PROJECT LEAD THE WAY PLTW

Aerospace Engineering

Computational and Analytical Skills

- Calculate the weight and moment of an aircraft
- Solve lift and drag equations
- Calculate pressure, density, and altitude given other variables
- Use a system of equations to solve coefficient of lift problems
- Calculate a structure's deflection, moment of inertia, and modulus of elasticity
- Analyze and interpret test data
- Calculate the impulse, max thrust, average thrust, burn time, and time delay
- Compare measured data to published engine specifications
- Compare measured flight data to expected results
- Analyze an issue in which Space Law applies
- Calculate energy needed for an orbital change
- Calculate impulse in terms of area under the thrust versus time curve
- Interpret a route from latitude and longitude waypoints
- Use air traffic control systems to estimate flight arrival time and predict collisions
- Calculate alternative vectors for safe operation of aircraft
- Calculate orbital periods and rank based on qualitative parameters

Design Work Experience

- Design a composite structure that meets certain criteria
- Design a turbine engine to meet specific criteria
- Design and analyze a system to mitigate space junk
- Design an alternative aerospace system such as a wind turbine or parachute
- Design and refine a remote system given design criteria
- Design a satellite orbit to meet specific criteria
- Create pseudocode to perform a complex task using sensor feedback
- Balance a glider based on center of gravity
- Balance gliders based on flight observations
- Optimize a glider to maximize performance
- Choose aircraft material to meet design requirements
- Determine what needs to be changed in an aircraft to achieve stability

Tools and Software

- VEX Robotics
- ROBOTC
- AERY software (glider design)
- Garmin eTrex Venture HC interface GPS unit
- Flight simulator
- Autodesk Inventor
- Logger Pro

Course Topics

- Aerospace history, major developments, and trends
- Major and minor components of aircraft and their function
- Motion about three major axes of the aircraft
- Control surfaces of an aircraft
- Control surface deflection and its effect on the attitude of an aircraft
- Four forces of flight and their direction relative to aircraft
- Forces of flight and how they relate to aircraft motion/acceleration
- Importance of weight and balance in an aircraft
- Lift and drag
- Major components of an airfoil
- Shape and angle of attack and how it effects the lift and drag
- Airfoil shape and how it relates to the application of an aircraft
- Variation of pressure, temperature, and density on a daily basis
- Variation of pressure, temperature, and density based on altitude
- Lines of latitude and longitude
- Typical components of common radio navigation aids
- Components of a Global Positioning System
- Purpose of an air traffic control system
- GPS system function
- Common aerospace materials and their properties
- Basic components used to create a composite material
- Benefits of using composite materials
- Newton's third law and how it relates to propulsion systems
- Four main types of turbine propulsion systems
- Model rocket components/functions
- Model rocket stability based on configuration
- Common human body systems critical to an aerospace environment
- Human body system impact on aircraft design
- NTSB and aircraft design
- Common celestial groups (galaxy, star, planet) and their relative sizes
- Space lawnand the governing agencies
- Space junk, where it comes from, and how it affects our future (Kessler's Syndrome)
- Commercialization of space and how commercial space flight affects government organizations in space activities
- Common orbital satellite pattern shapes and applications
- Energy forms involved in an orbital body and calculate gravitational potential, kinetic, and total energy
- Six Keplerian elements of an orbit
- Alternative applications for aerospace engineering
- Four environments for remote systems
- Advantages and challenges of remote systems
- Psuedocode

Achievement Level Descriptors for Aerospace Engineering

Achievement Level Descriptors (ALDs) are statements of what students should know and be able to do in a PLTW classroom. The ALDs can be used to better understand how students are performing on the End of Course examination.

The categories of basic, proficient, and advanced each provide a broad overview of student performance in that category. ALDs complement curriculum materials and can be used by teachers and students to better understand student performance and expectations. Each category builds upon the next category. For instance, a student who demonstrates an advanced understanding for a particular concept also is able to demonstrate basic and proficient understandings.

The ALDs are linked to the EoC score, and students are given an achievement indicator along with their EoC score. The achievement indicator is intended to provide an overall snapshot of the student's performance. Students who score in the proficient category may be advanced in some concepts or basic in others. Overall, their performance on the EoC indicates the level of overall achievement and performance as indicated by the ALDs.

	Basic	Proficient	Advanced
Descriptor	The student demonstrates a minimal or limited understanding of course concepts. Major gaps may be present in the student's knowledge and skills.	The student demonstrates a competent understanding of the course concepts. The student can apply knowledge and skills to familiar situations. There may be minor gaps in the student's understandings.	The student demonstrates a comprehensive and complex understanding of the course concepts. The student has the capability to transfer knowledge and skills to novel situations. Gaps in knowledge and skills are minimal.
Theme or Concept	A student who has reached the highest level of the basic category should be able to perform the following:	A student who has just reached the proficient level should be able to perform the following:	A student who has just reached the advanced level should be able to perform the following:
Historical Timeline	**Identify the correct order of major events in Aerospace.**	**Identify the correct order of major events in Aerospace and specify the approximate dates of major**	**Identify the correct order of major events in Aerospace and specify the accurate dates of**

		events in Aerospace.	major and minor events and developments in Aerospace.
Cause and Effect of Aerospace Developments	Affirm that the Aerospace timeline is a result of cause and effect.	Affirm that the Aerospace timeline is a result of cause and effect and give examples of specific cause/effects that led to Aerospace developments in the timeline.	Affirm that the Aerospace timeline is a result of cause and effect and give examples of specific cause/effects that led to Aerospace developments in the timeline. Reasonably predict how Aerospace achievements, or trends, will affect future accomplishments.
Major Components of the Aircraft	Identify major components of aircraft (e.g., fuselage, wings, empennage).	Identify major and minor components of aircraft and describe the sub-assemblies of major components and their locations.	Consistently identify major and minor components of aircraft and correctly describe their function.
Motion	Describe the motion about the three major axes of an aircraft.	Describe the motion about the three major axes of an aircraft and link to the control surfaces.	Without assistance describe the motion about the three major axes of an aircraft, link these to the control surfaces of an aircraft, and explain how the control surface deflection affects the attitude of an aircraft.
Forces of Flight	Identify the four forces of flight.	Identify the four forces of flight, their direction relative to the aircraft, and the opposing force of each.	Consistently identify the four forces of flight, their direction relative to the aircraft, the opposing force of each, and how those forces relate to aircraft motion and acceleration.
Weight and Balance	Explain the importance of weight and balance of an aircraft.	Explain the importance of weight and balance of an aircraft and calculate the weight and moment of an aircraft with prompting.	Explain the importance of weight and balance in an aircraft, independently calculate the weight and moment of an

			aircraft, and successfully determine what needs to be changed to achieve stability.
Aerodynamic Forces	State that lift and drag are generated by fluid flow around an airfoil.	State that lift and drag are generated by fluid flow around the airfoil and solve basic lift and drag equations given all variables without algebraic manipulation.	State that lift and drag are generated by fluid flow around the airfoil and solve lift and drag equations by converting and applying the four forces of flight (e.g., substitute weight for lift, drag for thrust, etc.).
Gliders	Independently balance a glider about its center of gravity.	Independently balance a glider about its center of gravity and dynamically balance with prompts.	Independently balance a glider about its center of gravity and dynamically balance independently based on flight observations. Independently optimize their glider to maximize performance.
Airfoils	Identify the major components of an airfoil (e.g., chord, upper camber, trailing edge, etc.).	Identify the major components of an airfoil and explain how the shape and angle of attack affects the lift and drag.	Identify the major components of an airfoil, explain how the shape and angle of attack affects the lift and drag, and explain how an airfoil shape is related to the application of an aircraft.
Atmosphere	Describe how pressure, temperature, and density vary on a daily basis and as an aircraft changes altitude.	Describe how pressure, temperature, and density vary on a daily basis and as an aircraft changes altitude. Calculate values for pressure, density, and altitude given other variables without algebraic manipulation.	Describe how pressure, temperature, and density vary on a daily basis and as an aircraft changes altitude. Calculate values for pressure, density, and altitude given other variables without algebraic manipulation. Independently use a system of equations to solve coefficient of lift problem.

Latitude/Longitude	Identify the meaning of lines of latitude and longitude.	Identify the meaning of lines of latitude and longitude and locate positions on a map with prompts.	Identify the meaning of lines of latitude and longitude, locate that point on a chart, and interpret a route from latitude and longitude waypoints without assistance.
Radio Navigation	Identify typical components of common radio navigation aids.	Identify typical components of common radio navigation aids and locate the line of position using radio navigation.	Identify typical components of common radio navigation aids and correct aircraft heading to an intended line of position using radio navigation without assistance.
GPS	Identify components of the Global Positioning System.	Identify the components of the Global Positioning System and what is required to obtain a position.	Identify the components of a Global Positioning System and what is required to obtain a position. Explain in-depth how augmentation systems increase the accuracy of a GPS system.
Air Traffic Control	Describe the purpose of an air traffic control system and explain how it functions.	Describe the purpose of an air traffic control system, explain how it functions, and estimate arrival time with prompts.	Independently describe the purpose of an air traffic control system, explain how it functions, estimate arrival time, predict collisions, and independently calculate alternative vectors for safe operation.
Aerospace Materials	Describe common aerospace materials and their properties.	Describe common aerospace materials, their properties, and explain how that affects design.	Describe common aerospace materials, their properties, explain how that material affects design, and justify material choices to meet design requirements.
Composites	Describe two basic components used to create a composite material.	Describe two basic components used to create a composite material and explain the benefits	Describe two basic components used to create a composite material, explain the benefits of

		of using composite materials.	using composite materials, and independently design a composite structure that meets certain criteria.
Structural Member Properties	Articulate the importance of a structure's deflection, moment of inertia, and modulus of elasticity.	Articulate the importance of and calculate the values of a structure's deflection, moment of inertia, and modulus of elasticity with prompts (no algebraic manipulation).	Articulate the importance of and consistently calculate the values of a structure's deflection, moment of inertia, and modulus of elasticity. Independently analyze and interpret test data.
Newton's Third Law	Articulate Newton's third law and give an example.	Articulate Newton's third law, give an example, and explain how it relates to propulsion systems.	Articulate Newton's third law, give an example, explain how it relates to propulsion systems, and consistently identify the two objects involved in a Newton's third law pair of forces.
Turbine Propulsion Systems	Identify the four main types of turbine propulsion systems.	Identify and describe the four main types of turbine propulsion systems.	Identify and describe the four main types of turbine propulsion systems and independently design a turbine engine to meet specific criteria.
Thrust and Impulse	Describe impulse in terms of area under the thrust versus time curve for a rocket engine test.	Describe impulse in terms of area under the thrust versus time curve and calculate the impulse for a rocket engine test with prompts.	Describe impulse in terms of area under the thrust versus time curve. Independently determine the impulse, max thrust, average thrust, burn time, and time delay. Independently compare measured data to published engine specifications.
Rocketry	Label model rocket components. Collect flight data with prompts.	Label model rocket components and functions. Independently collect flight data.	Independently label model rocket components/functions and describe how the configuration affects rocket

			stability. Independently compare measured flight data to expected results.
Human Body Systems	List some of the most common human body systems critical to an aerospace environment.	List some of the most common human body systems critical to an aerospace environment and explain how the aerospace environment affects their function.	List some of the most common human body systems critical to an aerospace environment and explain how the aerospace environment affects their function. Explain the HBS impact on aircraft design.
NTSB	Recapitulate what NTSB stands for and its function.	Recapitulate what NTSB stands for and its function. Explain why we investigate accidents to improve overall aviation safety.	Recapitulate what NTSB stands for and its function. Explain why we investigate accidents to improve overall aviation safety and how this is used in aircraft design.
Scale of Universe	Recognize common celestial groups (galaxy, star, planet).	Recognize common celestial groups (galaxy, star, planet) and describe the relative sizes of the celestial bodies.	Recognize common celestial groups (galaxy, star, planet), describe the relative sizes of the celestial bodies, and independently explain how celestial information is acquired.
Space Law	State the purpose of space law.	State the purpose of space law, cite specific examples, and identify the governing agencies.	State the purpose of space law, cite specific examples, and identify the governing agencies. Independently analyze an issue in which Space Law applies.
Space Junk	Explain what is considered space junk and where it comes from.	Explain what is considered space junk and where it comes from. Explain how space junk affects our future (Kessler's Syndrome). Design a basic system to mitigate space junk, with assistance.	Explain what is considered space junk and where it comes from. Explain how space junk affects our future (Kessler's Syndrome). Design and analyze a system to mitigate space junk.
Commercialization of Space	Describe the commercialization of	Describe the commercialization of	Describe the commercialization

	space.	space and cite specific examples.	of space and cite specific examples. Explain how commercial space flight affects the role of government organizations in space activities.
Types of Orbits	Identify common orbital satellite pattern shapes.	Identify common orbital satellite pattern shapes and applications.	Identify common orbital satellite pattern shapes and applications. Independently design a satellite orbit to meet specific criteria.
Energy of Orbits	Identify the energy forms involved in an orbital body.	Identify the energy forms involved in an orbital body and calculate gravitational potential, kinetic, and total energy (no algebraic manipulation).	Identify the energy forms involved in an orbital body and calculate gravitational potential, kinetic, and total energy. Consistently calculate energy needed for orbital change.
Orbital Elements	List and describe the six Keplerian elements of an orbit.	List and describe the six Keplerian elements of an orbit and calculate orbital periods with prompts.	List and describe the six Keplerian elements of an orbit, consistently calculate orbital periods, and rank based on qualitative parameters.
Alternative Applications for Aerospace	List some alternative applications for aerospace engineering.	List some alternative applications for aerospace engineering and explain how it can be applied to solve problems not directly related to aircraft.	List some alternative applications for aerospace engineering and explain how it can be applied to solve problems not directly related to aircraft. Independently design and test an alternative system such as a wind turbine or parachute.
Remote Systems	Identify the four environments for remote systems and give examples.	Identify the four environments for remote systems and give examples. Describe advantages and challenges for remote systems.	Identify the four environments for remote systems and give examples. Describe advantages and challenges for remote systems. Independently design

			and refine a remote system given design criteria.
Pseudocode	Explain the purpose of pseudocode and create pseudocode to perform a simple task with prompts.	Explain the purpose of pseudocode and independently create pseudocode to perform a simple task.	Explain the purpose of pseudocode and independently create pseudocode to perform a complex task using sensor feedback.
Career Paths	Describe factors that students should consider when planning a career.	Describe factors that students should consider when planning a career. Research a career.	Describe factors that students should consider when planning a career. Research a career, interview a professional, and present a career plan for evaluation.

Note: Assume that the higher levels of achievement include all prior columns.

Aerospace Engineering (AE) Detailed Outline

Unit 1: Introduction to Aerospace (49 days)

Lesson 1.1: Evolution of Flight (8 days)

Understandings

1. The evolution of flight instills an appreciation of past engineering accomplishments.
2. Aerospace history provides insight to future challenges involving travel through the atmosphere and space.
3. Aerospace engineers typically work in teams to design smaller components of a larger system. The success of the entire system relies on each component to function correctly and to interact correctly with each other.
4. Success often comes from learning from failures which is demonstrated throughout the history of aerospace development.

Performance Objectives

It is expected that students will:

1. Identify major Aerospace Engineering accomplishments.
2. Describe trends in Aerospace Engineering.
3. Analyze how Aerospace Engineering achievements were made.
4. Predict how Aerospace Engineering achievements will impact future accomplishments.
5. Synthesize discrete facts into a coherent sequence of events.
6. Deliver organized oral presentations of work tailored to the audience.

Lesson 1.2: Physics of Flight (22 days)

Understandings

1. Aircraft have fixed and moveable surfaces to control forces and change flight direction.
2. The center of gravity of an object is where its weight is concentrated.

3. Four major forces act on an aircraft flying in the Earth's atmosphere.
4. Lift and drag are generated by fluid flow around an airfoil.
5. Atmospheric conditions impact aircraft performance.
6. Aircraft performance can be simulated in a safe and cost effective environment.
7. Wind tunnels allow the performance of shapes to be tested in real fluid flow.
8. Gliders are designed to fly long distances without a system to produce thrust.

Knowledge and Skills

It is expected that students will:

1. Identify major components of an aircraft.
2. Approximate the center of gravity of geometric shapes.
3. Identify the three axis of an aircraft.
4. Label the motions about the three axis of an aircraft.
5. Describe the four major forces which act on an aircraft.
6. Describe the four ways that lift is generated by an airfoil.
7. Label the components of an airfoil.
8. Describe the Earth's atmosphere composition and layers.
9. Describe the relationship of altitude, temperature and pressure within the Earth's atmosphere.
10. Describe the factors that impact lift and drag.
11. Explain factors which improve aircraft stability.
12. Describe how the motions about the three axis of an aircraft are stabilized and controlled by aircraft components.
13. Calculate the center of gravity of an aircraft.
14. Revise the weight and location of masses onboard an aircraft for safe flight balance.
15. Demonstrate how lift may be created with an airfoil.
16. Calculate the values of Earth's atmosphere altitude, temperature and pressure relative to each other.
17. Calculate the values of lift, drag and Reynolds Number.
18. Predict how aircraft characteristics affect lift, drag, and Reynolds Number.
19. Design an airfoil to meet or exceed desired performance.
20. Design a glider to meet or exceed desired performance.
21. Summarize test data to evaluate glider performance against design criteria.
22. Revise a glider to meet or exceed desired performance.
23. Analyze the factors that contribute to a successful glider design.

24. Accurately construct a glider that represents a design.
25. Predict glider performance.
26. Compare glider performance to predicted performance.
27. Optimize glider performance to improve performance.

Lesson 1.3: Flight Planning and Navigation (19 days)

Understandings

1. The history of navigation is intertwined with technology development.
2. Pilots then apply the principles of navigation to safely travel to their destinations.
3. Each flight should be planned in advance of the actual flight.
4. The Global Positioning System, GPS, is a complex system designed to provide accurate location information to many users.
5. Simulations are widely used in the aerospace industry to develop skills which can be effectively applied to the actual device.
6. Air traffic is coordinated within a complex system to improve safety and efficiency.

Knowledge and Skills

It is expected that students will:

1. Describe major advances in navigation technology.
2. Identify components of common aviation navigation aids.
3. Describe how an aircraft reacts to flight control inputs.
4. Describe purpose of air traffic control system how it functions.
5. Explain how Global Positioning System, GPS, functions.
6. Identify the functions of a typical Global Positioning System, GPS, unit functions.
7. Describe the relationship of Tsiolkovsky rocket equation variables.
8. Identify characteristics which contribute to a successful team.
9. Interpret an indication shown on a navigation aid.
10. Illustrate navigation aid indication on a map.
11. Operate an aircraft in a simulated environment.
12. Plan a flight route.
13. Use a navigation aid to fly an aircraft to a destination in a simulated environment.
14. Predict an aircraft collision based on aircraft vectors.
15. Calculate an alternate aircraft vector for safe separation.
16. Create route consisting of latitude and longitude waypoints using a Global Positioning System, GPS, unit.

17. Interpret a route from latitude and longitude waypoints.
18. Select team members for a project based on characteristics.
19. Select propulsion system based on characteristics of each.

Unit 2: Aerospace Design (51 days)

Lesson 2.1: Materials and Structures (20 days)

Understandings

1. Aerospace material selection is based upon many factors including mechanical, thermal, electromagnetic, and chemical properties.
2. Composites combine different materials to create a material with properties superior to that of the individual materials.
3. Material testing provides a reproducible evaluation of material properties.
4. Structural design, including centroid location, moment of inertia, and a material's modulus of elasticity, are important considerations for an aircraft.
5. Static equilibrium occurs when the sum of all forces acting on a body is equal to zero.

Knowledge and Skills

It is expected that students will:

1. Describe common aerospace materials and their properties.
2. Identify moment of inertia and Young's Modulus equations.
3. Recognize the impact of loading conditions on a structure.
4. Classify materials for aerospace applications.
5. Model a structure using a 3D modeling software.
6. Analyze deformation of a structure as a result of force application.
7. Design a structure that meets a given criteria.
8. Construct a composite structure.
9. Measure mechanical properties of material.
10. Interpret measurements of a tensile tester.
11. Calculate moment of inertia and Young's Modulus equations.

Lesson 2.2: Propulsion (20 days)

Understandings

1. Energy transformed between forms of energy produces propulsion.
2. Newton's Three Laws of Motion are central to the idea of propulsion.
3. Engines vary in terms of efficiency, speed, and altitude.
4. Air and fuel are used for combustion.
5. Engine configuration impacts flight performance.
6. Rocket engines produce thrust through rapid expansion of gases.

Knowledge and Skills

It is expected that students will:

1. Describe the four primary forces acting on an aircraft.
2. Explain how Newton's Third Law applies to aerodynamic forces.
3. Describe the characteristics of the four types of propulsion systems.
4. Classify rocket engine systems.
5. Identify the thrust and impulse equations.
6. Describe parts and functions of a typical model rocket engine.
7. Outline model rocket safety suggestions.
8. Label model rocket components and functions.
9. Recognize the equation of center of gravity and center of pressure.
10. Identify common space propulsion systems.
11. Identify basic criteria to consider when designing a spacecraft.
12. Construct a physical model of a system.
13. Measure mechanical properties of material.
14. Interpret measurements of a test system.
15. Simulate performance of propulsion systems.
16. Design an aircraft propulsion system to meet a given objective such as maximum efficiency, maximum thrust to weight ratio.
17. Infer how changes in propulsion system parameters affect performance.
18. Interpret measurements of a model rocket engine thrust.
19. Design a stable model rocket.
20. Construct a stable model rocket.
21. Gather performance data associated model rocket launch such as maximum height of flight.
22. Construct a stable model rocket.
23. Calculate maximum height using rocket engine test data and indirect height measurements.
24. Organize and express thoughts and information in a clear and concise manner.

25. Select spacecraft components based on characteristics of each component.
26. Select spacecraft landing system based on characteristics of each component.

Lesson 2.3: Flight Physiology (11 days)

Understandings

1. The capabilities and limitations of the human body need to be understood by pilots, crews, and aerospace engineers.
2. The human body consists of systems that work together to ensure functionality and life.
3. An aerospace engineer considers the human interaction with the machine for more effective designs.
4. Extreme environments and forces can harm or kill a human.

Knowledge and Skills

It is expected that students will:

1. Describe common human body systems and their functions.
2. Recognize the formula for distance with respect to time and acceleration.
3. List common factors contribute to an aircraft accident.
4. Measure human vision quality such as acuity, astigmatism, color vision perception, depth perception and peripheral vision field.
5. Analyze how human factors affect aerospace system design.
6. Infer reaction time through indirect measurements.
7. Analyze an aircraft accident to determine likely causes.

Unit 3: Space (31 days)

Lesson 3.1: Space Travel (11 Days)

Understandings

1. The universe exists in a scale that is difficult to conceptualize.
2. Space law is a system based on international agreements designed to promote the use of space for the good of all humankind.
3. The exploration of space is successful through learning from previous missions and the development of technology and systems.

Knowledge and Skills

It is expected that students will:

1. Recognize common celestial groups such as galaxy, star and planet.
2. Describe the relative sizes of celestial bodies.
3. Explain how global governance applies to space issues.
4. Outline how past space faring achievements contributed to subsequent achievements.
5. Describe how commercial organizations contribute to space related activities.
6. Identify the impact that space junk has on space based activities.
7. Analyze an issue to which space applies.
8. Organize and express thoughts and information in a clear and concise manner.
9. Design a system to mitigate space junk.
10. Construct a prototype to demonstrate a design solution.

Lesson 3.2: Orbital Mechanics (20 Days)

Understandings

1. Orbital mechanics provides a means for describing orbital behavior of bodies.
2. The same laws that govern satellite orbits also govern celestial body (e.g. comets, planets and moons) orbits.
3. Objects in orbit are continuously falling toward the body about around which they orbit.
4. Objects orbit other objects in a pattern governed by forces exerted on each other.
5. All objects exert an attraction force to each other.
6. Orbital elements can be used to fully define a satellite's orbit, allowing the accurate prediction of the precise location of the satellite at a given time.
7. A satellite's mission is a major factor when designing its orbit.

Knowledge and Skills

It is expected that students will:

1. List major contributions made by people studying orbital mechanics.
2. Describe common satellite orbital pattern shapes and applications.
3. Name and describe the six Keplerian elements.
4. Explain Kepler's Laws.
5. Recognize the equations for orbital period, orbital gravitational potential energy, orbital kinetic energy, and total orbital energy.
6. Describe how an orbital mechanics modeling software can be applied design a satellite system.

7. Explain how financial factors impact a project.
8. Analyze how an orbital mechanics theory can describe satellite motion.
9. Organize and express thoughts and information in a clear and concise manner.
10. Identify the most appropriate orbital pattern for an application.
11. Calculate an orbiting body's orbital period, orbital gravitational potential energy, orbital kinetic energy, and total orbital energy.
12. Model a satellite system using a modeling software.
13. Formulate a financial proposal for a project.

Unit 4: Alternative Applications (45 Days)

Lesson 4.1: Alternative Applications (11 Days)

Understandings

1. Aerospace concepts traditionally considered applicable to flight can be used in a variety of applications and industries.
2. Fluid movement is an important consideration in the design of many products.
3. Air travel impacts society and the environment in many ways.
4. Efficiency is major criteria for aircraft design.

Knowledge and Skills

It is expected that students will:

1. List alternative applications than aircraft for aerospace engineering concepts.
2. Describe the parts and functions of a wind turbine.
3. Identify factors that impact aircraft efficiency.
4. Recognize the drag equation.
5. Design aerospace system as an alternate to an aircraft which use aerospace engineering concepts. Examples include a wind turbine and a parachute.
6. Construct an alternate aerospace system.
7. Measure output of an alternate aerospace system.
8. Optimize an alternate aerospace system.
9. Explain aircraft efficiency affects aircraft design.

Lesson 4.2: Remote Systems (26 Days)

Understandings

1. Remote system designs are used in air, ground, maritime, and space environments.
2. Remote systems can be designed to perform an extended operation with little human input or impact.
3. Operator input is established through the use of an operator interface and a means to communicate with the remote system.
4. Remote system design is based upon the integrated system design of mechanical, electrical, and software systems.
5. Remote systems use sensor feedback to modify behavior.

Knowledge and Skills

It is expected that students will:

1. Explain how unmanned systems can be integrated into aerospace systems.
2. Recognize factors that affect communication with equipment in space.
3. Describe how input and output devices function.
4. Explain the purpose of a flowchart or pseudocode.
5. Describe functions of a computer program.
6. Identify how functions of a computer program can be applied to perform a task.
7. Outline how a satellite data is gathered and used to create a map.
8. Describe how human factors impact space travel.
9. Describe how spacecraft systems function.
10. Analyze how aerospace unmanned systems function.
11. Synthesize a discrete knowledge into a coherent sequent of events.
12. Deliver organized oral presentations of work tailored to the audience.
13. Describe the impact of a communication delay on the success of a mission.
14. Operate output devices to perform a function.
15. Relate sensor input to the environment being measured.
16. Create a flowchart or pseudocode to perform a task.
17. Construct a control program to accomplish a specified goal.
18. Operate a remote system through a series of performance tasks including autonomous navigation
19. Gather data using robot control software.
20. Arrange data using spreadsheet software.
21. Operate a simulated spaceflight.

Lesson 4.3: Aerospace Careers (8 Days)

Understandings

1. The wide variety of career paths available to students requires careful consideration for future professional success.
2. Career planning should consider many factors.
3. Career planning should begin by exploring one's own interests and understanding possible options.

Knowledge and Skills

It is expected that students will:

1. Describe factors that a student should consider when planning a career
2. Outline questions as preparation to interview a professional.
3. Collect information related to a future career.
4. Interview a professional.
5. Assemble career information into a coherent plan.
6. Deliver organized presentations of work tailored to the audience.
7. Criticize the work of a peer.

Civil Engineering and Architecture (CEA) Detailed Outline

Unit 1: Overview of Civil Engineering and Architecture (23 days)

Lesson 1.1: History of Civil Engineering and Architecture

Understandings

1. Many features of ancient structures are seen in modern buildings.
2. Architectural style is often an important key to understanding how a community or neighborhood has developed and the aesthetic customs that have formed over time.
3. The multiple architectural styles that have been developed throughout history are an indication of changing needs of people and society and uses for space.
4. Visual design principles and elements constitute an aesthetic vocabulary that can be used to describe buildings and may contribute to their function, location, or time period.

Knowledge and Skills
It is expected that students will:

- Connect modern structural and architectural designs to historical architectural and civil engineering achievements.
- Identify three general categories of structural systems used in historical buildings.
- Explain how historical innovations have contributed to the evolution of civil engineering and architecture.
- Identify and explain the application of principles and elements of design to architectural buildings.
- Determine architectural style through identification of building features, components, and materials.
- Create a mock-up model depicting an architectural style or feature using a variety of materials. .

Lesson 1.2: Careers in Civil Engineering and Architecture

Understandings

1. Civil engineers and architects apply math, science, and discipline-specific skills to design and implement solutions.
2. Civil engineering and architecture careers are comprised of several specialties and offer creative job opportunities for individuals with a wide variety of backgrounds and goals.
3. Civil engineers are problem solvers involved in the design and construction of a diverse array of projects in a wide range of disciplines including structural, environmental, geotechnical, water resources, transportation, construction and urban planning.
4. Architects primarily focus on designing the interior and exterior "look and feel" of commercial and residential structures meant for human habitation.
5. An effective method for brainstorming possible solutions involves a collaboration of many stakeholders with a variety of skills coming together in an organized meeting called a charrette.

Knowledge and Skills
It is expected that students will:

- Identify the primary duties, and attributes of a civil engineer and an architect along with the traditional path for becoming a civil engineer or architect.
- Identify various specialty disciplines associated with civil engineering.
- Participate in a design charrette and recognize the value of using a charrette to develop innovative solutions to support whole building design.
- Understand the relationship among the stakeholders involved in the design and construction of a building project.

Unit 2: Residential Design (55 days)

Lesson 2.1: Building Design and Construction

Understandings

1. Many residential structures are constructed with wood framing systems and are built using standard practices.
2. A variety of roof shapes and materials are available for residential structures to address aesthetic preferences, carry design loads, and meet environmental challenges.
3. Designers design, modify, and plan structures using 3D architectural software.
4. Architects and engineers use a variety of views to document and detail a building project on construction drawings.

Knowledge and Skills
It is expected that students will:

- Identify typical components of a residential framing system.
- Recognize conventional residential roof designs.
- Model a common residential roof design and detail advantages and disadvantages of that style.
- Use 3D architectural software to design, model and document a small building.

Lesson 2.2: Cost and Efficiency Analysis

Understandings

1. The combination of concrete and rebar, called reinforced concrete, is an important component of residential foundations.
2. Accurately determining the cost and quantities for a construction project can ensure a successful building project providing a high quality structure with less material and financial waste.
3. An effective residential structure should include methods for adequate heating and cooling.
4. R-value and U-factor measurements are used to select materials that with ensure a structure is properly insulated.

Knowledge and Skills
It is expected that students will:

- Apply basic math skills to calculate the quantity and cost of concrete needed to pour the pad for a small building.
- Create a cost estimate for a small construction project, including a detailed cost break-down.
- Calculate the heat loss for a building envelope with given conditions appropriate for the project.

Lesson 2.3: Residential Design

Understandings

1. Responsible designers maximize the potential of the property, minimize impact on the environment, and incorporate universal design concepts in order to create an attractive and functional space.
2. Responsible designers anticipate the needs and requirements of the users.
3. Codes are created to protect the health and safety of the public, dictate the minimum requirements that must be met in a building project, and constrain the location of structures, utilities, building construction, and landscape components placed on a site.
4. Appropriate flow rate, pressure, and water quality are necessary for effective water supply and use.

5. When utilities are not available within a reasonable distance to be economically brought on site, substitutions must be designed and constructed.
6. Utilities and systems must be properly sized to minimize cost and appropriately serve the project and the structure occupants.
7. The design of electrical and plumbing systems must be carefully integrated into the architectural and structural design of a building.
8. Careful landscape design that takes into consideration local environmental conditions can improve energy efficiency, reduce noise, reduce water usage, reduce storm water runoff, and improve the visual impact of a building project.
9. Storm water runoff from a site often increases when the site is developed and is frequently regulated by local jurisdictions.
10. Universal Design involves the design of products and environments to be usable by all people and includes barrier free accessibility to projects that may be required by federal regulations.
11. Green or sustainable design reduces the negative impact of a project on the environment and human health and improves the performance of the project during its life-cycle.
    a. Activity 2.3.2 – Students research green and sustainable practices that can be applied to the design of their Affordable House design project. Research includes investigation of techniques to harvest rainwater, environmentally friendly construction methods, recycling of construction wastes, reducing energy consumption, incorporating a site's natural resources into the design of the structure.
    b. Activity 2.3.4 – Students create a proposal to gain LEED points toward LEED certification for their Affordable Home design project and explain how meeting the prerequisites and criteria for the LEED credit promotes the transformation of the homebuilding industry toward more sustainable practices.

Knowledge and Skills
It is expected that students will:

- Apply elements of good residential design to the design of a basic house to meet the needs of a client.
- Design a home design that complies with applicable codes and requirements.
- Incorporate sustainable building principles, energy conservation features, and universal design concepts into a residential design.
- Create bubble diagrams and sketch a floor plan.
- Identify residential foundation types and choose an appropriate foundation for a residential application.
- Calculate the head loss and estimate the water pressure for a given water supply system.
- Create sketches to document a preliminary plumbing and a preliminary electrical system layout for a residence that comply with applicable codes.
- Design an appropriate sewer lateral for wastewater management for a building that complies with applicable codes.

- Create a site opportunities map and sketch a project site.
- Choose an appropriate building location on a site based on orientation and other site-specific information.
- Calculate the storm water runoff from a site before and after development.
- Document the design of a home using 3D architectural design software and construction drawings.

Unit 3: Commercial Applications (57 days)

Lesson 3.1: Commercial Building Systems

Understandings

1. Commercial building systems differ from residential building systems in many significant ways.
2. Codes and building regulations define and constrain all aspects of building design and construction including the structure, site design, utilities, and building usage.
3. Zoning regulations are used to control land use and development.
4. Wall, roof, floor, and framing systems for commercial facilities are chosen based on many factors.

Knowledge and Skills
It is expected that students will:

- Identify common commercial wall systems and building materials and differentiate between load-bearing and non-load bearing walls.
- Identify common commercial building framing systems.
- Identify applicable building codes and regulations that apply to a given development.
- Classify a building according to its use, occupancy, and construction type using the International Building Code.
- Research Land Use regulations to identify zoning designations and allowable uses of property.
- Comply with specifications, regulations, and codes during a design process.
- Compare a variety of commercial wall systems and select an appropriate system for a given commercial application based on materials, strength, aesthetics, durability, and cost.
- Compare a variety of commercial low-slope roof systems and select an appropriate system for a given commercial application based on materials, strength, durability, and cost.
- Identify the pros and cons of the use of a green roof in a commercial building design.
- Incorporate sustainable building practices, especially a green roof, into the design of a commercial building.
- Use 3D architectural design software to incorporate revisions for the redesign of a building.
- Use 3D architectural design software to create appropriate documentation to communicate a commercial building design.

- Calculate the structural efficiency of a structure.
- Use load-span tables to design structural elements.

Lesson 3.2: Structures

Understandings

1. The purpose of a structure is to withstand all applied loads and forces and to transfer these forces to the Earth.
2. Structural engineering involves the critical analysis of forces and loads, the anticipated effect of these loads on a structure, and the design of structural elements to safely and efficiently resist the anticipated forces and loads.
3. Design loads are often dictated by building codes.
4. Structural design includes the determination of how structures disperse the applied loads.
5. The application of loads to a building results in resisting forces from the structure which can be predicted through the use of mathematics and physical science principles.

Knowledge and Skills
It is expected that students will:

- Given a structural form, describe how the structural form resists and transfers applied loads.
- Use building codes and other resources to calculate roof loading to a structure and select appropriate roof beams to safely carry the load.
- Analyze a simply supported beam subjected to a given loading condition to determine reaction forces, sketch shear and moment diagrams, and determine the maximum moment resulting in the beam.
- Use beam formula to calculate end reactions and the maximum moments of a simply supported beam subjected to a given loading condition.
- Use structural analysis software to create shear and moment diagrams of simply supported beams subjected to a given loading condition.
- Calculate the deflection of a simply supported beam subjected to a given loading condition.
- Use building codes and other resources to determine the required floor loading and design a structural steel floor framing system (beams and girders) for a given building occupancy.
- Identify and describe the typical usage of foundation systems commonly used in commercial construction.
- Determine the loads transferred from a steel framed structure to the ground through a foundation.
- Size a spread footing for a given loading condition.
- Check structural calculations created by others for correctness.

Lesson 3.3: Services and Utilities

Understandings

1. When utilities are not available within a reasonable distance to be economically brought on site, substitutions must be designed and constructed.
2. Utilities and systems must be properly sized to minimize cost and appropriately serve the project.
3. Responsible designers anticipate the needs and requirements of the users.
4. The design of mechanical systems impact the architectural and structural design of a building.
5. Energy codes are designed to conserve natural resources, reduce operating costs, protect the environment and create healthier living and working spaces. They dictate the minimum requirements for the building envelope, lighting, mechanical systems, and service water heating for commercial facilities.
6. The design of internal systems is documented with construction drawings specific to each system.

Knowledge and Skills
It is expected that students will:

- Identify typical utility services for a commercial building, typical transmission/distribution methods for each utility, and methods for measuring usage.
- Interpret and apply code requirements and constraints as they pertain to the installation of services and utilities.
- Read and understand HVAC construction drawings for a commercial project.
- Apply criteria and constraints to size and locate the new utility service connections for a commercial facility.
- Modify system designs to incorporate energy conservation techniques.

Lesson 3.4: Site Considerations

Understandings

1. Land surveying is used for many purposes during the design and construction of a project including establishing the topography of a site, setting control points, and establishing the location of project features.
2. Engineers must consider parking requirements, pedestrian access, ingress and egress, landscaping, storm water management, and site grading when creating a site design.
3. Ingress and egress, parking, pedestrian, and handicapped access must be planned to efficiently and safely move traffic, goods, and people.
4. The characteristics of soils present on a site impact the design and construction of improvements to a property.
5. Codes determine the type, sizing, and placement of site features such as parking lots, entrance and exit roads, pedestrian and handicapped access, and storm water facilities.
6. The surface conditions and topography of a site affect the quantity and quality of storm water runoff and the design of the storm water management system.

7. A soil can be classified according to its grain size and plasticity which impact the characteristics the soil will exhibit.

Knowledge and Skills
It is expected that students will:

- Use differential leveling to complete a control survey to establish a point of known elevation for a project.
- Design appropriate pedestrian access, vehicular access and a parking lot for a commercial facility.
- Analyze a site soil sample to determine the United Soil Classification System designation and predict soil characteristics important to the design and construction of a building on the site.
- Explain the impact of site development on storm water runoff.
- Estimate the increase in storm water runoff from a commercial site and create a preliminary design for a storm water storage facility.
- Identify and explain the purpose of Low Impact Development techniques in site development.
- Apply Low Impact Development techniques to a commercial site design reduce the impact of development on storm water runoff quantity and quality.
- Follow specifications and codes during a design process.
- Given 3D architectural design software, document a commercial site design.

Unit 4: Commercial Building Design (35 Days)

Lesson 4.1: Commercial Building Design Problem

Understandings

1. Detailed planning, documentation and management of a project is essential to its success.
2. People work in teams to produce solutions to complex problems.
3. A legal description of property is used to identify real estate in a legal transaction and can be found in a deed, mortgage, plat or other purchase documents.
4. The selection of a site and the project being planned are interrelated. A site should be thoroughly research to determine whether it is compatible with the project to be built.
5. Legal, physical, and financial conditions as well as the needs of the surrounding community should be taken into consideration when determining the viability of a project.

Knowledge and Skills
It is expected that students will:

- Work individually and in groups to produce a solution to a team project.
- Research codes, zoning ordinances and regulations to determine the applicable requirements for a project.
- Identify the boundaries of a property based on its legal description.

- Perform research and visit a site to gather information pertinent to the viability of a project on the site.
- Identify the criteria and constraints, and gather information to promote viable decisions regarding the development of their solution.
- Create an architectural program, a project organization chart, and a Gantt chart and hold project progress meetings to help manage the team project.
- Communicate ideas while developing a project using various drawing methods, sketches, graphics, or other media collected and documented.
- Identify the criteria for commercial property/project viability.
- Investigate the legal, physical, and financial requirements of a project and consider the needs of the community to determine project viability.
- Apply current common practices utilized in Civil Engineering and Architecture to develop a viable solution in their project.
- Develop an understanding of how software is used as a tool to aid in the solution and then the communication of a project.

Lesson 4.2: Commercial Building Design Presentation

Understandings

1. Critiques and reviews are used to inform and provide suggestions for improvement.
2. Presentations and displays of work provide the means to effectively promote the implementation of a project.
3. A well-done presentation will enhance the quality of a team's project.

Knowledge and Skills
It is expected that students will:

- Assemble and organize work from a commercial project to showcase the project in an effective and professional manner.
- Create visual aids for a presentation that include the appropriate drawings, renderings, models, documentation, and the rationale for choosing the proposal for project development.
- Conduct an oral presentation to present a proposal for the design and development of a commercial building project.

Biotechnical Engineering (BE) Detailed Outline

Unit 1: Safety and Documentation Review (9 days)

Lesson 1.1 - Biotechnical Engineering Procedures (9 days)

Understandings:

1. Project documentation is necessary to solve complex design problems and provide accurate communication.
2. Journals are used to document communication and the entire design process.
3. It is critical that lab instruments are giving reliable results (precise) and are representative (accurate) of what they are supposed to measure.
4. Workers in a biotechnical laboratory must follow safety procedures to protect themselves and others.

Knowledge and Skills
It is expected that students will:

- Communicate ideas for designing a project using various drawing methods, sketches, graphics, or other media collected and documented.
- Amend ideas, notes, and presentations based on personal review and feedback from others and will document them.
- Describe in daily journals the advantages and disadvantages of various information-gathering techniques, communications, and design processes in the development of the project.
- Follow procedures for ensuring accuracy and precision in measuring solutions.
- Follow laboratory safety procedures.

Unit 2: Introduction to Biotechnical Engineering (29 days)

Lesson 2.1 - Biotechnical Engineering History and Industry (21 days)

Understandings:

1. Biotechnical engineering involves the application of biological and engineering concepts in order to design materials and processes that directly measure, repair, improve, and extend living systems.
2. Historically, the use of engineering concepts has aided scientists to

further their knowledge of biological information and engineers by using scientific principles to enhance their design solutions.
3. The rapid rate of new biological discoveries is due in a large part to scientists' knowledge and their use of engineering concepts.
4. The fields of biotechnology are interconnected by the common elements of living organisms.
5. There is a correlation between what is happening in the financial markets and what drives the biotechnology industry.

Knowledge and Skills
It is expected that students will:

- Conduct a Biotechnology Timeline WebQuest to gather information about the evolution of biotechnical engineering.
- Develop a scaled timeline illustrating major biotechnical engineering milestones through the use of the internet, available hard copy resources, and their individual milestone impact cards describing future biotechnical developments.
- Assess the impact of each milestone based on their research.
- Identify the fundamental concepts common to all major industries in biotechnical engineering.
- Identify and explain how biotechnical engineered products impact society.
- Predict future developments in biotechnical engineering.
- Investigate and begin to develop an understanding of the relationship between financial markets and scientific research.

Lesson 2.2 – Lessons from Prometheus (8 days)

Understandings:
1. Technology in the life sciences cannot be studied without considering the impact of new technologies and the potential to benefit or harm living systems.
2. In order to make policy decisions regarding bioethics, it is important to understand what variables shape one's ethics and how those variables are distributed in society.
3. Due to the controversial nature of bioethical issues, they generally pose questions that have no clear-cut easy answers.
4. Bioethical issues involve questions of responsibility and obligations to others; such as, doing what is right involves reflecting on one's values, moral principles, and self-image.
5. Making decisions about the use of technology involves weighing the trade-offs between the positive and negative effects.
6. Consequences of actions need to be considered for the individual, for others, and for society as a whole.

Knowledge and Skills
It is expected that students will:

- Work individually and as a group to generate definitions of key terms to be addressed in the lesson.
- Discuss the differences between values and morals.
- Discuss the differences between morals and ethics.
- Describe the variables that shape one's ethics.
- Role-play a bioethics case study to address and personalize the different perspectives involved.
- Analyze the bioethical issues that arise when various technological advancements create new options.
- Create and test a public opinion survey on the bioethics of biotechnology.

Unit 3: Biochemical Engineering (30 days)

Lesson 3.1 – CSI Forensics: Engineers Needed (30 days)

Understandings:

1. Engineers provide the technological advances necessary for the identification and processing of DNA.
2. Advances in the techniques of DNA sequence analysis and DNA amplification has revolutionized medicine and forensic science.
3. The wealth of DNA sequence information that has recently been achieved has led to the development of a new field in biotechnology called bioinformatics.
4. The ability to rapidly perform comparative analysis pathology data and large databases of genetic information can potentially save lives and prevent human suffering.

Knowledge and Skills
It is expected that students will:

- Investigate molecular techniques that are used by bioinformaticists.
- Create a portfolio demonstrating the research and integration of forensics with engineering.
- Design and create a 3D model of a fuming chamber for lifting prints from evidence.
- Analyze the technology utilized in the field of forensics.
- Apply the skills of reverse engineering to a crime scene and solve the mystery.
- Create methods for evaluating collected evidence from a crime scene and prepare justifications for their conclusions.
- Apply their practical knowledge of genetic engineering to the design of a novel and beneficial application of the reporter gene, green fluorescent protein.
- Determine the proper techniques for isolating proteins.

- Form a start-up pharmaceutical company with an appropriate name that will attempt to produce a pharmaceutical via previous genetic engineering work followed by scaled up growth of genetically modified bacteria.
- Conduct facial reconstruction and experience the role of a forensic artist.

Unit 4: Environmental and Agricultural Engineering (21 days)

Lesson 4.1 – Grow to Go (44 days)

Understandings:

1. Whole organisms can be used as bioreactors to produce useful products instead of practicing complex synthetic approaches in the laboratory.
2. Chemostats are important tools of process engineers that require aseptic techniques and a thorough understanding of microbial metabolism.
3. Optimization of reactants or substrates is critical for efficient use of bioreactors.
4. Bioprocessing can lead to novel approaches of renewable energy.

Knowledge and Skills
It is expected that students will:

- Determine the applications of fermentation in food production and renewable energy.
- Design a method or instrumentation to be used for measuring rates of fermentation.
- Research and test different variables which affect CO2 production in yeast in order to determine the ideal conditions for fermentation.
- Design and run a yeast-powered vehicle.

Unit 5: Biomedical (61 days)

Lesson 5.1 - Biomedical Engineering (12 days)

Understandings:

1. Extensive and detailed engineering plans exist to better assist professionals at work.
2. Continued product evaluation must exist to improve equipment and meet the needs of patients.
3. Extensive communication and documentation are essential throughout the team of professionals.
4. Continued education must exist in order to advance with changes in technology.

Knowledge and Skills
It is expected that students will:

- Demonstrate the application of engineering design principles by improving upon existing hospital designs or surgical equipment designs.
- Demonstrate the application of product liability, product reliability, product reusability, and product failure.

Lesson 5.2 - Orthopedics (30 days)

Understandings:

1. The human musculo-skeletal anatomy is the primary support system in the human body.
2. The human skeletal system has five functions that affect the quality of human life.
3. Common disorders of the human musculo-skeletal anatomy can be overcome by use of artificial orthopedic devices.
4. A variety of specialized materials can be used for joint replacement devices.

Knowledge and Skills
It is expected that students will:

- Develop a portfolio identifying anatomical joint features and movements.
- Build a joint model with the same degrees of freedom as the human counterpart.
- Design and sketch a new joint replacement and solid model approved sketches.
- Develop a materials and development cost for the joint design and surgical implant.
- Synthesize skeletal system concepts with the design process for engineering joints.

Lesson 5.3: Cardiovascular Devices and Imaging (19 days)

Understandings:

1. Normal cardiac function can be accurately measured and abnormal cardiac functions can be diagnosed using a medical tool called an ECG.
2. Some cardiac defects can be corrected using prosthetic devices such as heart valves or stents.
3. The heart is an electrical as well as a mechanical organ which produces electrical fields that can be measured.
4. Electrical signals correspond to the cardiac cycle.

Knowledge and Skills
It is expected that students will:

- Research heart diseases and disorders.
- Sketch and provide a solid model of heart chambers and valves.
- Research procedures involving artificial heart surgery and present the cost of a proposed noninvasive implant.
- Research and create a set of improvements for imaging techniques.
- Design a portable ECG monitor and study the electrical aspects associated with the heart.
- Research and design improvements in heart implants or instruments.
- Perform a virtual heart surgery to better understand the instruments and implants in need of improving.

Total days: 173 Days

Computer Integrated Manufacturing (CIM) Detailed Outline

Unit 1: Principles of Manufacturing (32 days)

Lesson 1.1: History of Manufacturing (8 days)

Understandings

1. Manufacturing is a series of interrelated activities and operations that involve product design, planning, producing, materials control, quality assurance, management, and marketing of that product.
2. Manufacturing is essential to a healthy economy..
3. Manufacturing in the United States avoids health risks that are accepted in other countries.
4. There are many any careers associated with manufacturing.
5. A variety of processes are used in the creation of products.

Knowledge and Skills

It is expected that students will:

1. Describe why and how manufacturing evolved.
2. Identify components of a typical manufacturing system.
3. List common manufacturing techniques and processes.
4. Interpret how advances in techniques and technology impact modern manufacturing.
5. Categorize how components of a typical manufacturing system such as customer, knowledge and processes represent manufacturing activities.
6. Research common manufacturing techniques such as Kaizen and Flexible Manufacturing Systems and systems such as Computer Numerical Control and Automated Guided Vehicle.
7. Summarize how manufacturing techniques and processes have evolved.
8. Compare and contrast the advantages and disadvantages common manufacturing techniques and processes.

Lesson 1.2: Control Systems (10 days)

Understandings

1. Everyday products including cars, microwaves, ovens, hair dryers, coffee pots, and washing machines all use control systems to manage their operation.

2. A flowcharting and pseudocode are powerful tools used by technicians, computer programmers, engineers, and professionals in a variety of roles and responsibilities.
3. During the design and development process, a flowchart or pseudocode are used to plan and depict the process flow for an entire system and all of its subsystems.
4. Computer programmers use a flowchart and pseudocode to organize the flow of program control, including all inputs, outputs, and conditions that may occur.

Knowledge and Skills

It is expected that students will:

1. Identify open and closed loop systems.
2. Describe how input and output devices are part of an open and closed loop system.
3. Explain the purpose of a flowchart or pseudocode.
4. Describe functions of a computer program.
5. Identify how functions of a computer program can be applied to perform a task.
6. Operate output devices to perform a function.
7. Relate sensor input to the environment being measured.
8. Create a flowchart or pseudocode to perform a task.
9. Construct a control program to accomplish an objective such as motor reacting to the environment.
10. Modify an open loop system to be a closed loop system using sensors.

Lesson 1.3: Cost of Manufacturing (14 days)

Understandings

1. When designing a control system, cost and safety are two key factors that must be considered.
2. Many factors come into play when calculating the cost of manufacturing a product.
3. Tradeoffs may be made between hiring highly skilled or experienced workers and keeping costs down.
4. The less time a part takes to make, the more potential profit is available.
5. Long term planning and investments may cost more up front but may provide additional savings in the future.

Knowledge and Skills

It is expected that students will:

1. Recognize fixed and variable costs of manufacturing a product.
2. Identify direct and indirect costs of manufacturing a product.
3. Recognize costs of a manufacturing system
4. Classify typical costs of manufacturing a given product.
5. sign a manufacturing system with consideration to time and cost to produce a product.
6. Construct a model of a manufacturing system.
7. Construct a control program to operate a model factory.
8. Compare the efficiencies of multiple manufacturing systems.

Unit 2: Manufacturing Processes (54 days)

Lesson 2.1: Designing for Manufacturability (10 days)

Understandings

1. Design is a process that is used to systematically solve problems.
2. Many considerations must be made when manufacturing a quality part.
3. Analyzing case studies of engineering failures is a good way for engineers to avoid future failures.
4. Manufacturers have an ethical responsibility to create safe products and to provide a safe work environment.
5. Manufacturers have a legal responsibility to provide safety information about their products.
6. Many engineering disciplines have a code of conduct or code of ethics that their members are expected to follow.
7. Material properties must be considered as part of the design process.

Knowledge and Skills

It is expected that students will:

1. Describe steps in a design process.
2. Describe factors which affect a design.
3. Identify principles of engineering ethics.
4. Outline how mass properties impact manufacturing decisions.
5. Analyze how adequate product fulfills a function.
6. Summarize how a product can be modified to fulfill of function.
7. Apply the engineering code of ethics when considering a design.
8. Model an object using a drawing.
9. Show the volume, mass, surface area of a model.
10. a mathematical model to describe a manufacturing function.
11. Calculate costs and physical requirements impacted by product physical properties.

12. Explain how ethics impact engineering decisions.

Lesson 2.2: How We Make Things (6 days)

Understandings

1. Prototyping is part of a design process where a physical model can be evaluated to refine the design.
2. Before raw material can be used in manufacturing, it must undergo primary processing.
3. The separating process is one of the oldest manufacturing processes.
4. Milling and shearing utilize the subtractive process to create products.
5. Electrochemical Machining (ECM), Electrical Discharge Machining (EDM), water-cutting, and laser-cutting are using newer technologies to enhance the accuracy and efficiency of material removal.
6. Metals, plastics, and ceramics are types of materials that are well suited to the manufacturing process.
7. The way in which a product is made is dependent upon the properties of the material that will be used.

Knowledge and Skills

It is expected that students will:

1. Describe common prototyping techniques.
2. Explain the difference between primary and secondary manufacturing processes.
3. Describe common manufacturing processes.
4. Analyze common prototyping techniques.
5. Identify how manufacturing processes can be used to produce a product.

Lesson 2.3: Product Development (38 days)

Understandings

1. Many machines exist to perform manufacturing processes.
2. Products manufactured today have been greatly influenced by the advancement of machines and technology.
3. Machine code is an essential tool used to communicate with some machines.
4. Computer Aided Manufacturing (CAM) programming tools make it possible to manufacture physical models using Computer Aided Design (CAD) programs.
5. Several variables in machining operations affect the final product in manufacturing.
6. Jigs and fixtures are essential in maintaining consistency and quality control.
7. Profit margins are essential to a company's survival in a competitive market.

8. Prototyping is a major step in the design cycle of manufactured goods and has been greatly advanced with the advent and use of rapid prototyping processes.

Knowledge and Skills

It is expected that students will:

1. List examples of common CNC machines.
2. List common robot applications used in manufacturing.
3. Identify common cutting tools.
4. Describe parts and functions of common machines used in manufacturing.
5. Select formulas which are used to determine milling machine settings.
6. Describe common G & M Codes.
7. Describe a procedure to operate a milling machine.
8. Identify a machine which can be used to perform a process.
9. Calculate settings needed for a milling machine.
10. Interpret the actions that will be performed given a sample of machine code.
11. Manually create machine code required to manufacture a product.
12. Create machine code to manufacture a product using Computer Aided Manufacturing (CAM) program.
13. Test machine code accuracy using simulation software.
14. Create a model using Computer Aided Design (CAD) software.
15. Create a product using a CNC milling machine.

Unit 3: Elements of Automation (46 days)

Lesson 3.1: Introduction to Robotic Automation (19 Days)

Understandings

1. There are many factors that influence the evolution of automation.
2. Robots are widely used in industry to assist in the production of manufactured goods.
3. Robots have distinct advantages over humans in some industrial settings.
4. A variety of automation careers exist.
5. Robots and machines communicate and coordinate their activities through a process called handshaking.

Knowledge and Skills

It is expected that students will:

1. Identify common robot types.
2. Define accuracy and repeatability.
3. Describe components of a robotic work cell.
4. Describe roll angle.
5. List characteristics of robots in a manufacturing environment.
6. Describe methods for materials to be handled in a manufacturing environment.
7. Distinguish between accuracy and repeatability.
8. Describe the development of robot technology and application.
9. Create a program to control a robotic arm.
10. Calculate roll angle for robotic arm movement.
11. Create a program for robotic arm to communicate with another device.
12. Analyze factors that impact robots in a manufacturing environment.
13. Explain how materials handling impacts a manufacturing environment.

Lesson 3.2: Elements of Automation Power (10 Days)

Understandings

1. Power is produced in many ways and transmitted through various forms (e.g. electrical, pneumatic, hydraulic, and motion).

9. Fluid power is inversely proportional to the area upon which the force is being applied.

10. Pneumatics is one form of fluid power that can be used to operate machines and products.

11. Sensors provide feedback to control systems and products used by consumers.

Knowledge and Skills

It is expected that students will:

1. Define torque, pressure, work and power.

16. Identify equations of torque, pressure, work and power.

17. Apply torque, pressure, work and power equations to engineering problems.

18. Design a system to perform a task using fluid power.

19. Construct a fluid power system.

20. Create a program to operate a fluid power system.

Lesson 3.3: Robotic Programming and Usage (17 Days)

Understandings

1. Many everyday products use microcontrollers.

12. Robots are used to perform diverse functions and work in diverse environments.

13. A variety of robots and unique programming languages are used in the manufacturing industry.

14. Basic programming skills include variable declaration, loops, and debugging.
15. The size of a robot is based on the work envelope and payload needed to perform the task.

Knowledge and Skills

It is expected that students will:

1. Describe robot components including drive systems, electrical components.
21. Describe the envelope of common robot types.
22. Describe how robot geometry affects robot motion.
23. Identify elements of a robotic program.
24. Match robot type to application.
25. Predict robot motion resulting from movement of an actuator.
26. Create a program to control a robotic arm.
27. Create programs for a robotic arm to communicate with a related machine.

Unit 4: Integration of Manufacturing Elements (47 days)

Lesson 4.1: CIM Systems (10 Days)

Understandings

1. The process of mass production is used when the same product is created repeatedly.
2. A workcell is a group of machines in which each individual machine has its own specialty.
3. A flexible manufacturing system is one that can adapt to a wide variety of products.
4. Manufacturing and automation careers are varied in scope and location.
5. Tradeoffs are made when one system is utilized over another.
6. Process flow design has a major impact on overall production time and product profit.
7. During the design and development process, flowcharting is used to plan and depict the detailed process flow for an entire system and all of its subsystems.
8. Flowcharting can be used to illustrate the phases of the product development process.

Knowledge and Skills

It is expected that students will:

1. Describe common CIM systems.
2. Recognize machines and processes in a manufacturing setting.

3. Compare and contrast common CIM systems
4. Breakdown a manufacturing system into machines and processes.
5. Organize and express thoughts and information in a clear and concise manner.
6. Explain factors that effect a manufacturing career.

Lesson 4.2: Integration of Manufacturing Elements (37 Days)

Understandings

1. Process flow design has a major impact on overall production time and product profit.
2. During the design and development process, flowcharting is used to plan and depict the detailed process flow for an entire system as well as all of its subsystems.
3. Flowcharting can be used to illustrate the overall phases of the product development process.
4. Proper sequencing of automated operations is important in factory design.
5. Safe operating procedures must be addressed in a CIM environment at all times to avoid serious injury.
6. Tradeoffs occur between efficiency and cost when choosing a manufacturing system.
7. Engineers choose appropriate sensors to ensure high quality part production.
8. Identification of correct electrical and fluid power systems is required to complete the desired manufacturing system.

Knowledge and Skills

It is expected that students will:

1. Recognize process symbols.
2. Identify the potential safety issues with a CIM system.
3. Identify how functions of a computer program can be applied to perform a task.
4. Outline a process for a manufacturing process.
5. Design a system to manufacture a part.
6. Construct a system to manufacture a part.
7. Create a flowchart or pseudocode to perform a task.
8. Construct a control program to accomplish a goal.
9. Evaluate the effectiveness of a system to accomplish a goal.
10. Identify strategies to resolve team conflict.

PLTW | Computer Science

Computer Science and Software Engineering Course Outline

Open doors in any career with computer science!

Students create apps for mobile devices, automate tasks in a variety of languages, find patterns in data, and interpret simulations. Students collaborate to create and present solutions that can improve people's lives.

How will computing and connectivity transform your world?

Computer Science and Software Engineering (CSE) is a new PLTW course being offered for the 2014-2015 school year. Students work in teams to develop computational thinking and problem solving skills. The course covers the College Board's new CS Principles framework. The course does not aim to teach mastery of a single programming language but aims instead to develop computational thinking, to generate excitement about the field of computing, and to introduce computational tools that foster creativity. The course also aims to build students' awareness of the tremendous demand for computer specialists and for professionals in all fields who have computational skills. Each unit focuses on one or more computationally intensive career paths. The course also aims to engage students to consider issues raised by the present and future societal impact of computing.

Students practice problem solving with structured activities and progress to open-ended projects and problems that require them to develop planning, documentation, communication, and other professional skills. Problems aim for ground-level entry with no ceiling so that all students can successfully engage the problems. Students with greater motivation, ability, or background knowledge will be challenged to work further.

The following is a summary of the units of study that are included in the course for the 2014-2015 academic year. The course is designed to cover all learning objectives in the College Board's 2013 draft CS Principles framework. In specific CSE projects and problems, students create artifacts and associated writing for CS Principles performance assessment tasks. Alignment with CS Principles Learning Objectives and with CSTA Level 3B Objectives is indicated in the PLTW CSE Curriculum Framework at the activity level. Alignment with NGSS, Common Core, and other standards will be available through the PLTW Alignment web-based tool. Activities, projects, and problems will be provided to the teacher in the form of student-ready handouts, teacher notes, and supplementary materials, including code, instructional videos, and online practice questions as appropriate.

The course is planned for a rigorous pace, and it is likely to contain more material than a skilled teacher new to the course will be able to complete in the first iteration. Building enthusiasm for rigorous computer science among students is a primary goal of the course. Teachers are encouraged to emphasize content that will be fresh and exciting to students, and the course is structured to facilitate local adaptation to a particular group of students' prior knowledge and experience.

Unit 1	Algorithms, Graphics, and Graphical User Interfaces (48%)
Unit 2	The Internet (18%)
Unit 3	Raining Reigning Data (17%)
Unit 4	Intelligent Behavior (17%)

Unit 1: Algorithms, Graphics, and Graphical User Interfaces

The goal of Unit 1 is to excite students about programming and to build their algorithmic thinking and ability to use abstraction. Student creativity is emphasized as they work with Scratch™, App Inventor, and *Python*® programming languages to tell graphical stories, publish games and Android™ applications, and explore various development environments and programming techniques. Students will create original code and read and modify code provided from other sources. An Agile software development process is emphasized and personal, professional, and collaborative skills take center stage. Students debate policy questions about the ownership and control of digital data and examine the implications for creative industries and consumers. In this unit students begin their exploration of career paths tied to computing.

Lesson 1.1	Algorithms and Agile Development
Lesson 1.2	Mobile App Design
Lesson 1.3	Algorithms in *Python*
Lesson 1.4	Images and Object-Oriented Libraries
Lesson 1.5	GUIs in *Python*

Lesson 1.1 Algorithms and Agile Development

The goal of this lesson is to introduce students to programming at a level appropriate to novice programmers. With an introduction to pair programming and the Agile software development process, students create original programs in Scratch that incorporate audio and visual elements while tackling algorithmic problems. The lesson opens with an introduction to how computing is affecting our lives. Students explore tools for collaboration over the Internet and select from these tools in order to manage the projects that they create. The foundations for later algorithmic thinking are built by focusing on the most common roles that variables fulfill, with an introduction to the conventions of object-oriented programming.

Lesson 1.2 Mobile App Design

The goal of this lesson is for students to build their skills by analyzing existing code, particularly with an emphasis on the roles of variables. Students create an Android app of their own design. The lesson begins with an introduction to binary representations of numbers, letters, colors, images, etc. using a CS unplugged activity in which students create a physical representation of data storage. Students work with and make minor modifications to two App Inventor programs, building their ability to analyze a complex program and incorporate event handlers into programs in meaningful ways. Students conclude by designing and creating their own Android app using pair programming and practicing the Agile software design process.

Lesson 1.3 Algorithms in *Python*

The goal of this lesson is for students to understand all information as bits and to transfer their understanding of algorithms to a new language, *Python*, which is powerful enough to raise all the opportunities and issues targeted in the course. Students are introduced to functional, imperative, and declarative programming paradigms with *Python*, again learning to use variables in the most common roles. Before learning about variable types and the fundamental algorithmic structures in *Python*, students simulate program execution in a model assembly language. After building strength with basic *Python* algorithms, students create algorithms to compete in a round-robin tournament of the Prisoner's Dilemma, using the collaborative programming platform GitHub in the process.

Lesson 1.4 Images and Object-Oriented Libraries

The goal of this lesson is for students to become independent learners of a programming language, able to refer to documentation to use object-oriented libraries commonly available. The lesson begins with an unplugged activity to teach object-oriented concepts. Students build additional strength with *Python* algorithms, manipulating image files by modifying pixel data and using code libraries to work at higher levels of abstraction. As part of that work, they learn to use a variety of documentation including application-programming interfaces (APIs). Students read, discuss, and debate intellectual property issues associated with digital data. In the culminating problem of the lesson, they collaborate to create an image processing function that highlights the power of automation.

Lesson 1.5 GUIs in *Python*

The goal of this lesson is for students to conceive of any class of objects as an abstraction. Students will create a graphical user interface (GUI) with considerations of audience and accessibility. The lesson begins with an unplugged activity that generalizes the user interface topic of this lesson to the field of human-computer interaction. Students practice using an application-programming interface (API) to acquire methods that affect an object's state. Students work with two APIs: the Tkinter Canvas for drawing and animation, and then the Tkinter toolbox of GUI widgets. Students are provided code for a simple GUI that implements a model-view-controller (MVC) pattern. Students will modify the elements of that pattern to suit their own needs. The lesson concludes with a problem in which students create a model-view-controller GUI using Scratch or *Python*. Strategies for documentation are reinforced, and Agile development is emphasized in the concluding problem.

Unit 2: The Internet

The goal of Unit 2 is for students to have a more concrete understanding of the Internet as a set of computers exchanging bits and the implications of these exchanges. Students use PHP and SQL to structure and access a database hosted on a remote server, learn how HTML and CSS direct the client computer to render a page, and experiment with JavaScript™ to provide dynamic content. The focus of the unit is on the protocols that allow the Internet to function securely to deliver social media and eCommerce content. Students work briefly in each of several Web languages to understand how the languages work together to deliver this content. The history and workings of the Internet are explored, and issues of security, privacy, and democracy are considered. Practical cyber security hygiene is included. Career paths in cyber security, web development, and information technology are highlighted.

Lesson 2.1	The Internet and the Web
Lesson 2.2	Shopping and Social on the Web
Lesson 2.3	Security and Cryptography

Lesson 2.1 The Internet and the Web

In this lesson the goal is to build student understanding of the Internet as a set of computers exchanging bits in the form of packets. Students will learn to identify the components of their digital footprint. To provide a hook, students compare the designs, strengths, and weaknesses of their favorite web pages. In this context students use an unplugged activity to understand (in broad brushstrokes) the content and flow of data when browsing the Web. They compare results from different search engines and learn to refine their search techniques. They review how to assess the trustworthiness of web-based media and consider the data flow that permits targeted advertisements. Students employ appropriate tools to explore the hierarchical nature of DNS and IP. Students identify ways that a web developer's decisions affect the user and ways that the user's decisions impact society. The tree structure of web documents is introduced alongside HTML and CSS. Paired key encryption and authentication are introduced with an unplugged activity.

Lesson 2.2 Shopping and Social on the Web

The goal for this lesson is for students to understand the role of client-side code, server-side code, and databases in delivering interactive web content. The hook is a problem in which CS students collaborate with art students to publish content on the Web. Students are provided with JavaScript and PHP code and can access an SQL database from a secure shell command line as well as through PHP. Students compare languages encountered so far to generalize the concepts of sequencing instructions, selection of instructions by conditionals, iteration, and the common roles of variables. Students explore and compare career paths within computing.

Lesson 2.3 Security and Cryptography

The goal of this lesson is for students to personally invest in maintaining online security and to improve their personal cyber security hygiene. Students focus on cyber security from the perspectives of the user, the software developer, the business, the nation, and the citizen. In the team competition at the end of the lesson, students explore parallel strands in encryption and security. Encryption is used as a route to explore the efficiency of algorithms and how the time for an algorithm to execute can be dependent on its input.

Unit 3: Raining Reigning Data

The goal of Unit 3 is for students to see the availability of large-scale data collection and analysis in every area they can imagine. Students examine very large data sets tied to themselves as well as to areas of work and society. They learn a variety of data visualization techniques and work to recognize opportunities to apply algorithmic thinking and automation when considering questions that have answers embedded in data. The complexity of the data sets, visualizations, and analysis increases in the second lesson of the unit, challenging students to generalize concepts developed in the first lesson.

Lesson 3.1	Visualizing Data
Lesson 3.2	Discovering Knowledge from Data

Lesson 3.1 Visualizing Data

The goal of this lesson is for students to be able to create visualizations to analyze sets of large data and to meaningfully interpret the patterns they uncover. They draw conclusions about themselves from relevant data, including local weather, the economics of their community, and naming trends with their name. At the beginning of the lesson, students weigh societal concerns around the collection and persistence of Big Data. The students learn how to use *Python* to make useful graphic representations of data, developing from familiar visualizations to more modern visual analyses like scaled-dot or colorized scatter plots of multidimensional data sets. Students are introduced to basic Excel® spreadsheet programming and cell manipulation. A Monte Carlo simulation is used to help students appreciate the meaning of evidence for association between two variables.

Lesson 3.2 Discovering Knowledge from Data

As in the previous lesson, the goal of this lesson is for students to be able to create a range of visualizations to analyze complex sets of large data and to meaningfully interpret the patterns they uncover. Students use statistics to deepen the meaning of knowledge gained by visualization. The hooks are again conclusions they can draw about themselves from relevant data, including various geographic perspectives on their life and facial recognition of their own features. The lesson uses Excel as well as *Python* to manipulate and visualize data. Students examine multidimensional data sets using scatter plot arrays and view geographic and social data using heat maps and directed graphs. Students experiment with object recognition and face recognition. They are challenged to discover clustering and linear correlation patterns lurking in data sets distributed across student computers and school sites, such that data cleaning and warehousing are necessary. Finally, student teams choose a question and answer it using large data.

Unit 4: Intelligent Behavior

In Unit 4 the emergence of intelligent behavior is explored from two distinct approaches: from human crowd sourcing of data and from separate algorithmic agents working in parallel. The goal is to galvanize the connections among computing concepts and between computing and society. The first lesson explores the hardware layer of computing, working from discrete components to integrated circuits. The exponential advancement of electronics, low on the ladder of abstraction, is connected to advancements at the highest levels on the ladder of abstraction, where artificial intelligence and simulation and modeling are impacting all fields. In the concluding lesson, students identify problems and questions that can be addressed with computer simulation, incorporating agent-based modeling. Students are challenged to explore the assumptions and parameters built into several simulations and to attach meaning to the results. Having explored a few applications of intelligent behavior emerging from algorithmic components, students reflect on the current and future state of artificial intelligence.

Lesson 4.1	Moore's Law and Modeling
Lesson 4.2	Intelligent Agents

Lesson 4.1 Moore's Law and Modeling

In this lesson, students construct an understanding of how the explosion of technology over the last two decades has impacted every realm of study and employment. Students begin by researching the impact of computer modeling and simulation which have been made possible by the rapid increase in computational power due to the continued applicability of Moore's Law. They then manipulate discrete electronic components to create logic gates and create comparable results using integrated circuits to get a feel for what it means to double the number of transistors that can fit in a given area. Students explore simulation in NetLogo directly by manipulating a model of predation and a model of the spread of viruses in humans. The lesson concludes with an examination of the code of ethics for simulationists and reflection on the necessity of adhering to such a code.

Lesson 4.2 Intelligent Agents

In this lesson, students experiment with materials designed to illuminate the rise of intelligent and complex behavior from simple rules and seemingly unintelligent agents. Students begin by studying a model of Langton's ant, a simple Turing machine with some surprising emergent behavior. The students manipulate models of neurons and neural networks. Students design and conduct their own experiments on a model of their own choosing using Monte Carlo methods. Students explore the generation and observation of fractals and study a diffusion limited aggregation model for producing fractal behavior. In the final project of the course, students choose a tool or tools that they have learned about in the course and apply their knowledge to create a novel product of their own design. They present their product to their class along with reflections about how it is tied to everything they've learned about computer science.

Digital Electronics Detailed Outline

Unit 1 Fundamentals of Analog and Digital Electronics (32 Total Days)

Lesson 1.1 Foundations and the Board Game Counter (9 days)

Understandings Addressed in Lesson:

1. Safety is an important concept that must be considered for the safety of the individual, class, and overall environment of the classroom/laboratory.
2. Electricity, even at the nominal levels used in this curriculum, can cause bodily harm or even death.
3. Engineers and technicians use scientific notation, engineering notation, and Systems International (SI) notation to conveniently write very large or very small numbers frequently encountered when working with electronics.
4. Manufacturers of resistors and capacitors use an accepted industry standard to label the nominal value of resistors and capacitors.
5. Soldering is the process of joining two metal surfaces together to form an electrical connection. Soldering is used extensively in the assembly of electronic components.
6. The ability to properly solder electronic components and recognition of improper solder connections is an important skill for engineers and technicians.

Lesson 1.2 Introduction to Analog (11 days)

Understandings Addressed in Lesson:

1. Analog and digital signals have different waveforms with distinctive characteristics.
2. Digital signals have two well-defined voltage levels, one for logic high and one for a logic low.
3. Analog signals have an infinite number of voltage levels that vary continuously over the voltage range for that particular system.
4. The atomic structure of a material determines whether it is a conductor, an insulator, or a semiconductor.
5. An understanding of the basics of electricity requires the understanding of three fundamental concepts of voltage, current, and resistance

6. Engineers and technicians use Circuit Design Software as a tool to verify functionality of their analog and digital designs.

Lesson 1.3 Introduction to Digital (12 days)

Understandings Addressed in Lesson:

1. The manufacturer datasheet contains a logic gate's general description, connection diagram, and function table.
2. Integrated circuits are categorized by their underlying circuitry, scale of integration, and packaging style.
3. Transistor-Transistor Logic (TTL) gates are available in a series of sub-families, each having their own advantages and disadvantages related to speed and power.
4. Logic gates are depicted by their schematic symbol, logic expression, and truth table.
5. The input and output values of combinational and sequential logic function differently.
6. Combinational logic designs implemented with AND gates, OR gates and INVERTER gates are referred to as AOI designs.
7. The flip-flop is the fundamental building block of sequential logic.

Unit 2 Combinational Logic (60 Total Days)

Lesson 2.1 Introduction to AOI Logic (20 days)

Understandings Addressed in Lesson:

1. An understanding of the binary number system and its relationship to the decimal number system is essential in the combinational logic design process.
2. The first step in designing a combinational logic circuit is to translate a set of design specifications into a truth table.
3. A truth table describes the behavior of a combinational logic design by listing all possible input combinations and the desired output for each.
4. Logic expressions can be derived from a given truth table; likewise, a truth table can be constructed from a given logic expression.
5. All logic expressions can be expressed in one of two forms: sum-of-products (SOP) or products of sum (POS).
6. All logic expressions, whether simplified or not, can be implemented using AND, OR, & Inverter Gates.
7. There is a formal design process for translating a set of design specifications into a functional combinational logic circuit.

Lesson 2.2 Introduction to NAND and NOR Logic (14 days)

Understandings Addressed in Lesson:

1. Karnaugh Mapping is a graphical technique for simplifying logic expressions containing two, three, and four variables.
2. A don't care condition is a situations where the design specifications "don't care" what the output is for one or more input conditions. Don't care conditions in K-Maps can lead to significantly simpler logic expressions and circuit implementations.
3. A NAND gate is considered a universal gate because it can be used to implement an AND gate, OR gate, and an inverter gate. Any combinational logic expression can be implemented using only NAND gates.
4. A NOR gate is considered a universal gate because it can be used to implement an AND gate, OR gate, and an inverter gate. Any combinational logic expression can be implemented using only NOR gates.
5. There is a formal design process for translating a set of design specifications into a functional combinational logic circuit implement with NAND or NOR gates.
6. Combinational logic designs implemented with NAND gates or NOR gates will typically require fewer Integrated Circuits (IC) than AOI equivalent implementations.

Lesson 2.3 Date of Birth Design (9 days)

Understandings Addressed in Lesson:

1. Seven-segment displays are used to display the digits 0-9 as well as some alpha characters.
2. The two varieties of seven-segment displays are common cathode and common anode.
3. Any combinational logic expression can be implemented with AOI, NAND, or NOR logic.
4. A formal design process exists for translating a set of design specifications into a functional combinational logic circuit.

Lesson 2.4 Specific Comb Logic Circuits & Miscellaneous Topics (8 days)

Understandings Addressed in Lesson:

1. An understanding of the hexadecimal and octal number systems and their relationship to the decimal number system is necessary for comprehension of digital electronics.
2. XOR and XNOR gates can be used to implement combinational logic circuits, but their primary intended purpose is for implementing binary adder circuits.

3. The addition of two binary numbers of any bit length can be accomplished by cascading one half-adder with one or more full adders.
4. Multiplexer/de-multiplexer pairs are most frequently used when a single connection must be shared between multiple inputs and multiple outputs.
5. Electronics displays that use multiple seven-segment display utilize de-multiplexers to significantly reduce the amount of power required to operate the display.
6. Two's complement arithmetic is the most commonly used method for handling negative numbers in digital electronics.

Lesson 2.5 Programmable Logic – Combinational (9 days)

Understandings Addressed in Lesson:

1. Engineers and technicians use Circuit Design Software to enter and synthesize digital designs into programmable logic devices.
2. Programmable logic devices can be used to implement combinational logic circuits.
3. Circuits implemented with programmable logic devices require significantly less wiring than discrete logic, but they typically require a dedicated printed circuit board to hold the device.
4. Programmable logic devices can be used to implement any combinational logic circuits but are best suited for larger, more complex designs.

Unit 3 Sequential Logic (56 Total Days)

Lesson 3.1 Latches & Flip-Flops (6 days)

Understandings Addressed in Lesson:

1. The flip-flop and transparent latch are logic devices that have the capability to store data and can act as a memory device.
2. Flip-flops and transparent latches have both synchronous and asynchronous inputs.
3. Flip-flops can be used to design single event detection circuits, data synchronizers, shift registers, and frequency dividers.

Lesson 3.2 Asynchronous Counter (14 days)

Understandings Addressed in Lesson:

1. Asynchronous counters, also called ripple counters, are characterized by an external signal clocking the first flip-flop. All subsequent flip-flips are clocked by the output of the previous flip-flop.

2. Asynchronous counters can be implemented using small scale integrated (SSI) and medium scale integrated (MSI) logic gates.
3. Asynchronous counters can be implemented with either D or J/K flip-flops.
4. Up counters, down counters, and modulus counters all can be implemented using the asynchronous counter method.

Lesson 3.3 Synchronous Counters (14 days)

Understandings Addressed in Lesson:

1. Synchronous counters, also called parallel counters, are characterized by an external signal clocking all flip-flops simultaneously.
2. Synchronous counters can be implemented using small scale integrated (SSI) and medium scale integrated (MSI) logic gates.
3. Synchronous counters can be implemented with either D or J/K flip-flops.
4. Up counters, down counters, and modulus counters all can be implemented using the synchronous counter method.

Lesson 3.4 Introduction to State-Machine Design (20 days)

Understandings Addressed in Lesson:

1. A state machine is a circuit design that sequences through a set of predetermined states controlled by a clock and other input signals.
2. State machines are used to control common everyday devices such as elevator doors, traffic lights, and combinational (electronics) locks.
3. State machines can be implemented in one of two variations: Mealy or Moore.
4. State machines can be implemented using small and medium scale integrated gates and programmable logic devices.

Unit 4: Microcontrollers (29 Total Days) Optional (2013-2014)

Lesson 4.1 Introduction to Microcontrollers (9 days)

Understandings Addressed in Lesson:

1. Flowcharting is a powerful graphical organizer used by technicians, computer programmers, engineers, and professionals in a variety of roles and responsibilities.
2. Basic programming skills include variable declaration, loops, and debugging.
3. Programming languages have their own grammar, called syntax.
4. Many everyday products use microcontrollers.

5. Variables used in programming are declared and given a size that is expressed in binary.

Lesson 4.2 Microcontrollers – Boe-Bot (9 days)

Understandings Addressed in Lesson:

1. Microcontrollers are used to control many everyday products like robots, garage door openers, traffic lights, and home thermostats.
2. A servo motor is one that delivers continuous motion at various speeds.
3. Microcontrollers can be programmed to sense and respond to outside stimuli

Lesson 4.3 Boe-Bot Design Projects (11 days)

Understandings Addressed in Lesson:

1. Digital devices are only relevant if they can interact with the real world.
2. Digital control devices are increasingly necessary for mechanical systems.
3. Realistic problem solving with a control system requires the ability to interface analog inputs and outputs with a digital device.
4. Microcontrollers are a practical tool for controlling a mechanical system.

Engineering Design & Development Detailed Outline

Component 0: Project Management (175 Total Days)

Understandings Addressed Course Wide:

1. The work of engineers has an impact on our society.
2. An open ended design process involves identifying a justifiable problem and developing an original solution that attempts to solve it.
3. The engineering design process is typically non-linear. Designers may need to re-visit steps in the process or take next steps based on feedback from previous steps.
4. The engineering design process is both a guide and a series of waypoints for effective problem solving. It is a tool for self-evaluation as an engineer moves through the process.
5. There are principles and practices related academic research. Topic selection and design decisions should be research driven and driven data whenever possible.
6. There are principles, practices, and techniques related to technical writing.
7. There are principles and practices related to documenting an engineering design process that allow teams to work effectively, preserve the work allowing continuation at a later date, and protect the designer's intellectual property.
8. Project management is the discipline of planning, organizing, motivating, utilizing resources to achieve specific goals.
9. Relevant principles and practices of Science, Technology, Engineering, and Mathematics (STEM) should be used to inform and justify design choices. They should be evident and well documented in an engineering design process.
10. Individuals and other entities put extraordinary effort into protecting their intellectual property so they can control who has access to and use of their work. Intellectual property protections allow individuals or companies to maintain rights to profit from their ideas.
11. There are many stakeholders involved in an open ended engineering design process.
12. The ability to communicate as a professional is a critical skill for engineers.
13. Measurable design requirements are developed from a problem statement. Design requirements guide engineers through the design process and help determine if the solution is successful at solving the identified problem.
14. Multiple design possibilities should be explored in an engineering design process.
15. Testing is a critical component to any engineering design process. A plan and process for testing the proposed solution both qualitatively and quantitatively against design requirements should be created and carried out.
16. Engineering design projects are typically peer reviewed. Stakeholder feedback and design reviews help guide engineers through the design process.
17. Presentation of this design process and project findings are critical to the engineering design process.

Component 1: Researching a Problem (40 Days)
Problem Identification, Justification and Defining Solution Requirements

Understandings Addressed in Component:

1. Project management is the discipline of planning, organizing, motivating, utilizing resources to achieve specific goals.
2. The work of engineers has an impact on our society.
3. An open ended design process involves identifying a justifiable problem and developing an original solution that attempts to solve it.
4. There are principles and practices related academic research. Topic selection and design decisions should be research driven and driven data whenever possible.
5. There are principles, practices, and techniques related to technical writing.
6. There are principles and practices related to documenting an engineering design process that protect the designer's intellectual property. This ensures that the designer has generated an original solution.
7. A well developed and accurately written problem statement identifies a need and guides an engineering design process.
8. A well developed and accurately written problem statement identifies a need and aims the engineer toward developing measureable and objective design requirements which guide the rest of the design process.
9. Individuals and other entities put extraordinary effort into protecting their intellectual property so they can control who has access to and use of their work. Intellectual property protections allow individuals or companies to maintain rights to profit from their ideas.
10. Experts are professionals that have specific knowledge in an area of interest and can guide the research needed for accurate justification and solutions to design problems.
11. The ability to communicate as a professional is a critical skill for engineers.
12. Effective market research focuses on potential users and buyers to gauge whether a problem is worth the investment required for a solution to be attempted.
13. Effective market research focuses on potential users and buyers to gauge whether a problem is worth the investment required for it to be solved.
14. Research and analysis of past solution attempts can help a designer identify critical design specifications or features in any viable solution designed.
15. Engineering design projects are typically peer reviewed. Stakeholder feedback and design reviews help guide engineers through the design process.
16. Design goals include specifications, constraints, parameters, desired features, and fundamental design considerations.
17. Presentation of a project proposal is a critical way-point in the design process.

Component 2: Designing a Solution (25 Days)
Generating and Defending an Original Solution

Understandings Addressed in Component:

1. Relevant principles and practices of Science, Technology, Engineering, and Mathematics (STEM) should be used to inform and justify design choices. They should be evident and well documented in an engineering design process.
2. Engineers use a peer review process to evaluate design solutions, provide feedback, and implement necessary revisions.
3. Effective design teams typically have a diverse set of viewpoints.
4. Multiple design possibilities should be explored in an engineering design process.
5. Design goals include specifications, constraints, parameters, desired features, and fundamental design considerations.
6. Testing is a critical component to any engineering design process. A prototype should be created that can be tested qualitatively and quantitatively.
7. Assessing a product's lifecycle creates an opportunity for identifying potential improvements in the process and provides a method for evaluating the product's degree of success.
8. A decision matrix is one tool designers can use to compare preliminary design solutions. A solution path can be determined by assessing each alternate design based on the design requirements specified.
9. Drawings and sketches are used to organize, record, and communicate ideas.
10. An effective use of the design process includes the use of a variety of forms of technical visual communication. This may include, but not be limited to technical drawings, circuit diagrams, process or flow charts.
11. Virtual solutions for designs allow engineers to plan, test, and prepare for building a prototype.
12. Engineers and designers have ethical responsibilities to clients, peers, their profession, and the general public.
13. Product development will result in consequences, both good and bad, that must be considered when deciding whether or not to develop a product.
14. There are many stakeholders involved in an open ended engineering design process.
15. The ability to communicate as a professional is a critical skill for engineers.
16. A Preliminary Design Review is a peer review process to determine the viability of the final design proposed and if other modifications can be identified before the prototyping and testing phase.

Component 3 – Creating a Prototype and Testing Plan (45 Days)
Creating and Testing a Prototype

Understandings Addressed in Component:

1. Relevant principles and practices of Science, Technology, Engineering, and Mathematics (STEM) should be used to inform and justify design choices. They should be evident and well documented in an engineering design process.
2. Project management is the discipline of planning, organizing, motivating, utilizing resources to achieve specific goals.
3. During the construction of a prototype, safety in the workplace is a critical component. All safety guidelines and procedures should be followed.
4. Material, tools, and equipment requirements are defined by creating a materials and cost analysis before the construction of a prototype.
5. A prototyping provides the engineer with a scaled working model of the design solution that can be tested.
6. Engineers write step-by-step instructions for the prototype assembly to guide the fabrication of the design solution.
7. Designers must consider characteristics such as strength and weight of materials and fastening procedures to be sure that the final design meets design specifications.
8. Testing is a critical component to any engineering design process. A plan and process for testing the proposed solution both qualitatively and quantitatively against design requirements should be created and carried out.
9. Prototypes can generally be broken down into subsystems in order to isolate problems and conduct incremental testing.
10. Prototype testing is a controlled procedure that is used to evaluate a specific aspect of a design solution.
11. In order to gather useful data, specific criteria for success or failure of a test must be determined before testing begins.
12. A detailed description of the testing procedure helps to ensure that the results of the design solution testing are valid.
13. Data can be classified as either quantitative because it can be measured or qualitative because it describes a quality or categorization.
14. The results of prototype testing are used to refine the design and to improve the design solution.
15. A Critical Design Review is used to determine the quality and functionality of the final prototype. Designers should seek feedback from key stakeholders to determine if any modifications or improvements can be made before finalizing the testing process.

Component 4 – Evaluation and Reflection on the Design Process (30 Days)
Evaluation, Reflection, and Designer Recommendations

Understandings Addressed in Component:

1. The engineering design process is typically non-linear. Designers may need to re-visit steps in the process or take next steps based on feedback from previous steps.
2. The engineering design process is both a guide and a series of waypoints for effective problem solving. It is a tool for self-evaluation as an engineer moves through the process.
3. There are many stakeholders involved in an open ended engineering design process.
4. The ability to communicate as a professional is a critical skill for engineers.
5. Engineering design projects are typically peer reviewed. Stakeholder feedback and design reviews help guide engineers through the design process.
6. Presentation of this design process and project findings are critical to the engineering design process.

Component 5 – Presentation of the Design Process (30 Days)
Final Presentation and Documentation

1. Presentation of this design process and project findings are critical to the engineering design process.
2. Presentations and displays of work provide the means to effectively promote and justify the implementation of a project.
3. There are principles and practices related to documenting an engineering design process that protect the designer's intellectual property. This ensures that the designer has generated an original solution.
4. A well-done presentation can enhance the perception of the quality of work completed for a team project.
5. The use of presentation software allows designers to present visual aids and project information in a professional manner.
6. The media format used for a presentation is chosen in order to effectively communicate the design solution process to a target audience.

Component 6 – Going Beyond EDD (5 Days)

PLTW | Engineering

Engineering Design and Development

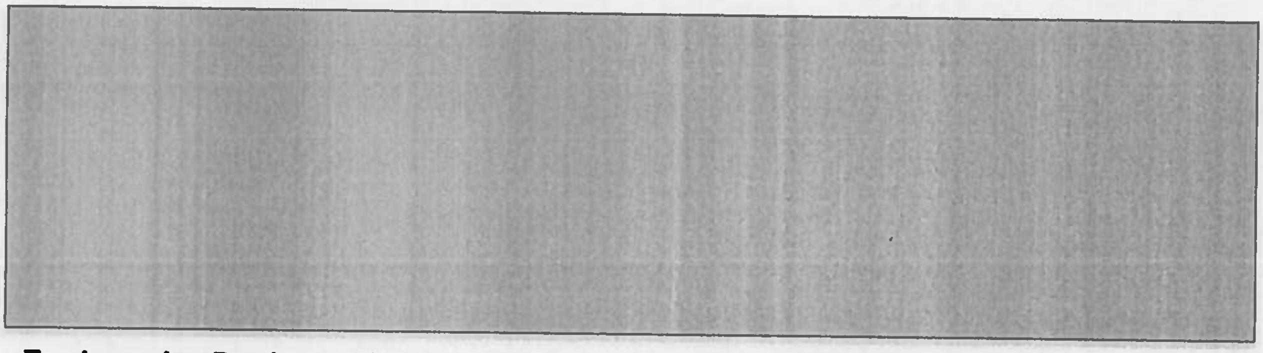
Course Outline

PROJECT LEAD THE WAY

PLTW

PLTW Engineering

Engineering Design and Development



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.

The Engineering Design and Development course of study includes:

- Engineering Design Processes
- Project Management
- Documenting an Engineering Design Process
- Teamwork and Professional Skills
- Problem Identification and Justification
- Research
- Intellectual Property
- Design Requirements
- Project Proposals
- Design
- Virtual Design and Testing
- Preliminary Design Reviews
- Prototyping
- Testing a Prototype
- Presenting the Process and Results

The structure of Engineering Design and Development is aligned to the Engineering Design Process Portfolio Rubric. Students in this course are encouraged to format their Engineering Design Process Portfolio according to the Components and Elements defined within this rubric.

Student may also wish to capture the Engineering Design Process Portfolio through the online Innovation Portal eportfolio system. This free collaborative tool allows students to share their work securely with key stakeholders and experts in order to receive feedback throughout the design process.

Below is the Engineering Design and Development course structure.

Component 0: Project Management

(α) - The EDD Design Process and Project Management
(β) - Documenting the Engineering Design Process
(γ) - Teams, Timelines, and Contacting Experts
(δ) - Project Evaluations and Classroom Management
(ε) - Intellectual Property

Component 1 - Research

Element A - Identification and Justification of the Problem
Element B - Documentation and Analysis of Prior Solution Attempts
Element C - Presentation and Justification of Solution Requirements

Component 2 - Design

Element D - Design Concept Generation, Analysis, and Selection
Element E - Application of STEM Principles and Practices
Element F - Consideration of Design Viability

Component 3 - Prototype and Test

Element G - Construction of a Testable Prototype
Element H - Prototype Testing and Data Collection Plan
Element I - Testing, Data Collection, and Analysis

Component 4 - Evaluation of Project and Process

Element J - Documentation of External Evaluation
Element K - Reflection on the Design Project
Element L - Presentation of Designer's Recommendations

Component 5 - Reflection and Presenting the Design Process

Element M - Presentation of the Project and Project Portfolio
Element N - Writing Like an Engineer

Component 6 - Going Beyond EDD

Component 0 - Project Management

Major focuses of the course are project management and professional skills required to successfully complete and document an engineering design process. Topics student will study and skills they will refine are:

(α) - The EDD Design Process and Project Management
(β) - Documenting the Engineering Design Process
(γ) - Teams, Timelines, and Contacting Experts
(δ) - Project Evaluations and Classroom Management
(ε)- Intellectual Property

Component 1 - Research

This component requires students to identify a problem for which they will design a solution during the remainder of the course. In the first lesson, students will write a clear problem statement and validate the problem by documenting credible sources that indicate that the problem exists. Validation is carried out through research and input from experts and mentors. Once their work is defined, students are asked to perform additional research in order to justify the problem by confirming that the expense and effort involved with solving the problem is warranted based on need and cost. Students will explore and analyze prior solution attempts. Based on their research, student will create a testable design requirement which will be used to explore possible solutions. The students will present a project proposal to ensure the project is justified and that all prior solution attempts have been explored.

Element A - Identification and Justification of the Problem
Element B - Documentation and Analysis of Prior Solution Attempts
Element C - Presentation and Justification of Solution Requirements

Component 2 - Design

Based on the design requirement identified through research, students develop multiple solution possibilities. Through an evaluation process that involves feedback from experts and stakeholders and the application of a decision matrix or data-driven process, students will select the best potential solution to pursue.
Students will refine the final selected solution path and provide evidence that the solution selected is viable.

Element D - Design Concept Generation, Analysis, and Selection
Element E - Application of STEM Principles and Practices
Element F - Consideration of Design Viability

Component 3 - Prototype and Test

Student will create a testable prototype and an unbiased testing plan based on the defined design requirements to determine the effectiveness of the solution created.

Element G - Construction of a Testable Prototype
Element H - Prototype Testing and Data Collection Plan
Element I - Testing, Data Collection, and Analysis

Component 4 - Evaluation of Project and Process

At this point in the design process, it is critical to seek and document feedback from all stakeholders. The designer(s) should reflect on all design decisions and the analysis that was generated from the testing process. Finally, the designer(s) can begin to formulate next steps.

Element J - Documentation of External Evaluation
Element K - Reflection on the Design Project
Element L - Presentation of Designer's Recommendations

Component 5 - Reflection and Presenting the Design Process

At the conclusion of the design process, students will be asked to present and defend the process and decision.

Element M - Presentation of the Project and Project Portfolio
Element N - Writing Like an Engineer

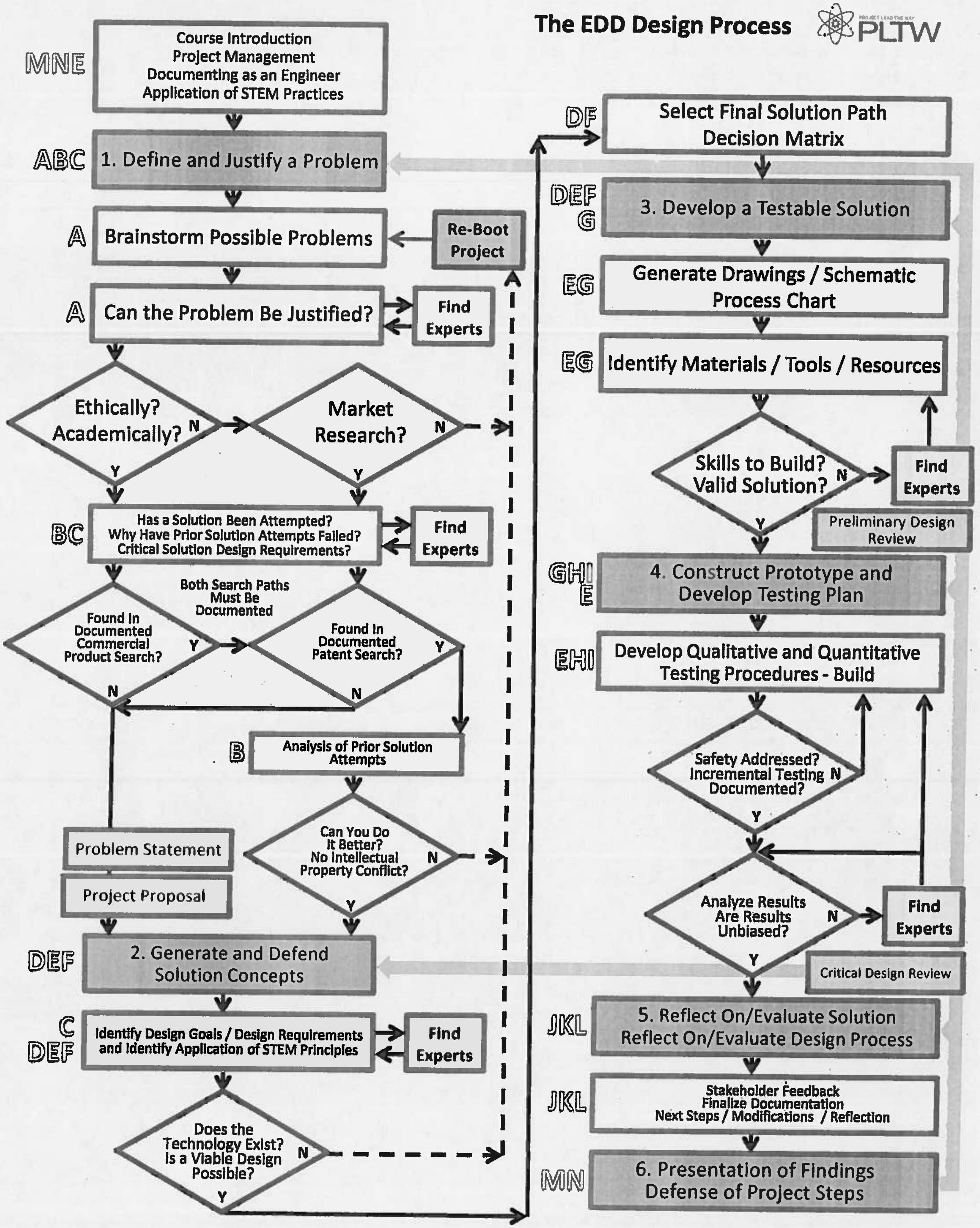
Component 6 - Going Beyond EDD

Many opportunities exist for students to receive tangible value for their work beyond the classroom walls. These opportunities range from competitions, scholarships, and university admission notoriety, to interest from business representatives to further develop the ideas created in EDD classrooms.

This section of the curriculum is dedicated to providing resources, examples, and suggestions for helping your students obtain tangible value for their work. Below you will find examples of student success stories related to College Recognition, Competitions, and Business Opportunities.

- Design and Problem Solving Competitions
- Scholarship and Internship Opportunities
- Product and Business Development Opportunities
- Patents
- Admission Preference or College Level Recognition

The EDD Design Process



The Engineering Design and Development Design Process Flow Chart

Engineering Design Process Rubric

PLTW | Engineering

Research	Presenting and Justifying a Problem Worth Solving					
	Rubric Score - 0	Rubric Score - 1	Rubric Score - 2	Rubric Score - 3	Rubric Score - 4	Rubric Score - 5
Presentation and Justification of the Problem	The identification and/or definition of the problem is missing OR cannot be inferred from information included. A justification of the problem is missing, cannot be inferred from information included as evidence, OR is essentially only the opinion of the researcher.	The identification and/or definition of the problem is unclear, is unelaborated, and/or the problem is clearly subjective; Any intended justification of the problem does not highlight the concerns of any primary stakeholders and/or is based on sources that are overly general, outdated, and/or of dubious credibility; Information included is insufficient to allow for the determination any measurable design requirements.	The identification and/or definition of the problem is somewhat clear and/or The problem is somewhat clear but is superficial defined and/or The problem minimally elaborated with specific detail; The justification of the problem highlights the concerns of only one or two primary stakeholders and/or may be based on insufficient sources or ones that are outdated or of dubious credibility; Although little information included is objective, it is in enough detail to allow at least a few design requirements to be determined; however, these may not be measurable.	The problem is somewhat clearly identified and defined with adequate depth and/or the problem is somewhat objectively defined; The problem is sometimes elaborated with specific detail, although some information may be imprecise or general; The justification of the problem highlights the concerns of at least a few primary stakeholders and is based on at least a few sources which are timely and credible; Although not all information included may be objective, it is in enough detail to allow at least a few measurable design requirements to be determined.	The problem is clearly identified and defined with some depth, and the problem is objectively defined with some depth; the problem is generally elaborated with specific detail; The justification of the problem highlights the concerns of some primary stakeholders and is based on various timely and generally credible sources; The information included offers generally objective detail from which multiple measurable design requirements can be determined.	The problem is clearly identified and defined with considerable depth, and the problem is objectively defined with considerable depth; the problem is well elaborated with specific detail; The justification of the problem highlights the concerns of many primary stakeholders and is based on comprehensive, timely, and consistently credible sources; The information offers consistently objective detail from which multiple measurable design requirements can be determined.
Documentation and Analysis of Prior Solution Attempts	Documentation of existing attempts to solve the problem and/or related problems is missing or minimal (a single source that is not clearly identified and/or credible) OR Documentation of existing attempts to solve the problem cannot be inferred from information intended as analysis of past and/or current attempts to solve the problem.	Documentation of existing attempts to solve the problem is drawn from only one or two sources that may not be clearly identified and/or credible; The analysis of past and current attempts to solve the problem is vague and is missing any relevant details and/or is missing relevant supporting data.	Documentation of existing attempts to solve the problem is drawn from a limited number of sources, that may not be clearly identified and/or credible; The analysis of past and current attempts to solve the problem is overly general and contains little detail and/or contains little relevant supporting data.	Documentation of existing attempts to solve the problem is drawn from several-but not necessarily varied-clearly identified sources that are most often clearly identified and/or credible; The analysis of past and current attempts to solve the problem is generally clear and contains some detail and contains some relevant supporting data.	Documentation of existing attempts to solve the problem is drawn from a variety of clearly identified sources that are identified clearly and are consistently credible sources; The analysis of past and current attempts to solve the problem is clear and is generally detailed and clearly supported by relevant data.	Documentation of plausible prior attempts to solve the problem and/or related problems is drawn from a wide array of clearly identified and that are identified clearly and are consistently credible sources; The analysis of past and current attempts to solve the problem is consistently clear, is consistently detailed, and supported by relevant data.
Presentation and Justification of the Design Requirements	Design requirements are either not presented or are too vague to be used to outline the measurable attributes of a possible design solution to the problem identified.	An attempt is made to list, format, and prioritize requirements; These design requirements may overly general, making them insufficiently measurable to support a viable solution to the problem identified; There is no evidence that the requirements represent the needs of, or have been validated by, any primary stakeholder groups.	Design requirements are listed and prioritized, but may be incomplete and/or lack specificity; These design requirements may be only sometimes objective and/or sometimes are measurable. It is not clear that they will lead to a tangible and viable solution to the problem identified; There is evidence that the requirements represent the needs, of/and or have been validated by, only one primary stakeholder group.	Design requirements are listed and prioritized, and they are generally clear and somewhat detailed; These design requirements presented are generally objective and generally measurable. They have the potential to lead to a tangible and viable solution to the problem identified; There is evidence that requirements represent the needs of, and have been validated by, at least a few primary stakeholder groups.	Design requirements are listed and prioritized, and they are generally clear and detailed; These design requirements presented are nearly always objective and nearly always measurable. They would be likely to lead to a tangible and viable solution to the problem identified; There is evidence that requirements represent the needs of, and have been validated by, several primary stakeholder groups.	Design requirements are listed and prioritized, and they are consistently clear and detailed; These design requirements presented are consistently objective and consistently measurable. They would be highly likely to lead to a tangible and viable solution to the problem identified; There is evidence that requirements represent the needs of, and have been validated by, many if not all primary stakeholder groups.
Checkpoint **Project Proposal**	**Is the problem well defined, worth solving, and can lead to a testable solution attempt?**					

Design	Generating and Defending an Original Solution					
	Rubric Score - 0	Rubric Score - 1	Rubric Score - 2	Rubric Score - 3	Rubric Score - 4	Rubric Score - 5
Design Concept Generation, Analysis, and Selection	There is no evidence an attempt to arrive at a design solution through an iterative process based on design requirements.	The process for generating a possible design solution was incomplete and was only minimally iterative and/or was only minimally defensible; Any attempted explanation for the design solution chosen lacked support related to design requirements and the design solution proposed cannot be tested.	The process for generating a possible design solution was partial or overly general and only somewhat iterative and/or was only somewhat defensible, raising issues with the viability of the design solution chosen; The design solution was not sufficiently explained with reference to design requirements; There is insufficient detail to allow for testing for replication of results.	The process for generating and comparing possible design solutions was adequate and was generally iterative and was defensible, making a viable design possible; The choice of design solution was explained with reference to at least some design requirements; The plan of action might not clearly or fully support repetition and testing for effectiveness by others.	The process for generating and comparing possible design solutions was thorough, was iterative, and was generally defensible, making a viable design likely; The design solution chosen was justified and demonstrated attention to most if not all design requirements; The plan of action would support repetition and testing for effectiveness by others.	The process for generating and comparing possible design solutions was comprehensive, was iterative, and was consistently defensible, making a viable and well-justified design highly likely; The design solution ultimately chosen was well-justified and demonstrated attention to all design requirements; The plan of action has considerable merit and would easily support repetition and testing for effectiveness by others.
Application of **STEM Principles and Practices**	The proposed solution is not substantiated with STEM principles or practices applicable to any design requirements and/or functional claims.	The proposed solution is minimally substantiated with STEM principles or practices applicable to at least a few design requirements and functional claims; There is no evidence that the application of those principles and practices by the student has been reviewed by an expert (qualified consultant or project mentor).	The proposed solution is minimally substantiated with STEM principles and practices applicable to at least a few design requirements and functional claims; There is minimal evidence that the application of those principles and practices by the student has been reviewed by at least one expert (qualified consultant or project mentor) but there is no evidence of confirmation (verification) and/or no detail to inform a corrective response.	The proposed solution is partially substantiated with STEM principles and practices applicable to at least a few design requirements and functional claims; There is some evidence that the application of those principles and practices by the student has been reviewed by at least one expert (qualified consultant or project mentor) but there might not be clear confirmation (verification) or at least some detail to inform a corrective response.	The proposed solution is generally substantiated with STEM principles and practices applicable to some design requirements and functional claims; There is some evidence that the application of those principles and practices by the student has been reviewed by at least two experts (qualified consultants and/or project mentors) and that those reviews provide confirmation (verification) or some detail necessary to inform a corrective response.	The proposed solution is well-substantiated with STEM principles and practices applicable to all or nearly all design requirements and functional claims; There is substantial evidence that the application of those principles and practices by the student has been reviewed by two or more experts (qualified consultants and/or project mentors) and that those reviews provide confirmation (verification) and/or provide detail necessary to inform a corrective response.
Consideration of **Design Viability**	There is no evidence that the proposed design was reviewed based on any extra- functional considerations. Note: In this context, extra-functional considerations represent the capacity of the proposed solution to address the problem. They do not relate to the function on the proposed design, rather the ability to deliver the solution to primary stakeholder and that the primary stakeholder would actually use the solution.	The proposed design was superficially reviewed based on one or two extra-functional considerations of marginal relevance; A judgment about design viability based on those considerations may be unrealistic and/or not supported with any credible evidence.	The proposed design was superficially reviewed based on one or two relevant extra-functional considerations; A judgment about design viability based on those considerations may be generally although not completely unrealistic and/or may be inadequately supported with credible evidence.	The proposed design was partially reviewed based on one or two relevant extra-functional considerations; A judgment about design viability based on those considerations is only somewhat/sometimes realistic and is only partially supported with credible evidence.	The proposed design was adequately reviewed based on several relevant extra-functional considerations; A judgment about design viability based on those considerations is generally realistic and adequately supported with credible evidence.	The proposed design was carefully reviewed based on several relevant extra-functional considerations; A judgment about design viability based on those considerations is clearly realistic and well supported with credible evidence.
Checkpoint **Preliminary Design Review**	**Is the proposed solution well defined, realistic, and viable? Can it lead to a solution attempt that can be tested for most or all of the design requirements?**					

Prototype and Test

Creating and Testing a Prototype

	Rubric Score - 0	Rubric Score - 1	Rubric Score - 2	Rubric Score - 3	Rubric Score - 4	Rubric Score - 5
Creation of a Testable Prototype	Any attempt to explain the final prototype iteration is unclear or is missing altogether; There is no evidence that the prototype would facilitate testing by suitable means for any of the design requirements.	The final prototype iteration is only minimally explained and/or is not constructed with enough detail to assure that objective data on at least one design requirements could be determined; no more than one attribute (sub-system) of the unique solution that can be tested or modeled mathematically and any attempt at justification for those attributes that cannot be tested or modeled mathematically is unclear and thus required expert review is missing.	The final prototype iteration is explained only somewhat clearly and/or completely and is constructed with enough detail to assure that objective data on at least a few design requirements could be determined; a few attributes (sub-systems) of the unique solution that can be tested or modeled mathematically but there may be insufficient justification for those attributes that cannot be tested or modeled mathematically and thus require expert review.	The final prototype iteration is clearly and adequately explained and is constructed with enough detail to assure that objective data on some design requirements could be determined; some attributes (sub-systems) of the unique solution that can be tested or modeled mathematically and an adequately supported justification is provided for those attributes that cannot be tested or modeled mathematically and thus require expert review.	The final prototype iteration is clearly and adequately explained and is constructed with enough detail to assure that objective data on many design requirements could be determined; most attributes (sub-systems) of the unique solution that can be tested or modeled mathematically and a generally supported justification is provided for those attributes that cannot be tested or modeled mathematically and thus require expert review.	The final prototype iteration is clearly and fully explained and is constructed with enough detail to assure that objective data on all or nearly all design requirements could be determined; all attributes (sub-systems) of the unique solution that can be tested or modeled mathematically and a well-supported justification is provided for those attributes that cannot be tested or modeled mathematically and thus require expert review.
Prototype Testing & Data Collection Plan	Any testing plan included fails to address at least one of the high priority design requirements by describing at least minimally the conduct (through physical and/or mathematical modeling) of a test that is feasible and/or providing for an at least generally logical and/or partially developed explanation of how testing would yield objective data regarding the effectiveness of the design; OR a testing plan is missing altogether.	The testing plan addresses one of the high priority design requirements by describing at least minimally the conduct (through physical and/or mathematical modeling) of a test that is feasible and/or providing for an at least generally logical and/or partially developed explanation of how testing would yield objective data. Confirmation of explanation by even one field expert missing.	The testing plan addresses a few of the high priority design requirements by at least partially describing the conduct (through physical and/or mathematical modeling) of those tests that are feasible and providing for others an only somewhat logical and/or partially developed explanation of how testing would yield objective data, confirmed by one or more field experts.	The testing plan addresses some of the high priority design requirements by adequately describing the conduct (through physical and/or mathematical modeling) of those tests that are feasible and providing for others a generally logical and adequately developed explanation of how testing would yield objective data, confirmed by one or more field experts.	The testing plan addresses many of the high priority design requirements by describing in a generally effective way the conduct (through physical and/or mathematical modeling) of those tests that are feasible and providing for others a logical and generally developed explanation of how testing would yield objective data, confirmed by one or more field experts.	The testing plan addresses all or nearly all of the high priority design requirements by effectively describing the conduct (through physical and/or mathematical modeling) of those tests that are feasible based on the instructional context and providing for others a logical and well-developed explanation of how testing would yield objective data, confirmed by one or more field experts.
Prototype Testing & Data Analysis	Any test(s) for requirement(s) or attempts at physical or mathematical modeling fail to demonstrate even minimal understanding of testing procedure, including the gathering and analysis of resultant data; OR there is no evidence of testing or physical or mathematical modeling to address any requirements.	Through the conduct of one or two tests for requirements (which may or may not be high priority) that are reasonable based on instructional contexts, or through physical or mathematical modeling, the student demonstrates minimal understanding of testing procedure, including the gathering and analysis of resultant data; the analysis of the effectiveness of the design attempted an explanation and summary of the data but may not be supported by any pictures, graphs, charts or other visuals; the analysis may be missing a summary of the implications of any of the data for proceeding with the design and solving the problem.	Through the conduct of one or two tests for high priority requirements that are reasonable based on instructional contexts, or through physical or mathematical modeling, the student demonstrates partial or overly general understanding of testing procedure, including the gathering and analysis of resultant data; the analysis of the effectiveness of the design includes a partial explanation and summary of the data, and is at least minimally supported by pictures, graphs, charts and other visuals; the analysis includes a partial or overly-general summary of the implications of at least some of the data for proceeding with the design and solving the problem.	Through the conduct of a few tests for high priority requirements that are reasonable based on instructional contexts, or through physical or mathematical modeling, the student demonstrates adequate understanding of testing procedure, including the gathering and analysis of resultant data; the analysis of the effectiveness of the design includes a somewhat detailed explanation and summary of the data from each portion of the testing procedure and from expert reviews, and is at least somewhat supported by pictures, graphs, charts and other visuals; the analysis includes a summary of the implications of at least some of the data for proceeding with the design and solving the problem.	Through the conduct of several tests for high priority requirements that are reasonable based on instructional contexts, or through physical or mathematical modeling, the student demonstrates ample understanding of testing procedure, including the gathering and analysis of resultant data; the analysis of the effectiveness of the design includes a generally detailed explanation and summary of the data from each portion of the testing procedure and from expert reviews, and is generally supported by pictures, graphs, charts and other visuals; the analysis includes an overall summary of the implications of most if not all of the data for proceeding with the design and solving the problem.	Through the conduct of several tests for high priority requirements that are reasonable based on instructional contexts, or through physical or mathematical modeling, the student demonstrates considerable understanding of testing procedure, including the gathering and analysis of resultant data; the analysis of the effectiveness of the design includes a consistently detailed explanation and summary of the data from each portion of the testing procedure and from expert reviews, and is generously supported by pictures, graphs, charts and other visuals; the analysis includes an overall summary of the implications of all data for proceeding with the design and solving the problem.
Checkpoint **Critical Design Review**	**Does the prototype address the design requirements and is the testing plan unbiased?**					

Reflect	Evaluation, Reflection, and Recommendations					
	Rubric Score - 0	Rubric Score - 1	Rubric Score - 2	Rubric Score - 3	Rubric Score - 4	Rubric Score - 5
Documentation of External Evaluation	Documentation of project evaluation by any representative stakeholder or field expert is non- existent OR if included is minimal; synthesis is minimal or missing and if present, does not address any questions, concerns, or opinions of an evaluator related to design requirements.	Documentation of project evaluation by one or two stakeholders and/or field experts is presented but (some of whom may not be demonstrably qualified) is presented and the documentation synthesis is sparse, with few specifics/details; the synthesis of evaluations addresses only one or two of an evaluator's questions, concerns, and/or opinions related to design requirements.	Documentation of project evaluation by two or three stakeholders and/or field experts (some of whom may not be demonstrably qualified) is presented and the documentation is synthesized in a somewhat specific and/or detailed but incomplete or overly general way; the synthesis of evaluations addresses at least a few of evaluators' specific questions, concerns, and/or opinions related to design requirements.	Documentation of project evaluation by three or four demonstrably qualified stakeholders and/or field experts is presented and is the documentation is synthesized in a somewhat specific and detailed way, but may not be thorough; documentation may not be sufficient in any category to yield a meaningful analysis of that evaluation data; the synthesis of evaluations addresses at least some of evaluators' specific questions, concerns, and opinions related to design requirements.	Documentation of project evaluation by two or more demonstrably qualified stakeholders and field experts is presented and is the documentation is synthesized in a generally specific, detailed, and thorough way; documentation is sufficient in at least one category to yield a meaningful analysis of that evaluation data; the synthesis of evaluations generally addresses evaluators' specific questions, concerns, and opinions related to design requirements.	Documentation of project evaluation by multiple, demonstrably qualified stakeholders and field experts is presented and is the documentation synthesized in a consistently specific, detailed, and thorough way; documentation is sufficient in two or more categories to yield meaningful analysis of that evaluation data; the synthesis of evaluations consistently addresses evaluators' specific questions, concerns, and opinions related to design requirements.
Reflection on the Design Project	The project designer attempts a reflection on, and value judgment of, at least one or two of the major steps in the project, although the reflection may be minimal, unclear, and/or extremely superficial; any lessons learned are unclear and/or of no likely use to others attempting the same or similar project; OR there is no evidence of a reflection and/or lessons learned.	The project designer provides a reflection on, and value judgment of, at least some of the major steps in the project, although the reflection may be minimal, unclear, and/or extremely superficial; the reflection includes a few lessons learned of which at least one would be useful to others attempting the same or similar project.	The project designer provides a generally clear, at least somewhat insightful, and partially developed reflection on, and value judgment of, most if not all of the major steps in the project; the reflection includes some lessons learned which would be useful to others attempting the same or similar project.	The project designer provides a generally clear and insightful, adequately-developed reflection on, and value judgment of, major steps in the project, although one or two steps may be addressed in a more cursory manner; the reflection includes a summary of lessons learned, at least most of which would be useful to others attempting the same or similar project.	The project designer provides a clear, insightful and well-developed reflection on, and value judgment of, each major step in the project; the reflection includes a summary of lessons learned that would be clearly useful to others attempting the same or similar project.	The project designer provides a consistently clear, insightful, and comprehensive reflection on, and value judgment of, each major step in the project; the reflection includes a substantive summary of lessons learned that would be clearly useful to others attempting the same or similar project.
Presentation of The Designer's Recommendations	The project designer includes one or two recommendations (with or without plans) that bear little/no relation to the conduct of the same or similar project in the future OR fails to offer any recommendations or plans regarding the conduct of the same or similar project in the future	The project designer includes one or two overly general and/or questionably relevant recommendations regarding the conduct of the same or similar project in the future; any plans for implementation included are vague/unclear or minimally related to the recommendations provided	The project designer includes recommendations regarding the conduct of the same or similar project in the future; recommendations may include some specific ways the project could be improved but plans for the implementation of those improvements may be missing OR the recommendations (with or without plans) may be partial and/or overly general.	The project designer includes a few detailed and salient recommendations regarding the conduct of the same or similar project in the future; recommendations include some specific ways the project could be improved along with what may be only minimally detailed plans for the implementation of those improvements and may also include one or two caveats for others	The project designer includes generally detailed and salient recommendations regarding the conduct of the same or similar project in the future; recommendations include caveats as warranted and specific ways the project could be improved with generally detailed plans for the implementation of those improvements	The project designer includes consistently detailed and salient recommendations regarding the conduct of the same or similar project in the future; recommendations include caveats as warranted and specific ways the project could be improved with consistently detailed plans for the implementation of those improvements
Summary of Testing Results	Does the prototype address the design requirements? How well does the solution attempt work to actually meet the design requirements and addressing the problem?					

Present

Documenting and Communicating the Process

	Rubric Score - 0	Rubric Score - 1	Rubric Score - 2	Rubric Score - 3	Rubric Score - 4	Rubric Score - 5
Documenting the Project: **Notebook and ePortfolio**	The portfolio attempts to document the design process and project but little/none of that information supports subsequent replication and refinement by the designer(s) and/or others; little/no attention to audience and purpose was evident in the choice of mode(s) of presentation, professionalism of style and tone, or the variety, quality, and suitability of any supporting materials included.	The portfolio provides minimal documentation of the design process and project that would be likely to facilitate subsequent replication and refinement by the designer(s) and/or others; attention to audience and purpose was rarely evident in the choice of mode(s) of presentation, professionalism of style and tone, and the variety, quality, and suitability of supporting materials.	The portfolio provides partial or sometimes overly general documentation of the design process and project that would be likely to facilitate subsequent replication and refinement by the designer(s) and/or others; although there may be some minor omissions or inconsistencies; attention to audience and purpose was only sometimes/somewhat evident in the choice of mode(s) of presentation, professionalism of style and tone, and the variety, quality, and suitability of supporting materials.	The portfolio provides generally clear and thorough documentation of the design process and project that would be likely to facilitate subsequent replication and refinement by the designer(s) and/or others, although there may be some minor omissions or inconsistencies; attention to audience and purpose was generally-but not always--evident in the choice of mode(s) of presentation, professionalism of style and tone, and the variety, quality, and suitability of supporting materials.	The portfolio provides clear, generally detailed and thorough documentation of the design process and project that would be likely to facilitate subsequent replication and refinement by the designer(s) and/or others; attention to audience and purpose was evident in the choice of mode(s) of presentation, professionalism of style and tone, and the variety, quality, and suitability of supporting materials.	The portfolio provides consistently clear, detailed, and extensive documentation of the design process and project that would with certainty facilitate subsequent replication and refinement by the designer(s) and/or others; attention to audience and purpose was abundantly evident in the choice of mode(s) of presentation, professionalism of style and tone, and the variety, quality, and suitability of supporting materials.
Communicating the Project: **Writing Like an Engineer**	Virtually no evidence of the ability to write even somewhat clear and organized texts that are developed for the audience and purposes intended (to explain, question, persuade, etc.); texts demonstrate virtually no ability to adjust language, style and tone to address the needs and interests of at least two different audiences (e.g., expert, informed, general/lay audience); there may be evidence of an attempt to use at least two different forms which are commonplace among STEM disciplines but these are not correctly differentiated; there is virtually no evidence of any attempt to provide documentation in standardized form where needed.	Little evidence of the ability to write clear and organized texts that are at least partially developed for the audience and purposes intended (to explain, question, persuade, etc.); texts demonstrate little ability to adjust language, style and tone to address the needs and interests of at least two different audiences (e.g., expert, informed, general/lay audience) but many adjustments are not evident- although warranted; texts demonstrate the attempt to use at least two different forms which are commonplace among STEM disciplines; appropriate documentation in standardized form (e.g., APA) is usually missing or incorrect.	Only some evidence of the ability to write clear and organized texts that are at least partially developed for the audience and purposes intended (to explain, question, persuade, etc.); texts demonstrate some ability to adjust language, style and tone to address the needs and interests of at least two different audiences (e.g., expert, informed, general/lay audience) but adjustments are not evident-although warranted-in a number of instances; texts demonstrate the ability to use at least two different forms which are commonplace among STEM disciplines; where required by convention, appropriate documentation in standardized form (e.g., APA) is frequently missing or incorrect.	Adequate evidence of the ability to write usually clear and generally organized texts that are at least partially developed for the audience and purposes intended (to explain, question, persuade, etc.); texts demonstrate the ability to adjust language, style and tone to address the needs and interests of several different audiences (e.g., expert, informed, general/lay audience) but may be unsuccessful at doing so on occasion; texts demonstrate the ability to use several different forms which are commonplace among STEM disciplines; where required by convention, appropriate documentation in standardized form (e.g., APA) is sometimes evident, although attempts at documentation may reveal minor errors;	Clear evidence of the ability to write clear and well organized texts that are generally well-developed for the audience and purposes intended (to explain, question, persuade, etc.); texts generally demonstrate the ability to adjust language, style and tone to address the needs and interests of a variety of audiences (e.g., expert, informed, general/lay audience) with minor exceptions and demonstrate the ability to use a variety of forms which are commonplace among STEM disciplines (e.g., notes, descriptive/narrative accounts, research reports); where required by convention, appropriate documentation in standardized form (e.g., APA) is generally evident.	Abundant evidence of the ability to write consistently clear and well organized texts that are developed to the fullest degree suitable for the audience and purposes intended (to explain, question, persuade, etc.); texts consistently demonstrate the ability to adjust language, style and tone to address the needs and interests of a variety of audiences (e.g., expert, informed, general/lay audience) and to use a wide variety of forms which are commonplace among STEM disciplines (e.g., notes, descriptive/narrative accounts, research reports); where required by convention, appropriate documentation in standardized form (e.g., APA) is consistently evident.

Conclusion of First Iteration of Project

Communicate the Process	Does the portfolio clearly and accurately communicate the entire process to a reviewer?
Document the Process	Is the engineering notebook accurate and does it document the entire process to STEM standards?
Present the Process	Does the prepared presentation of the process to a group of reviewers defend all decisions and claims?