of the data distribution to determine the center (median, mean) and spread (interquartile range, standard deviation) of a data

set and/or compare data sets.

KS3.2.3 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.

O3.3 Apply mathematical (including graphical) models and interpret the output of models to test ideas or make predictions.

KS3.3.1 Represent data for two quantitative variables on a scatter plot, and describe how the variables are related.

KS3.3.2 Fit a function to the data; use functions fitted to data to solve problems in the context of the data, especially linear, quadratic, and exponential functions.

KS3.3.3 In linear models, interpret the rate of change (slope) and the intercept (constant term) in the context of the data.

KS3.3.4 Distinguish between sample statistics and population statistics and know appropriate applications of each.

O4.4 Manage project timelines and resources as part of an engineering design process.

KS4.4.3 Select and use a system of collaborative tools, such as cloud-based tools, document sharing, and video and text functions, to successfully complete a project.

O5.1 Communicate effectively with an audience based on audience characteristics.

KS5.1.1 Adhere to established conventions of written, oral and electronic communications (grammar, spelling, usage, and mechanics).

KS5.1.2 Follow acceptable formats for technical writing and professional presentations.

KS5.1.5 Properly cite references for all communication in an accepted format. Clearly label tables and figures with units and explain the information presented in context.

KS5.1.6 Describe characteristics important to oral delivery of information (volume, tempo, eye contact, articulation, and energy). Vary these elements of delivery to convey and emphasize information and engage the audience.

KS5.1.7 Describe characteristics important to oral delivery of information (volume, tempo, eye contact, articulation, and energy). Vary these elements of delivery to convey and emphasize information and engage the audience.

Evidence of Student Learning		
Activities (A) Projects (P) Problems (B)	**Assessment FOR Learning**	**Assessment OF Learning**
Element G – Creation of a Testable Prototype	• EDPPSR evaluation tool. • Engineering Book Check	• Deliverable
Inventor Drawings	• EDPPSR evaluation tool. • Engineering Book Check	• Deliverable • Inventor file
Materials List/ Bill of Materials	• Engineering Book Check	• Deliverable • Engineering Book Check
Construction Documentation	• Engineering Book Check	• Engineering Book Check
Element H – Prototype Testing and Data Collection Plan	• EDPPSR evaluation tool. • Engineering Book Check	• Deliverable
List of Tests	• Engineering Book Check	• Deliverable • Engineering Book Check
Purpose for Each Test	• Engineering Book Check	• Deliverable • Engineering Book Check

Element I – Data Results and Testing Analysis	• EDPPSR evaluation tool. • Engineering Book Check	• Deliverable
Data Analysis	• EDPPSR evaluation tool. • Engineering Book Check	• Deliverable
Documentation	• Engineering Book Check	• Engineering Book Check
Unit Assessment Items Summative – EoC	-- All items	-- All items

Core Instructional, References and Supplemental Materials

Abts, Leigh. (2011). *Analysis of the barriers, constraints and issues for dual credit and/or an Advanced Placement pathway for introduction to engineering*. American Society for Engineering Education.

Foreman, L. J., & Welytok, J. G. (2009). *The independent inventor's handbook*. New York, NY: Workman Publishing Company, Inc.

Grissom, F. E., & Pressman, D. (2008). *Inventor's notebook*: *A patent it yourself companion*. (5th ed.). Berkely, CA: Nolo.

Industrial Designers Society of America. (2009). Okala: *Learning ecological design*. Phoenix, AZ.

International Technology Education Association. (2000). Reston, VA: ITEA.

InvestorWords.com. (n.d.). Retrieved from **http://www.investorwords.com/**

Pressman, D. (2009). *Patent it yourself*. (14th ed.). Berkely, CA: Nolo

Ulrich, K. T., & Eppinger, S. D. (2008). *Product design and development*. New York, NY: McGraw Hill.

Williams, M. (2008). *The principles of project management*. Victoria, Australia: SitePoint Pty. Ltd.

Teacher Notes:

Component 4	Evaluation and Reflection on the Design Process	**Duration:** 30 days

Standards/Learning Targets

Focus Standards (Major Standards)

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.

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. - 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. **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. - Design a test of a model to ascertain its reliability. - 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. - Develop a complex model that allows for manipulation and testing of a proposed process or system. - Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems.	**DCI - ETS1.A** - Engineering Design - 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. (secondary to HS-PS2-3) **DCI - ETS1.A** - Engineering Design - Defining and Delimiting Engineering Problems - 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. (HS-ETS1-1)	**Cause and Effect: Mechanism and Prediction** - Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering. - Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. - Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. - 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**.**

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 - 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. - Plan and conduct an investigation or test a design solution in a safe and ethical manner including considerations of environmental, social, and personal impacts. - 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. - Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data. - Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations. - Evaluate the impact of new data on a working explanation and/or model of a proposed process or system. - 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. **Constructing Explanations and Designing Solutions** - Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue		

to do so in the future. - Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. - Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. - 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. - Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. - 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 contradictions. - Construct, use, and/or present an oral and written argument or counter-arguments based on data and 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. - 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). **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. - Evaluate the validity and reliability of and/or synthesize		

multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible. Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (i.e., orally, graphically, textually, mathematically).		

Supporting and Additional Standards

English Language Arts

AS.R.1 - 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.2 - Determine central ideas or themes of a text and analyze their development; summarize the key supporting details and ideas.
AS.R.4 - Interpret words and phrases as they are used in a text, including determining technical, connotative, and figurative meanings, and analyze how specific word choices shape meaning or tone.
AS.R.6 - Assess how point of view or purpose shapes the content and style of a text.
AS.R.7 - Integrate and evaluate content presented in diverse formats and media, including visually and quantitatively, as well as in words.
AS.R.8 - Delineate and evaluate the argument and specific claims in a text, including the validity of the reasoning as well as the relevance and sufficiency of the evidence.
AS.R.9 - Analyze how two or more texts address similar themes or topics in order to build knowledge or to compare the approaches the authors take.
AS.R.10 - Read and comprehend complex literary and informational texts independently and proficiently.
AS.W.1 - Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.
AS.W.2 - 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.3 - Write narratives to develop real or imagined experiences or events using effective technique, well-chosen details, and well-structured event sequences.
AS.W.4 - Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
AS.W.5 - Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach.
AS.W.6 –Use technology, including the Internet, to produce and publish writing and to interact and collaborate with others.
AS.W.7 - Conduct short as well as more sustained research projects based on focused questions, demonstrating understanding of the subject under investigation.
AS.W.8 - 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 - Draw evidence from literary or informational texts to support analysis, reflection, and research.
AS.W.10 - 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 - 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 - Integrate and evaluate information presented in diverse media and formats, including visually, quantitatively, and orally.
AS.SL.3 - Evaluate a speaker's point of view, reasoning, and use of evidence and rhetoric.
AS.SL.4 - 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 - Make strategic use of digital media and visual displays of data to express information and enhance understanding of presentations.
AS.SL.6 - Adapt speech to a variety of contexts and communicative tasks, demonstrating command of formal English when indicated or appropriate.
AS.L.1 –Demonstrate command of the conventions of standard English grammar and usage when writing or speaking.
AS.L.2 - Demonstrate command of the conventions of standard English capitalization, punctuation, and spelling when writing.
AS.L.3 - Apply knowledge of language to understand how language functions in different contexts, to make effective choices for meaning or style, and to comprehend more fully when reading or listening.
AS.L.4 - Determine or clarify the meaning of unknown and multiple-meaning words and phrases by using context clues, analyzing meaningful word parts, and consulting general and specialized reference materials, as appropriate.
AS.L.5 - Demonstrate understanding of word relationships and nuances in word meanings.
AS.L.6 - 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.

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.
S.ID.1 - Represent data with plots on the real number line (dot plots, histograms, and box plots).
S.ID.2 - Use statistics appropriate to the shape of the data distribution to compare center (median, mean) and spread (interquartile range, standard deviation) of two or more different data sets.
S.ID.3 - Interpret differences in shape, center, and spread in the context of the data sets, accounting for possible effects of extreme data points (outliers).
S.ID.4 - 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.
S.ID.5 - Interpreting Categorical and Quantitative Data - Summarize categorical data for two categories in two-way frequency tables. Interpret relative frequencies in the context of the data (including joint, marginal, and conditional relative frequencies). Recognize possible associations and trends in the data.
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.b - Interpreting Categorical and Quantitative Data - Informally assess the fit of a function by plotting and analyzing residuals.
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.9 - Interpreting Categorical and Quantitative Data - Distinguish between correlation and causation.
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.
S.IC.2 - Making Inferences and Justifying Conclusions - Decide if a specified model is consistent with results from a given data-generating process, e.g., using simulation. For example, a model says a spinning coin falls heads up with probability 0.5. Would a result of 5 tails in a row cause you to question the model?
S.IC.3 - Making Inferences and Justifying Conclusions - Recognize the purposes of and differences among sample surveys, experiments, and observational studies; explain how randomization relates to each.
S.IC.4 - Making Inferences and Justifying Conclusions - Use data from a sample survey to estimate a population mean or proportion; develop a margin of error through the use of simulation models for random sampling.
S.IC.6 - Making Inferences and Justifying Conclusions - Evaluate reports based on data.
S.MD.5 - Using Probability to Make Decisions (+) Weigh the possible outcomes of a decision by assigning probabilities to payoff values and finding expected values.
S.MD.5.a - Using Probability to Make Decisions Find the expected payoff for a game of chance. For example, find the expected winnings from a state lottery ticket or a game at a fast-food restaurant.
S.MD.5.b - Using Probability to Make Decisions Evaluate and compare strategies on the basis of expected values. For example, compare a high-deductible versus a low-deductible automobile insurance policy using various, but reasonable, chances of having a minor or a major accident.
S.MD.6 - Using Probability to Make Decisions (+) Use probabilities to make fair decisions (e.g., drawing by lots, using a random number generator).
S.MD.7 - Using Probability to Make Decisions **(**+) Analyze decisions and strategies using probability concepts (e.g., product testing, medical testing, pulling a hockey goalie at the end of a game).

Instructional Plan – Component 4 - Evaluation and Reflection on the Design Process	
Suggested Activities	**Resources "Project Lead The Way "**
Activities (A) Projects (P) Problems (B)	**UNDERSTANDINGS: Students will understand that …**
Element J – Documentation of External Evaluation Tradeshow / Presentation Display Board **Element K –** Reflection on the Design Project Looking back Where did the Project Go? **Element L –** Presentation of Designer's Recommendations Looking Ahead Patent Attorney	**D1 Engineering Mindset** Successful engineers typically exhibit specific personal and professional characteristics that lend themselves to the creative, collaborative, and solution-driven nature of the profession. **D2 Design Process** An engineering design process is an iterative, systematic approach to problem solving. **D4 Collaboration** Demonstrate an ability to function on multidisciplinary teams. **D5 Communication** Engineering practice requires effective communication with a variety of audiences using multiple modalities.
ESSENTIAL QUESTIONS: Students will keep considering …	
C4.1 What do end users and experts directly related to this project and problem statement think of the testing results and my/our conclusions about the effectiveness of this idea? **C4.2** If I/we were going to do this project over, what should be done differently during the design process to improve the project? How would those recommendations make the project better overall?	**C4.3** Did I/we document each step of the design process in this portfolio well enough that anyone else interested in the problem could pick up this work and replicate what I/we have done, as well as continue working from where I/we ended up?

KNOWLEDGE / Skills: Students will …
O1.1 Demonstrate independent thinking and self-direction in pursuit of accomplishing a goal. **KS1.1.2** Plan and use time in pursuit of accomplishing a goal without direct oversight. **KS1.1.3** Plan how to gain additional knowledge and learning to accomplish a goal. **O1.2** Demonstrate flexibility and adaptability to change. **KS1.2.1** Adapt to varied roles, job responsibilities, schedules, and contexts. **O1.3** Persevere to solve a problem or achieve a goal.. **KS1.3.**1 Describe why persistence is important when identifying a problem and/or pursuing solutions. **KS1.3.2** Accept failure as part of an evolution of individual growth and necessary to the expansion of the engineering profession **KS1.3.3** Reflect critically on past experiences to inform future progress. **O2.1** Explain and justify an engineering design process. **KS2.1.1** Explain that there are many versions of a design process that describe essentially the same process. **KS2.1.4** Outline how iterative processes inform engineering decisions, improve solutions, and inspire new ideas. **KS2.1.5** Document a design process in an engineering notebook according to best practices. **O2.7** Make judgments and decisions based on evidence. **KS2.7.1** Explain that a conclusion is valid if the evidence supports the conclusion while acknowledging the limitations, opposing views, and biases. **O3.2 Interpret and analyze data for a single count or measurement variable.** **KS3.2.2** Use statistics appropriate to the shape of the data distribution to determine the center (median, mean) and spread (interquartile range, standard deviation) of a data set and/or compare data sets.

O4.2 Contribute individually to overall collaborative efforts.
KS4.2.1 Critically and realistically self-evaluate personal contributions and collaboration effectiveness within a team.
O4.3 Analyze and evaluate the work of others to provide helpful and effective feedback.
KS4.3.1 Describe the purpose and positive outcomes of a peer review process.
KS4.3.2 Describe the characteristics of effective feedback.

O4.4 Manage project timelines and resources as part of an engineering design process.
KS4.4.2 Develop a project plan using a project planning tool such as a Gantt chart.
KS4.4.3 Select and use a system of collaborative tools, such as cloud-based tools, document sharing, and video and text functions, to successfully complete a project.
O5.1 Communicate effectively with an audience based on audience characteristics.
KS5.1.1 Adhere to established conventions of written, oral and electronic communications (grammar, spelling, usage, and mechanics).
KS5.1.2 Follow acceptable formats for technical writing and professional presentations.
KS5.1.3 Describe how the size and characteristics of an audience will affect communication.
KS5.1.4 Modify the content, format, level of technical detail, and length of communications to meet the needs of the audience.
KS5.1.5 Properly cite references for all communication in an accepted format. Clearly label tables and figures with units and explain the information presented in context.
KS5.1.6 Describe characteristics important to oral delivery of information (volume, tempo, eye contact, articulation, and energy). Vary these elements of delivery to convey and emphasize information and engage the audience.
KS5.1.7 Describe characteristics important to oral delivery of information (volume, tempo, eye contact, articulation, and energy). Vary these elements of delivery to convey and emphasize information and engage the audience.

PLTW Engineering

Presentation Rubric Template

Elements	Weight	5 Points	4 Points	3 Points	2 Points	1-0 Points	Total
Content		The information included is accurate and completely addresses each component of the assigned topic or research question.	The information included adequately addresses each component of the assigned topic or research question.	The information included inadequately addresses the assigned topic or research question. The information included is sometimes inaccurate.	The information included does not address the assigned topic or research.	There is no evidence of accurate content information.	
Delivery		The presenter effectively and creatively delivers the information while staying on topic. The presenter appears relaxed and self-confident. Body language, voice modulation, and eye contact are effectively used.	The presenter adequately delivers the information while staying on topic. The presenter appears relaxed and self-confident. Body language, voice modulation, and eye contact are mostly appropriate.	The presenter delivers the information but does not stay on topic. The presenter appears tense or nervous. Body language, voice modulation, and eye contact are inappropriate or lacking.	The presenter omits important information and does not stay on topic. The presenter appears tense or nervous. Body language, voice modulation, and eye contact are inappropriate or lacking.	The presenter does not effectively deliver the necessary information.	
Organization		The presentation content has been organized using a logical sequence. The presentation is engaging and effective.	The presentation content has been mostly organized using a logical sequence, but some flaws exist. The presentation is adequate.	The presentation content has been organized using a somewhat logical sequence. The presentation is sometimes confusing.	The presentation content is disorganized, unclear, or confusing. The presentation is not adequate.	The presentation does not include evidence of organization.	
Preparation		Presentation indicates detailed preparation.	Presentation indicates adequate preparation.	Presentation indicates minimal preparation.	Presentation indicates a lack of preparation.	Presentation shows no evidence of preparation.	
Visual Aids		Visual aids are of excellent quality, easy to read, and	Visual aids are adequate, easy to read, and relevant	Visual aids are somewhat effective but may include	Visual aids lack effectiveness. Aids may lack appropriate	The presentation shows no	

Evidence of Student Learning		
Activities (A) Projects (P) Problems (B)	**Assessment FOR Learning**	**Assessment OF Learning**
Element J – Documentation of External Evaluation	• EDPPSR evaluation tool. • Engineering Book Check	• Deliverable
Tradeshow / Presentation	• EDPPSR evaluation tool. • Engineering Book Check	• EDPPSR evaluation tool.
Display Board	• Engineering Book Check	• EDPPSR evaluation tool.
Element K – Reflection on the Design Project	• EDPPSR evaluation tool. • Engineering Book Check	• Deliverable
Looking back / Where did the Project Go?	• Engineering Book Check	• Engineering Book Check
Documentation	• Engineering Book Check	• Engineering Book Check
Element L – Presentation of Designer's Recommendations	• EDPPSR evaluation tool. • Engineering Book Check	• Deliverable
Looking Ahead / Patent Attorney	• EDPPSR evaluation tool. • Engineering Book Check	• Engineering Book Check
Documentation	• Engineering Book Check	• Engineering Book Check
Unit Assessment Items Summative – EoC	-- All items	-- All items

Core Instructional, References and Supplemental Materials

Abts, Leigh. (2011). *Analysis of the barriers, constraints and issues for dual credit and/or an Advanced Placement pathway for introduction to engineering*. American Society for Engineering Education.

Foreman, L. J., & Welytok, J. G. (2009). *The independent inventor's handbook*. New York, NY: Workman Publishing Company, Inc.

Grissom, F. E., & Pressman, D. (2008). *Inventor's notebook*: *A patent it yourself companion*. (5th ed.). Berkely, CA: Nolo.

Industrial Designers Society of America. (2009). Okala: *Learning ecological design*. Phoenix, AZ.

International Technology Education Association. (2000). Reston, VA: ITEA.

InvestorWords.com. (n.d.). Retrieved from **http://www.investorwords.com/**

Pressman, D. (2009). *Patent it yourself*. (14th ed.). Berkely, CA: Nolo

Ulrich, K. T., & Eppinger, S. D. (2008). *Product design and development*. New York, NY: McGraw Hill.

Williams, M. (2008). *The principles of project management*. Victoria, Australia: SitePoint Pty. Ltd.

Teacher Notes:

Component 5	Presentation of the Design Process	**Duration:** 15 days

Standards/Learning Targets

Focus Standards (Major Standards)

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.

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
Analyzing and Interpreting Data - 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. - Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data. - Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations. - Evaluate the impact of new data on a working explanation and/or model of a proposed process or system. - 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. **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. - Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. - Respectfully provide and/or receive critiques on	**DCI - ETS1.A** - Engineering Design - 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. (secondary to HS-PS2-3) **DCI - ETS1.A** - Engineering Design - Defining and Delimiting Engineering Problems - 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. (HS-ETS1-1)	**Cause and Effect: Mechanism and Prediction** - Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering. - Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. - Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. - 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.

scientific arguments by probing reasoning and evidence, challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining additional information required to resolve contradictions. - Construct, use, and/or present an oral and written argument or counter-arguments based on data and 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. - 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). **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. - Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible. - Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (i.e., orally, graphically, textually, mathematically).		

Supporting and Additional Standards
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AS.R.1 - 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.2 -** Determine central ideas or themes of a text and analyze their development; summarize the key supporting details and ideas. **AS.R.4 -** Interpret words and phrases as they are used in a text, including determining technical, connotative, and figurative meanings, and analyze how specific word choices shape meaning or tone. **AS.R.6** - Assess how point of view or purpose shapes the content and style of a text. **AS.R.7** - Integrate and evaluate content presented in diverse formats and media, including visually and quantitatively, as well as in words.

AS.R.8 - Delineate and evaluate the argument and specific claims in a text, including the validity of the reasoning as well as the relevance and sufficiency of the evidence.

AS.R.9 - Analyze how two or more texts address similar themes or topics in order to build knowledge or to compare the approaches the authors take.

AS.R.10 - Read and comprehend complex literary and informational texts independently and proficiently.

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

AS.W.2 - 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.3 - Write narratives to develop real or imagined experiences or events using effective technique, well-chosen details, and well-structured event sequences.

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

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

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

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

AS.W.8 - 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 - Draw evidence from literary or informational texts to support analysis, reflection, and research.

AS.W.10 - 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 - 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 - Integrate and evaluate information presented in diverse media and formats, including visually, quantitatively, and orally.

AS.SL.3 - Evaluate a speaker's point of view, reasoning, and use of evidence and rhetoric.

AS.SL.4 - 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 - Make strategic use of digital media and visual displays of data to express information and enhance understanding of presentations.

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

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

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

AS.L.3 - Apply knowledge of language to understand how language functions in different contexts, to make effective choices for meaning or style, and to comprehend more fully when reading or listening.

AS.L.4 - Determine or clarify the meaning of unknown and multiple-meaning words and phrases by using context clues, analyzing meaningful word parts, and consulting general and specialized reference materials, as appropriate.

AS.L.5 - Demonstrate understanding of word relationships and nuances in word meanings.

AS.L.6 - 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.

Mathematics

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

A.REI.1 - Reasoning with Equations and Inequalities Explain each step in solving a simple equation as following from the equality of numbers asserted at the previous step, starting from the assumption that the original equation has a solution. Construct a viable argument to justify a solution method.

A.REI.2 - Reasoning with Equations and Inequalities Solve simple rational and radical equations in one variable, and give examples showing how extraneous solutions may arise.

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.

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

S.ID.2 - Use statistics appropriate to the shape of the data distribution to compare center (median, mean) and spread (interquartile range, standard deviation) of two or more different data sets.

S.ID.3 - Interpret differences in shape, center, and spread in the context of the data sets, accounting for possible effects of extreme data points (outliers).

S.ID.4 - 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.

S.ID.5 - Interpreting Categorical and Quantitative Data - Summarize categorical data for two categories in two-way frequency tables. Interpret relative frequencies in the context of the data (including joint, marginal, and conditional relative frequencies). Recognize possible associations and trends in the data.

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.b - Interpreting Categorical and Quantitative Data - Informally assess the fit of a function by plotting and analyzing residuals.

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

S.IC.3 - Making Inferences and Justifying Conclusions - Recognize the purposes of and differences among sample surveys, experiments, and observational studies; explain how randomization relates to each.

S.IC.4 - Making Inferences and Justifying Conclusions Use data from a sample survey to estimate a population mean or proportion; develop a margin of error through the use of simulation models for random sampling.

S.IC.5 - Making Inferences and Justifying Conclusions - Use data from a randomized experiment to compare two treatments; use simulations to decide if differences between parameters are significant.

S.IC.6 - Making Inferences and Justifying Conclusions - Evaluate reports based on data.

S.MD.5 - Using Probability to Make Decisions - (+) Weigh the possible outcomes of a decision by assigning probabilities to payoff values and finding expected values.

S.MD.5.b - Using Probability to Make Decisions - Evaluate and compare strategies on the basis of expected values. For example, compare a high-deductible versus a low-deductible automobile insurance policy using various, but reasonable, chances of having a minor or a major accident.

S.MD.6 - Using Probability to Make Decisions - (+) Use probabilities to make fair decisions (e.g., drawing by lots, using a random number generator).

Instructional Plan – Component 5: Presentation of the Design Process	
Suggested Activities	**Resources "Project Lead The Way "**
Activities (A) Projects (P) Problems (B)	**UNDERSTANDINGS: Students will understand that …**
Element M – Presentation of the Engineering Design Process **Element N –** Writing Like an Engineer	**D1 Engineering Mindset** Successful engineers typically exhibit specific personal and professional characteristics that lend themselves to the creative, collaborative, and solution-driven nature of the profession. **D2 Design Process** An engineering design process is an iterative, systematic approach to problem solving. **D4 Collaboration** Demonstrate an ability to function on multidisciplinary teams. **D5 Communication** Engineering practice requires effective communication with a variety of audiences using multiple modalities.

ESSENTIAL QUESTIONS: Students will keep considering …	
C5.1 How did I/we document each step of the design process in this portfolio so that anyone else interested in the problem could pick up this work and replicate what I/we have done as well as continue working from where I/we ended up? **C5.2** Throughout the entire portfolio, why is it critical that the explanations, descriptions and information in each section be developed and presented with a wide variety of readers in mind?	

KNOWLEDGE / Skills: Students will …

O1.1 Demonstrate independent thinking and self-direction in pursuit of accomplishing a goal.
- **KS1.1.2** Plan and use time in pursuit of accomplishing a goal without direct oversight.
- **KS1.1.3** Plan how to gain additional knowledge and learning to accomplish a goal

O1.3 Persevere to solve a problem or achieve a goal..
- **KS1.3.**1 Describe why persistence is important when identifying a problem and/or pursuing solutions.
- **KS1.3.3** Reflect critically on past experiences to inform future progress.

O2.1 Explain and justify an engineering design process.
- **KS2.1.4** Outline how iterative processes inform engineering decisions, improve solutions, and inspire new ideas.
- **KS2.1.5** Document a design process in an engineering notebook according to best practices.

O2.7 Make judgments and decisions based on evidence.
- **KS2.7.1** Explain that a conclusion is valid if the evidence supports the conclusion while acknowledging the limitations, opposing views, and biases.
- **KS2.7.2** Evaluate evidence and arguments to identify deficiencies, limitations, and biases or appropriate next steps in the pursuit of a better solution.

O4.2 Contribute individually to overall collaborative efforts.
- **KS4.2.1** Critically and realistically self-evaluate personal contributions and collaboration effectiveness within a team.

O4.3 Analyze and evaluate the work of others to provide helpful and effective feedback.
- **KS4.3.1** Describe the purpose and positive outcomes of a peer review process.
- **KS4.3.2** Describe the characteristics of effective feedback.

O4.4 Manage project timelines and resources as part of an engineering design process.
- **KS4.4.3** Select and use a system of collaborative tools, such as cloud-based tools, document sharing, and video and text functions, to successfully complete a project.

O5.1 Communicate effectively with an audience based on audience characteristics.
- **KS5.1.1** Adhere to established conventions of written, oral and electronic communications (grammar, spelling, usage, and mechanics).
- **KS5.1.2** Follow acceptable formats for technical writing and professional presentations.
- **KS5.1.5** Properly cite references for all communication in an accepted format. Clearly label tables and figures with units and explain the information presented in context.
- **KS5.1.7** Describe characteristics important to oral delivery of information (volume, tempo, eye contact, articulation, and energy). Vary these elements of delivery to convey and emphasize information and engage the audience.

Evidence of Student Learning

Activities (A) Projects (P) Problems (B)	Assessment FOR Learning	Assessment OF Learning
Element M – Presentation of the Engineering Design Process	• EDPPSR evaluation tool. • Engineering Book Check	portfolio
Innovation Portal	Portal Rubric	Portal Rubric
Element N – Writing Like an Engineer	• EDPPSR evaluation tool. • Engineering Book Check	• Deliverable
Engineering Notebook	• EDPPSR evaluation tool. • Engineering Book Check	• EDPPSR evaluation tool. • Engineering Book Check
Unit Assessment Items Summative – EoC	-- All items	-- All items

PLTW Engineering

Project Report Rubric

Elements	Weight	5 Points	4 Points	3 Points	2 Points	1 – 0 Points	Total
Title Page		All components required for the title page have been listed.	80% or more of the components required for the title page have been listed.	70% or more of the components required for the title page have been listed.	50% or more of the components required for the title page have been listed.	Few to none of the components required for the title page have been listed.	
Abstract		The abstract completely and concisely summarizes the project or report in one paragraph.	The abstract summarizes the project or report.	The abstract does not clearly summarize the report. Information is difficult to understand.	The abstract does not completely summarize the report. Pertinent information on multiple report sections is missing or unclear.	There is little to no evidence that an abstract is included in the report.	
Concepts		The concepts section provides a comprehensive explanation of how major unit concepts or themes are addressed in the project.	The concepts section provides an explanation of how major unit concepts or themes are addressed in the project.	The concepts section provides a cursory description of how major unit concepts or themes are addressed in the project.	The concepts section provides an insufficient description of how major unit concepts or themes are addressed in the project. Pertinent information is missing or unclear.	There is little to no evidence that a concepts section is included in the project.	
Materials List		100% of the appropriate tools and materials have been selected and listed.	80% of the appropriate tools and materials have been selected and listed.	70% of the appropriate tools and materials have been selected and listed.	50% of the appropriate tools and materials have been selected and listed.	Little to no evidence of a materials list is included.	
Procedure		100% of the procedure is correctly detailed. 100% of support material is included.	80% of the procedure is correctly detailed. 80% of support material is included.	70% of the procedure is detailed though sequence is questionable. 70% of support material is included.	50% of the procedure is detailed with major sequence errors. Major support material is missing.	The procedure is missing or thoroughly incomplete.	
Concept Sketches		Concept sketches are included from all team members. Design development and subsequent modifications are shown.	Concept sketches are included from most team members. Design development shown. Some subsequent modifications shown.	Concept sketches are included from some team members. Design development shown. No subsequent modifications shown.	Concept sketches are included from one team member. Design development vaguely shown. No subsequent modifications shown.	Concept sketches are incomplete or missing.	
Technical Drawings		Technical drawings are included with appropriate annotations. Project could be re-created using these drawings.	Technical drawings are included. Project could be re-created with assumptions using these drawings.	Technical drawings are included. Project could be partially re-created using these drawings.	Technical drawings are included. Project could be recreated only after consulting the design team.	Technical drawings are incomplete or missing.	
Conclusion		The conclusion paragraph clearly and concisely states all of the key points addressed in the report.	The conclusion paragraph states the key points addressed in the report.	The conclusion paragraph states most of the key points addressed in the report.	The conclusion paragraph is wordy, confusing, or missing most of the key points of the report.	The conclusion is incomplete or not included in the report.	
Content		The information included is accurate and completely addresses each component of the assigned topic or research question.	The information included adequately addresses each component of the assigned topic or research question.	The information included inadequately addresses the assigned topic or research question. The information included is inaccurate.	The information included does not address the assigned topic or research.	There is little to no evidence of accurate content information.	
Documentation		A wealth of high quality sources are used in the report. The sources are all properly documented in the appropriate APA or MLA format.	The required number of high quality sources is used in the report. The sources are properly documented in the appropriate APA or MLA format.	Fewer than the required number of sources is used in the report. Not all sources are of substantial quality. Minor APA or MLA documentation errors may exist.	Few sources are included. No attempt is made to document sources using appropriate APA or MLA format.	There is little to no evidence that sources are used in the report. Sources are not documented using the appropriate APA or MLA format.	
Grammar		Punctuation, grammar, usage, and spelling are effectively used throughout the report.	Minor errors in punctuation, grammar, usage, and spelling are evident, but they do not interfere with the readability of the report.	Occasional errors in punctuation, grammar, usage, and spelling are evident and interfere with the readability of the report.	Major errors in punctuation, grammar, usage, and/or spelling interfere with the readability of the report.	The report contains significant errors in punctuation, grammar, usage, and spelling.	
Organization		The report content has been organized using the appropriate method. The required information is easy to locate within the report.	The report content has been mostly organized using a logical sequence, but some flaws exist. The required information is generally easy to locate within the report.	The report content has been organized using a somewhat logical sequence. The presentation is sometimes confusing.	The report content is disorganized. The required information is difficult to locate within the report.	The report includes little to no evidence of organization.	

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Written Report Rubric

Elements	Weight	5 Points	4 Points	3 Points	2 Points	1 – 0 Points	Tot
Title Page		All components required for the title page have been listed.	80% or more of the components required for the title page have been listed.	70% or more of the components required for the title page have been listed.	50% or more of the components required for the title page have been listed.	The title page is not included in the report.	
Abstract		The abstract completely and concisely summarizes the project or report in one paragraph.	The abstract summarizes the project or report.	The abstract does not clearly summarize the report. Information is difficult to understand.	The abstract does not completely summarize the report. Pertinent information on multiple report sections is missing or unclear.	The abstract is not included in the report.	
Introduction		The introduction provides a succinct, accurate overview of the content of the report.	The introduction provides an accurate overview of the content of the report. The introduction may not be succinct.	The introduction does not provide a completely accurate overview of the content of the report. The introduction is wordy and confusing.	The introduction does not provide an overview of the content of the report.	The introduction is not included in the report.	
Conclusion		The conclusion paragraph clearly and concisely states all of the key points addressed in the report.	The conclusion paragraph states the key points addressed in the report.	The conclusion paragraph states most of the key points addressed in the report.	The conclusion paragraph is wordy, confusing, or missing most of the key points of the report.	The conclusion is not included in the report.	
Content		The information included is accurate and completely addresses each component of the assigned topic or research question.	The information included adequately addresses each component of the assigned topic or research question.	The information included inadequately addresses the assigned topic or research question. The information included is sometimes inaccurate.	The information included does not address the assigned topic or research.	There is no evidence of accurate content information.	
Documentation		A wealth of high quality sources are used in the report. The sources are all properly documented in the appropriate APA format.	The required number of high quality sources is used in the report. The sources are properly documented in the appropriate APA format.	Fewer than the required number of sources is used in the report. Not all sources are of substantial quality. Minor APA documentation errors may exist.	Few sources are included. No attempt is made to document sources using appropriate APA format.	There is no evidence that sources are used in the report. No sources are documented using the appropriate APA format.	
Grammar		Punctuation, grammar, usage, and spelling are effectively used throughout the report.	Minor errors in punctuation, grammar, usage, and spelling are evident, but they do not interfere with the readability of the report.	Occasional errors in punctuation, grammar, usage, and spelling are evident and interfere with the readability of the report.	Major errors in punctuation, grammar, usage, and/or spelling interfere with the readability of the report.	The report contains significant errors in punctuation, grammar, usage, and spelling.	
Organization		The report content has been organized using the appropriate method. The required information is easy to locate within the report.	The report content has been mostly organized using a logical sequence, but some flaws exist. The required information is generally easy to locate within the report.	The report content has been organized using a somewhat logical sequence. The presentation is sometimes confusing.	The report content is disorganized. The required information is difficult to locate within the report.	The report does not include evidence of organization.	

Core Instructional, References and Supplemental Materials

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Teacher Notes: