Chino Valley Unified School District
High School Course Description #5U03

CONTACTS	
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A. COVER PAGE - COURSE ID	
1. Course Title:	Engineering Geometry with Physics- Math
2. Transcript Title/Abbreviation:	Engineering Geometry with Physics- Math
3. Transcript Course Code/Number:	5U03
4. Seeking Honors Distinction:	No
5. Subject Area/Category:	(c) Mathematics
6. Grade level(s):	9-10
7. Unit Value:	5 credits per semester/10 total credits
8. Was this course previously approved by UC?	Yes
9. Is this course classified as a Career Technical Education course?	Yes
10. Is this course modeled after an UC-approved course?	Yes

11. Brief Course Description:
Students learn how Geometry and Physics have played vital roles in the development and innovation of the world around them through engineering discoveries like catapults, roller coasters, musical instruments, and more. Upon completion of this course, students receive credit in both University of California (UC) "c" mathematics and "d" lab science areas. Students explore the world of engineering and its connected career fields and disciplines.

12. Prerequisites:	Algebra I or high math / Teacher recommendation

13. Context for Course:
This is an integrated course utilizing physics concepts and math concepts in an engineering environment. The course is designed to generate interest in physics and math through engineering projects in a way that increases students' likelihood of success. The applications throughout the course allow students to see the connection between physics and math concepts and engineering design and architectural and structuring engineering. Also, this course may be part of an Engineering Academy in a sequence of Engineering courses.

14. History of Course Development:
This course was developed at the Spring 2011 University of California Curriculum Integration (UCCI) Institute focusing on subject area "c" math and "d" lab science and the Career Technical Education (CTE) Engineering industry sector. It has been challenging for educators to find and develop linkages with certain disciplines, including English, history/social sciences, and lab science. To address these challenges, the University of California created the UCCI Institute to focus on subject areas that have proven to be difficult to develop integrated curriculum. Over sixty California high school academic and CTE instructors, administrators, curriculum specialists, and UC staff were assembled into teams and challenged to develop innovative model courses that infuse core foundational academic concepts with relevant career technical elements.

B. COURSE CONTENT

Course Purpose:

Engineering Geometry with Physics is designed as an introductory college and career preparatory course in physics and geometry with continuous integration of Engineering CTE industry sector pathways (such as Engineering Design or Architectural and Structural Engineering). The course is comprised of a series of units that are guided by project-based learning strategies to ensure adequate ramping and integration of content knowledge and requisite skills in the three focus areas of geometry, engineering, and physics. These units include: catapults, bridges, solar energy, wind energy and turbines, Archimedes screw, telescopes, energy efficient houses, musical instruments, and race cars. In order to gain an understanding that all new engineering discoveries have relied on the innovations of the past, each unit begins with a historical perspective and progress to the point where students in their design brief challenges are asked to make new innovations while keeping the spirit of the original innovation or technology.

The expected outcomes of Engineering Geometry with Physics:

- A mastery of geometry standards satisfying a UC "c" mathematics requirement
- An understanding of core Physics concepts
- A project based learning environment that satisfies a UC "d" lab requirement
- Experience applying an iterative design process
- Analyze and interpret topographic and other symbolic representations of actual location
- Diagrams
- Interpret and construct appropriate diagrams for a given task
- Label and caption drawings to add to understanding of displayed information
- Tables
- Construct and manipulate tables to adequately organize and display data
- Analyze the contents of the table as it applies to the current project
- Apply geometric proofs to engineering projects
- Understand and apply correct theorems to justify design choices
- Apply the logic used in geometric proofs to reason through a design problem
- Become fluent in different symbolic representations in science, and math
- Learn to read with a scientific mind
- Understand and interpret graphs and other representations of data and information in a scientific context
- Use standard geometric tools (i.e. compass, protractor, rulers)

Course Outline:

<u>Unit 1: Introduction to Engineering Geometry & Physics</u>

This unit is designed as an introduction and survey to the course. The unit grounds students in the scientific process as it relates to engineering and design through the cross disciplinary building of a working catapult. This catapult must be able to launch an object a desired distance set by the teacher. Students are introduced to the social/co-operative learning models that are used throughout the course so special emphasis is placed on establishing group norms and effectively brainstorming. Students explore key scientific literacy strategies, such as, the vocabulary in geometry needed to understand proofs, congruency and congruency theorems. During the exploration, students learn the necessary interpretive processes to translate quantitative or technical information into a variety of media forms and perform analyses intrinsic to the nature of the engineering process. Basic engineering presentation skills are emphasized.

Although students use math and physics concepts to design the catapult, this is not be a highlighted part of the project. This project focuses on the engineering process that is used throughout the course with an emphasis on mechanical engineering. However, using the properties of similarity, students learn how to create a scale drawing with standard geometric tools like rulers, compasses, protractors.

Unit 2: Building Bridges

This unit entails the incorporation of geometry, engineering and physics to design and build a bridge with the highest efficiency. The students design, calculate, and construct a bridge using a set amount of materials for each student/group. This project focuses on the engineering process that is used throughout the course with an emphasis on mechanical, civil, and manufacturing engineering pathways.

For geometry, this unit focuses on congruent and similar polygons, particularly triangles. The students are able to apply geometric strategies to solve design problems by tying together the relationships of sides and angles in congruent triangles as well as parallel lines to help find congruent parts in triangles and parallelograms and prove parallelograms are congruent. Truss bridges, in particular, require parallel construction to ensure loads are evenly distributed, to avoid structural failure. Continuing with an introduction of trigonometry and similar triangles, the students use the Pythagorean theorem to see the special relationship of 30-60-90 degree triangles and 45-45-90 degree triangles, again to understand how to maintain structural strength and stability. These special relationships also tie together the meaning of similarity as the equality of all corresponding pairs of angles and the proportionality of all corresponding pairs of sides. The students visualize relationships between two-dimensional and three-dimensional objects and are able to implement these relationships into a 2D and 3D model or bridge blueprint. They are exposed to coordinate geometry and are able to prove simple geometric theorems algebraically when their design is graphed. Also, they are introduced to radius and arc length of a circle towards the end of the unit to illustrate the various methods used to calculate support beams and cables in suspension and arch bridges.

This unit explores the concepts of forces and Newton's laws of motion as they relate to static structures, such as bridges and buildings. Within bridges, the supporting members and the forces exerted on them are governed primarily by Newton's Second and Third Laws of Motion. In calculating and analyzing these forces, students need to be able to identify action/reaction pairs at not only supporting structures in the bridge but also in the joints holding the bridge together. Structural members in bridges are often not aligned to purely vertical and horizontal axes, requiring students to resolve these vectors, so they can be utilized in completing calculations and analyses of the forces acting within the bridge structure.

This unit also allows students to learn how civil engineers impact our daily lives, identify different areas of specialization, understand the benefits of a career in civil engineering, and identify the necessary skills to become a civil engineer.

Unit 3: Solar Energy

This unit allows students to explore solar energy through researching the history of solar energy, the current applications of solar energy, and the possibilities for solar energy in the future. Students create a solar water heater as their final product. Students explore how energy from the sun is converted into electrical and thermal energy. As the energy from the sun is transported via electromagnetic radiation, the electromagnetic waves encounter a solar cell; the conversion of this energy to electrical energy requires understanding of energy, work, and the law of conservation of energy. This electrical energy is transported away from the generation unit using electrical circuits, requiring the understanding of Ohm's Law. Also, students explore the world of thermodynamics and how the basic laws of thermodynamics can be used to harness the power of the sun. Students explore the concepts of heat flow through conduction, convection, and radiation as they apply to convection currents created with the solar collector and how fluids behave in such systems.

Students explore the surface area and shapes made by a cross-section of a three-dimensional object (such as a cylinder, a cube, or a prism). Understanding these shapes allows students to look at and measure a cross section of a solar collector to determine how to effectively harness the sun's energy on a determined target. They learn to apply the concepts of perimeter and area to find the volume of solids. Also, they apply concepts of density based on area and volume in modeling situations. Parallel lines, corresponding angles, and the theorems governing them are explored as students diagram how light rays are reflected by a variety of shaped mirrors. Students testing and diagramming mirrors determine the most appropriate shapes for these mirrors based on the application of theorems and geometric diagrams.

The project focuses on the engineering process that is used throughout the course with an emphasis on mechanical, electrical, and environmental engineering. The unit covers the relationship between concepts, such as safety, system design, electrical and mechanical design, and subsystem design. Students review technical drawings, such as blueprints. Students analyze and learn about incorporating the following systems into building a house: lighting, climate control, mechanical systems, electrical, and plumbing. Students develop a site analysis that considers passive energy techniques, sustainability, landscaping and construction.

Unit 4: Windmills (Turbine Challenge)

During this unit, students utilize the interactive design process and collaborative teaming to construct a wind turbine that generates enough electricity to power a small light bulb or other electronic device.

The students analyze the relations between interior angles and the remote exterior angle, vertical angle relationships, and the relationship of the angles formed when a transversal passes through two parallel lines. They learn that the measurements of a triangle sum up to 180 degrees, base angles of isosceles triangles are congruent. They prove geometric theorems using congruency; identify that the segment joining midpoints of two sides of a triangle is parallel to the third side and half the length; and the medians of a triangle meet at a point. Application of the Pythagorean theorem aids in solving trigonometric ratios. When exploring circles in the units, the students become familiar with key terminology of parts of a circle. The students identify and describe relationships among interior and exterior angles, chords, secants, and tangents to a circle. Also, they find arc lengths and areas of sectors of circles in order to properly construct wind turbines large enough to produce adequate power while still maintaining the required size constraints.

From the physics standpoint, this unit focuses on transforming energy from the wind into electrical energy through the processes of rotational mechanical energy. Electrical and gravitational potential energy as they relate to conservation of energy is stressed. This process requires the understanding that it is a force that causes rotation by the process of torque. Torque is dependent on the radius of rotation and the magnitude of the force acting. Understanding that centripetal force is a constant that points towards the center of a circle eases the calculation of centripetal acceleration ($a=v^2/r$). The rotation of the windmill causes a magnet to spin and induces an electrical current that can be transported away from the generation source using circuits to the location of need. To further understand this concept of direction of magnetic field affecting circuits, students apply knowledge by constructing simple electrical circuits using magnetic materials.

Unit 5: Archimedes Screw

Through incorporating the history and theory of screw pumps, students design and construct a working screw pump model. Students work in teams to build, test, and evaluate their designs. Writing a technical report supports their designs with research on the historical context, present applications and future possibilities of the screw pump. Students present this information in a public forum.

Students explore the relationships of force, energy, and gravity. As the screw applies a force to the liquid, work is done to transform rotational mechanical energy into gravitational potential energy by lifting the liquid to a higher elevation. This process requires work because the law of universal gravitation dictates that two objects with mass are attractive to each other requiring energy to move them further apart.

Coordinate geometry plays a key role in the standards covered. The students use coordinates to prove simple geometric theorems algebraically. The students visualize relationships between two-dimensional and three-dimensional objects, implement these relationships into a 2D and 3D model as they take 2D blueprints and drawings, and translate them into a working 3D model. Also, students implement this skill set in the initial stages as they take a 3D idea in concept and sketch it during the drawings and design phase. The relationship between coordinate geometry and 2D/3D modeling are used when exploring the construction of the Archimedes pump as it pertains to tube size, angles, and pump rate.

Unit 6: Telescopes

Students study aspects of optics, lenses, mirrors, and geometry to engineer a telescope that allows them to view objects at a reasonable distance from the observer. The project focuses on the engineering process that is used throughout the course with an emphasis on mechanical engineering. Also, students practice public speaking and through the use of digital social media present their ideas and findings from the project.

Students explore the phenomena of electromagnetic energy, its waveform, anatomy, and function. Learning telescope design and its interactions with visible and invisible waves assists students in understanding how waves are concentrated to allow a more detailed analysis of the information they carry through the universe. This concentration process is achieved through the use of mirrors and lenses using the concepts of reflection and refraction. Students may explore how weather may or may not affect data acquisition.

Using a variety of tools and methods, the students continue to make formal geometric constructions of congruent segments/angles, bisecting segments/angles, parallel lines, perpendicular bisectors, and various polygons inscribed in a circle or triangle to fully understand the construction of an object clarity of telescopes. When exploring spherical lenses and mirrors, the concepts of circles in the unit continue as students become familiar with key terminology for parts of a circle, identify and describe relationships among interior and exterior angles, chords, secants, and tangents as they apply to the determination of focal points in lenses and mirrors. Also, they find arc lengths and areas of sectors of circles.

Unit 7: Roller Coasters

In this unit within teams, the students design and engineer a roller coaster that integrates concepts from geometry and physics. The students showcase their knowledge in problem solving as a team. They come to a consensus on the materials used to fabricate a prototype and then conduct test simulations to determine whether their initial design specifications are met.

By exploring the workings of a roller coaster, students discover the interplay between kinetic and gravitational potential energy. They discover that both potential and kinetic energy can be transformed into one another and how friction and other forces are integrated into this process. Also, students uncover the connection between kinetic energy and momentum, as well as how to calculate these quantities based on an object's physical properties, such as mass and velocity. Newton's Second Law provides the basis for students to understand kinematic equations in one dimension, using acceleration to calculate time and velocity. Conceptually, students unpack Newton's Third Law by looking at the interaction between the train and the track and the riders and their seats.

The students tie the relationships of sides and angles in congruent triangles, as well as parallel lines, to help find congruent parts in parallelograms and prove parallelograms are congruent. The definition of parallelogram is addressed more and the students are able to see that other polygons fall in the parallelogram category, such as rectangles and squares. From there students explore the properties of a right triangle and explore the relation of the side measurements to the complementary angles, leading into similar triangles and trigonometry. Then students are able to distinguish the relationship between the sine and cosine of complementary angles. Also, these special relationships tie together the meaning of similarity as the equality of all corresponding pairs of angles and the proportionality of all corresponding pairs of sides. Coordinate geometry plays a key role in the determination of slope and layout of the roller coaster track as well. The students use coordinates to prove simple geometric theorems algebraically and how the use of certain shapes can add stability and flexibility to the roller coaster structure.

Students develop a heightened and mature emphasis to understand the various forces that bear on and within structures, including axial force, shear, torsion, and moment. Students conduct evaluations of available building materials (e.g., steel and wood) considering their properties and effects on building form recognizing strengths and limitations. From this evaluation, a preliminary building plan is developed by using the appropriate materials. The stress-strain relationship of building structures and the laws of conservation of energy and momentum provide a way to predict and describe the movement of objects.

Unit 8: The Energy Efficient House

Students learn current and future methodologies to minimize the use of electricity in residential dwellings through the use of thermodynamic principles. This involves correctly placing the house on a lot to maximize electrical efficiency. Students investigate which building materials allow them to maximize electrical efficiency. Students learn residential mechanical systems which include climate control, and electrical circuits. Students explore usage of strategic landscaping to maximize electrical efficiency. Students are preparing to design an energy efficient home or "green home" in this class. As part of their research, students study green building practices and techniques as well as energy efficient designs like passive solar solutions for integration into their design. Also, students learn types of renewable alternative energy sources, such as solar energy and wind power. Using the Internet and a variety of sources and materials, students create a presentation with appropriate props explaining the design choices for their house based on their research, class lectures, and presentations. Students present the information in class as a sales pitch to a prospective buyer.

When testing insulating materials, students explain that quantities of energy tend to flow until they become distributed uniformly, and students brainstorm ways to slow down this process. Insulation functions to limit this flow of energy between interior and exterior environments of rooms, houses, and other structures. Students investigate the heat conductivity of various materials and develop explanations for the causes of high and low heat capacity by researching the molecular structures of materials and the ease in which thermal energy is transferred through these structures. Students discuss thermal energy as a function of temperature during these activities.

In this unit, the definition of a parallelogram is addressed in more depth and the students are able to understand that other polygons fall into the parallelogram category, such as rectangles and squares, and from there explore the properties of a right triangle and the relation of the side measurements to the complementary angles. The concepts of volume and surface area become vital as students consider how energy and air flow are addressed in various configurations and orientations of rooms. They also learn to use coordinates to compute perimeters of polygons and areas of triangles and rectangles via the distance formula or midpoint formula as they sketch blueprints or technical drawings in the construction of the model. In some instances, the students are able to use geometric shapes and their properties to describe objects in an application. Once the students are familiar with polygons and circles, they explore the shapes made by a cross-section of a three-dimensional object. They learn to apply the perimeter and area towards finding the volume of solids and determine how changes in dimensions affect the perimeter, area, and volume of common geometric figures and solids as they apply these to designing a house or other habitable structure. They are able to apply concepts of density based on area and volume in modeling situations, such as air flow and convection.

Students use modeling or Computer-Aided Design and Drafting (CADD) software to aid in the design of their energy efficient house, as well as in the presentation and discussion of their final product. This final presentation is accomplished by creating a website or PowerPoint showcasing the energy-efficient features of the house along with a discussion of why these features function to reduce the energy consumption of the house.

Unit 9: Building an Instrument

In this project, students explore the workings of current instruments and utilize those concepts to design and build a new musical instrument.

As students investigate the designs of various musical instruments, they discover the fact that sound travels at different speeds through different mediums. Students utilize this fact to engineer instruments to produce various frequencies depending on the density and molecular structure of the material they choose. Throughout this unit, students research how sound is a longitudinal wave and transfers energy to our ear drum. This provides a deeper understanding of wave functions learned in Unit 6. Students discover how a string vibrating as a standing wave can produce a longitudinal wave in the air and that the frequency and speed of that wave is dependent on the medium it is traveling through.

When analyzing circles, the students derive the equation of a circle of given center and radius using the Pythagorean Theorem and complete the square to find the center and radius of a circle given by an equation. In some instances, the students are able to use geometric shapes and their properties to describe objects in an application. Also, they learn to use coordinates to compute perimeters of polygons and areas of triangles and rectangles via the distance formula or midpoint formula. These concepts and relationships are employed in understanding how an instrument is tuned and the determination of the shape and size of its resonator.

Unit 10: Vehicle Efficiency

In this unit, ideas in geometry, physics and engineering are explored through the design and construction of a model race car powered by a single mousetrap. This unit emphasizes two topical areas of physics: energy and rotation. Through the build and design aspects of the project, students explore the connections between stored energy and mechanical energy and how they can be used to induce a rotation in the wheels to propel the car forward in a linear fashion. The geometry of the wheels and axle system has a direct effect on the performance of the car in terms of speed, accuracy of travel, and distance traveled.

Students refine their ability to apply the process of logical thought through application of geometric proofs and theorems. Students prove the slope criteria for parallel and perpendicular lines and use them to solve geometric problems. Also, transformations are addressed in ways for the students to analyze the effects of rotation, reflection, and translation and develop definitions for these transformations in terms of angles, circles, perpendicular lines, parallel lines, and line segments, and describe the rotations and reflections that carry onto itself in application to the design of various components of the car and its overall design. The students have an opportunity to draw transformed figures with one transformation or a sequence of transformations to create congruent or similar figures. The physics of the car involve storing energy in the spring of the mousetrap and using that stored energy to move a lever arm. This motion causes a torque in the axle of the wheel via a string that is attached to the lever arm and wound around the axle assembly. As the torque is applied, it causes the wheel and axle to rotate, propelling the car forward.

The project focuses on the engineering process that is used throughout the course with an emphasis on mechanical, automotive, electrical, and manufacturing engineering. Students experiment with aspects of the racecar to explore vehicle performance tasks, such as speed, power, accuracy, and how these performance tasks are affected by different aspects of the car.

This project is expected to be the last unit and therefore a culmination of the content and skills the students have learned throughout the course. The unit parallels a real world engineering project with marketing and business models, product specifications, complete documentation including manufacturing specifications, design reviews, product testing, advertising and sale of the product. The teacher will choose which aspects to include in detail for the project. The project results in a technical paper, a multi-purpose vehicle and a presentation.

Key Assignments:

<u>Unit 1: Introduction to Engineering Geometry & Physics</u>

There are many online resources which explain the fundamental of building a catapult. For example: http://hubpages.com/hub/How-to-Build-a-Catapult---An-Illustrated-Guide

Students build one catapult which meet the criteria outlined in the rules and designed to answer one of the following variables:

- Distance - farthest distance thrown of a single projectile
- Accuracy – nearest distance projectile impacts to two ground level targets
- Strength – greatest mass of projectiles delivered to a vertical target

As part of the design process, students complete the following tasks to finalize the catapult construction:

- Conduct short, as well as more substantial research projects on the history of constructive design projects.
- Create and submit a written proposal that includes a scale drawing, a cost spreadsheet, and justification as to why the design works. Redesign and resubmit after analysis.
- Build the project with design constraints in an iterative fashion, making new drawings for any changes implemented.

Using engineering presentation models, the students present their products, including both an oral and a written component, with attention to what worked, what did not, and any changes that should be implemented in a redesign with justification (evaluation of design). Students need to highlight modern interpretations of the catapult and be able to discuss the similarities between the historic catapult and modern versions.

<u>Unit 2: Building Bridges</u>

<u>Assignment 1</u>: After lecturing on action-reaction forces and congruent angles, students brainstorm at least three truss designs for a bridge and identify on their drawings the forces and angles. Students then construct small scale models of their trusses and test them for strength failure points.

<u>Assignment 2</u>: In groups, students research at least three famous structures and create a presentation on how these structures function, identifying forces and angles.

<u>Assignment 3</u>: After discussing bridge terminology and introducing the manila folder bridge project, students write a proposal for their bridge design.

<u>Bridge terminology</u>: (Trusses, top core, bottom core, rods (hollow/solid), and solids) and effectiveness of materials for various designs/types.

<u>Bridge project</u>: Design and build a-truss/king post-bridge structure out of manila folders that sustains at least 5 kg at mid span and has an overall span of 30 cm. The bridge that has highest strength to weight ratio is considered the exemplar.

<u>Written proposal</u>: Describing the initial design of a truss bridge, including a scale drawing, calculations of the amount and weight of the material used, and justification as to why the design will work.

<u>Assignment 4</u>: Truss calculations (stress/strain) to show effects of different variables. Students determine tensile and compressive forces within a truss system. Students consider the static determinacy, $2j = m + r$, to determine the stability of the truss system or bridge.

<u>Assignment 5</u>: Working drawings: full-size sketch of bridge on grid-paper showing angles in each triangle and use of deductive reasoning and theorems to prove that top and bottom chords are parallel.

<u>Assignment 6</u>: Build/construct the bridge using drawings and assembly plans.

<u>Assignment 7</u>: Oral presentation: students describe the approach they took to designing their bridge, using geometry

and physics vocabulary to justify their designs.
Assignment 8: Test your bridge for maximum load and record your results. Calculate its strength to weight ratio.
Assignment 9: Written report: Students reflect on their design, what their initial thoughts were, what physics and geometry they used, what contributed to its collapse, and how they would change it if they were to build it again.

Unit 3: Solar Energy
Assignment 1: Students bring an object from home to use as a solar water heating device (volume and initial water temperature are controlled). Students measure water temperatures at predetermined intervals and graph the results. Students draw conclusions about the most effective variables in solar water heater design (teacher discussion points: surface area, volume, color, transparency, surface reflectance, shape, etc.).
Assignment 2: Students research the past, present, and future of solar energy and present their findings to the class. Teacher may decide to make this an individual written report with a brief summary in front of the class or a group oral presentation. Teacher may choose to assign one third of the class the history of solar energy, one third its present applications, and one third future technologies of solar energy.
Assignment 3: Students describe initial design of a solar water heater, including a scale drawing, a cost spreadsheet, and use geometric proofs and coordinates in justification as to why the design will work. Students are instructed on how to construct perpendicular lines, midpoints, and angle bisectors.
Assignment 4: Students build and test their initial design and measure water temperature over time. Students graph their results and discuss them with the class.
Assignment 5: Students describe what they learned from comparing their water heater to those of their classmates.
Assignment 6: Students redesign their solar water heaters and sketch a scaled drawing with lengths and angles labeled.
Assignment 7: Students build and test their new solar water heaters and graph the results.
Assignment 8: Students present a description of their designs, using physics and geometry vocabulary to describe its advantages and three results.
Assignment 9: Students produce a written evaluation describing the process they went through in designing their solar water heater, the physics and geometry used, and how they would change it if they were to redesign.

Unit 4: Windmills
Assignment 1: Students research and present the historical and modern applications of turbines to discover the historical and modern applications. After the presentations, the class is introduced to the design challenge of building a turbine of their own.
Assignment 2: Students construct simple series and parallel circuits using light bulbs, resistors, motors, and batteries. Students discover the relationship between voltage, resistance, and current through the use of a multi-meter and derive the relationships in Ohm's Law. They explore the relationships between electric motors and electric generators. Student's findings are presented to the class.
Assignment 3: Students rely on their research and the discoveries about electricity to come up with an initial design for their wind turbine. They experiment with different blade designs (surface area, shape, etc.) and materials and test them by simple means of lifting and winding capabilities. They explore the concepts of rotational dynamics and torque and how these concepts relate to the design challenge.
Assignment 4: Students evaluate their designs using a decision matrix that allows them to rank aspects of their designs in order to choose the design that best suits the challenge. Once the students select their designs, they formalize a plan to build their designs. This plan must include scale drawings showing the explicit geometry formulas or proofs, as applied to buildings, and materials. The design is presented to the class as well.
Assignment 5: Student teams test their built windmills and collect data on electricity generated. They connect their windmills to a simple circuit containing a light bulb to verify that their design produces enough power to produce light. Student teams evaluate their windmills and brainstorm improvements, both structurally and mathematically, and how those improvements affect the performance of their windmill. The results of their tests are presented to the class.

Assignment 6: The student teams analyze their collected data and extrapolate their findings to a full scale version of their windmills. They scale up all materials, costs, and power generation, using the appropriate geometry to make the conversions. Students then compare their extrapolations to actual windmill or turbine costs and power output.

Unit 5: Archimedes Screw

Unit 5 is a practical application of geometric principles and concepts which have been learned to date with an emphasis on transforming 2D representations into 3D models and 3D ideas into explicit 2D representations as this applies to producing technical drawings.

Assignment 1: Students research the Archimedes screw to learn how this mechanism works as well as how it is still being used today. Students present their findings to the class either through oral presentation, web page creation, or a poster.

Assignment 2: Students are given their design brief describing the screw pump project. In the design brief, there is a description of how much water or other liquid must be raised to a given height in a set period of time. Student teams brainstorm how they could create an Archimedes screw and what materials they could use that fulfill the design brief. Then, they produce schematics and instructions on how to build their pump and submit those for approval by the teacher.

Assignment 3: Students are asked to rethink how the screw pump can be used in a manner that is not currently in commonly accepted. They redesign their pump in order to function in their proposed manner. Students submit their proposal with updated drawings, materials, and build instructions for approval.

Assignment 4: Students construct and test their redesigned screw pump and evaluate its performance based on anticipated functionality. They construct a written report encompassing the historical, modern, and proposed functionality as well as a discussion of the performance of their prototype.

Assignment 5: Students present the content of the written report orally including the applications of geometry and physics to the project.

Unit 6: Telescopes

Assignment 1: Students complete research on the history of the telescope and its progression to modern times. They present this research in the medium of their choice as well.

Assignment 2: Students follow the "Funland" Activity #78 in the accompanying lab manual for Hewitt by Paul Robinson. This lab explores the relationships of concave and convex spherical mirrors and how they produce images that are virtual, real, enlarged, or reduced based on the geometry of the mirror and the relationship of distance between the object and the focal length of the mirror. This exploration reinforces the math and angles of lenses as an introduction to building their telescopes. Other helpful labs that extend this exploration of mirrors and lenses are The Camera Obscura #79, in which students learn how a basic camera obscura functions and how small volumes of air can act as a spherical lens and Bifocals #82, in which the differing appearances of images produced are directly related to the differing geometries of the sections of the a bifocal lens.

Assignment 3: Students follow a standard optics bench lab in which they have to determine the focal length of spherical lenses and mirrors as well as predict and test whether the image produced by these mirrors and lenses will be real or virtual, inverted or right side up, and whether the image will be enlarged or reduced depending on the placement of the original object.

Assignment 4: Practice problems exploring light rays and their interactions with spherical mirrors and lenses. Student's ability to predict how an image is refracted or reflected in mirrors and lenses to produce images in optical instruments is expanded.

Assignment 5: Practice problems exploring construction of circular sections and angles as related to the laws of reflection and refraction of light.

Assignment 6: Students are given the design brief describing the criteria they must follow to construct a telescope of their own. Students must brainstorm and develop a proposal which includes detailed drawings and materials lists; this

must be submitted for approval.
Assignment 7: Student teams build and test their telescope; they evaluate its performance against the criteria described in the design brief. Students present the telescope and design process through a multimedia presentation. This presentation must include the design and building process and discuss the results of their project as a presentation to the class. This discussion includes how the core academic concepts from the unit apply to their telescopes and results of the project.
Assignment 8: Students write a comparison paper with data between the various group products.

Unit 7: Roller Coasters
Assignment 1: Students research the history of roller coaster and how they are designed and constructed today. Also, they need to research the modern technologies employed in current roller coasters.
Assignment 2: Students are given a challenge to determine the maximum potential and kinetic energy using factors of mass and height of a varying slope. The students document their data and findings in a lab report. At this point, they begin a preliminary design sketch of their proposed roller coaster.

Assignment 3: With the basis of kinetic and potential energy and slopes, the students discover different measurements of radii and arc lengths of a circle to help calculate potential or kinetic energy at each peak of the coaster to lead into centripetal force. The students investigate which materials to use and document a bill of materials.
Assignment 4: Students are introduced to velocity and acceleration. The students research in groups what the maximum gravitational force that is allowed for a human. From that, they tie that information together with assignment 3 and understand if the calculations made meet the safety specifications of a roller coaster. Students use their preliminary designs and begin building prototypes they begin to test and evaluate effectiveness and safety. They are required to document all their findings and design changes in a lab journal as well.
Assignment 5: Students compare their current designs to another peer's and discuss successes and possible shortfalls and illustrate how they overcame these shortfalls using specific geometry, physics, and engineering concepts. All conversations are prompted and documented for review by the teacher.
Assignment 6: Students begin to write their business proposals. This proposal should include a discussion of how the use of geometry and physics has been incorporated into the design and safety aspects of the coaster.
Assignment 7: Students finalize their design specifications and documentation and put together an oral and written presentation with a finalized design drawing (PowerPoint optional). The final testing stages should be completed as well.

Unit 8: The Energy Efficient House
Assignment 1: Given a topographical map and climate study, students determine the best orientation and placement of a house. The video "Graphisoft EcoDesigner: Informed Decisions" (available on YouTube) shows the students the use of "Building Orientation" in design and the use of software applications in achieving presentation format. The teacher is to perform a CADD demonstration on how to create the particular drawing the students create as their assignments; this allows the students to use prior knowledge in designing and applying the applications to the project.
Assignment 2: Students are given a sand box with an uneven terrain. Students are asked to make a flat plane or pad for a house to sit on. Then students calculate the amount of earth (sand) redistributed in cubic inches. This assignment reinforces the ideas of volume of parallelograms and surface area in that excavated sections of terrain often mimic basic parallelograms in shape. Students needing to create a specific size pad for the house need to know how to calculate the surface area of that pad and its relationship to the specific side of the parallelogram to be excavated from the terrain.
Assignment 3: Students learn about R-value, specific heat, convection, and conduction as it relates to insulating a home. Students test various building materials by measuring and recording the temperature on both sides of the materials when one side is exposed to a heat source for approximately fifteen minutes. They report on whether they categorize each material as an insulator or conductor.

Assignment 4: This assignment builds upon the previous assignment. Students investigate heat transfer between an outside environment and an insulated indoor environment with the goal of minimizing loss of heat using insulating materials. Then students use a mock economy to purchase insulation and insulate a paper box house. The houses are placed over a light bulb for a class period, and the temperatures are measured inside and out. Students use a spreadsheet to determine the cost of the insulation to preserve a degree of temperature as well.
Assignment 5: Students research and report their findings about passive solar design and how the purposeful flow of heat can help a space maintain comfortable temperatures year round.
Assignment 6: Students begin project layout based upon the attached handout. Students work in groups and develop a multi-use software knowledge base when developing the project. Students use CADD modeling software, Microsoft Word, Microsoft Excel and Microsoft PowerPoint in developing the project. Also, students are required to build a scaled model of the building and site they design, this allows them to look at the construction of their design and visualize its form and function of the building design. Students are allowed to use their creativity and architectural style using shape and color and how it all relates to orientation and green construction. Students must take the 2D drawings from the blueprints and construct a 3D model, again reinforcing the relationship between 2D and 3D.
Assignment 7: Students complete their presentations in a classroom presentation setting. They are graded on their presentation skills as well as the content of the presentation. They are required to show pictures of their model during construction and the process of building a model from their design. They are required to indicate the style of their building and what makes it a green building and the effect it has on their lives in the future. They are also required to indicate the process of drawing the project in a CADD modeling program as well.

Unit 9: Building an Instrument
Assignment 1: Students complete practice problems dealing with frequency, period, amplitude, wave speed, wavelength, air columns, stings, and membranes.
Assignment 2: Students research the major families of instruments to learn what makes each family unique and how instruments within each family produce and modulate sound waves.
Assignment 3: Students complete the wave interference worksheet, which is designed as scaffolding to explore wave anatomy and the interactions between waves.
Assignment 4: Students complete the individual instrument planning research to help define the function, construction, and type of instrument he or she is building. They must include detailed drawings and a materials/cost analysis.
Assignment 5: Students complete the vibrations in air columns worksheet which is designed as scaffolding to explore how vibrations are formed and waves are propagated in closed and open tube columns.
Assignment 6: Students complete the vibrations in strings and membranes worksheet which is designed as scaffolding to explore how vibrations are formed and waves are propagated in strings and worksheets.
Assignment 7: Students begin constructing their instruments. They need to make careful calculations in the dimensions of their instruments in order to produce correct frequencies that correspond to notes on a standard musical scale.
Assignment 8: Students make a final presentation of their instruments and a discussion of how their instrument functions. Students discuss how their instrument generates vibrations and waves and how those vibrations are modified to produce different tones and frequencies.

Unit 10: Vehicle Efficiency
Assignment 1: The students are given a challenge to design and build a vehicle using an instructor-supplied mousetrap that travels a maximum straight-line distance. Students have complete design freedom, with the exception of having to use the supplied mousetrap for propulsion and purchased hobby store-type kits being prohibited. Students initially brainstorm and sketch ideas individually, before assembling into teams for an enhanced brainstorming design process. Team size depends on instructor preference and class size.

Assignment 2: Student teams brainstorm ideas for the design, construction, and function of their race car. They complete and submit detailed drawings, materials lists and costs, and assembly instructions for approval prior to building. They must take into account the physics and geometry concepts learned throughout the year in making their proposals.

Assignment 3: Student teams consolidate their ideas into a practical and efficient design. Mechanical drawings are produced, including bill of materials, orthographic, pictorial and assembly drawings with all required dimensions. Students begin procurement of materials at this point, with instructor approval required for all component parts. Students need to be prepared to answer any engineering design questions presented by the instructor regarding their vehicle design.

Assignment 4: Student teams now enter into the manufacturing and construction phase of this unit. Students use adhesion, cohesion and/or mechanical fastening methods to produce their design. This stage requires extensive laboratory time and the manufacturing processes used depend on available resources and equipment. All construction and assembly procedures are completed done in class under instructor supervision with a strict adherence to all safety protocols.

Assignment 5: Student teams begin testing their vehicles and evaluating the results. Data is accumulated, recorded and examined. The instructor uses these test results to focus conversations on physics, geometry, and engineering concepts reinforcement. Re-design requires the iterative engineering design process to begin again and complete the cycle as many times as necessary. Extensive laboratory time is required for manufacturing and construction processes to continue.

Assignment 6: Students evaluate peer vehicles for constructive feedback using an instructor-designed rubric. The instructor can use this opportunity for stimulating class discussion in any area(s) that need additional input. Also, the instructor uses this time to reinforce the requirements of the technical report, oral presentation, and final vehicle competition rules.

Assignment 7: Student teams assign individual duties for the final written technical report. Details on aspects of technical reporting have been covered throughout the course in most units and each team member must have a specified role in the project. Team members begin planning the oral presentation during this assignment. A breakdown of the technical writing process can be found in Appendix B.

Assignment 8: Race day! The instructor has the opportunity to build into the grading rubric many other aspects in addition to maximum displacement, such as aesthetics, creativity, materials, engineering, problem solving, teamwork, etc. All results are carefully recorded, synthesized, evaluated and presented in the technical report and oral presentation.

Assignment 9: All members of the team play a role in the presentation of findings to the class. The instructor develops a rubric of specific aspects that are covered (this rubric having been used in prior units) with the students being fully aware of the expectations required for a quality presentations, but most definitely includes a thorough discussion of the physics and geometry concepts utilized in the construction, testing, and redesign of their cars.

Instructional Methods and/or Strategies:

Overview of Iterative Engineering Design Process

The iterative design process is the cornerstone of all engineering work. Throughout the course, students utilize this cyclical process to develop and refine their ideas and designs for each of the units. The most important aspect of the design process is that it is a continuous cycle:

- Identify the need or problem
- Research the need or problem
- Examine current state of the issue and current solutions
- Explore other options via the Internet, library, interviews, etc.
- Develop possible solution(s)
- Brainstorm possible solutions
- Draw on mathematics and science

- Articulate the possible solutions in two and three dimensions
- Refine the possible solutions
- Select the best possible solution(s)
- Determine which solution(s) best meet(s) the original requirements
- Construct a prototype
- Model the selected solution(s) in two and three dimensions
- Test and evaluate the solution(s) Does it work? Does it meet the original design constraints? Communicate the solution(s)
- Make an engineering presentation that includes a discussion of how the solution(s) best meet(s) the needs of the initial problem, opportunity, or need
- Discuss societal impact and trade-offs of the solution(s)
- Redesign
- Overhaul the solution(s) based on information gathered during the tests and presentation

Throughout the course, students use the following technical writing process to learn and strengthen their abilities to communicate their designs and purpose in written form.

Class/Group Discussion

In order to clearly identify the required written elements of their designs students participate in class/group discussions. Writing as a team as an apprenticeship strategy to support team members through the writing process using the following roles:

- Writer – This person is responsible for writing drafts and revisions of the introduction, discussion, conclusions, recommendations, acknowledgements, and abstract sections. This person concentrates in writing and addressing all relevant aspects of the technical paper.
- Editor – This person is in charge of correcting all grammatical mistakes on the paper and scoring the paper using the technical paper rubric. This person provides written comments on the paper's strengths and weaknesses. The editor returns corrected documents back to the writer for revisions.
- Researcher – This person is in charge of gathering all information and data related to the vehicle. This person creates charts and graphs that the writer or editor requests. This person is responsible for the references and appendix sections.
- Graphic Designer – This person is in charge of aesthetically packaging the technical paper. This person is responsible of the title page and table of contents pages. The designer works on making the paper look orderly and neat. Also, the designer is responsible for making copies and ensuring the paper is postmarked by the deadline.
- Begin the writing process – At the start, the writer the only one writing. Other team members continue construction of the project and/or working on specific team-assigned roles. Each team member keeps detailed, up-to-date records of their progress in a logbook.
- Final Edit – Student teams review and revise documents, drawings, and presentations to meet the requirements for written communication of design decisions and outcomes.
- Authentic – Full set of engineering skills is used. The final product is put up for sale relevant to life situations and collaborative work: teams and leadership roles.
- Embedded technology – Presentations, mechanical drawings, CAD, data recording and analysis using computers.
- Full spectrum of skills – This is the unit that pulls the course together.

Unit 1: Introduction to Engineering Geometry & Physics: Catapult - Teaching Strategies
Ideas include showing a clip of *Stuart Little* where Stewart uses a catapult to launch himself over the cat. Show a clip of *Monty Python and the Holy Grail*, *Lord of the Rings*, etc.
This unit is the students' introduction to cooperative learning that is used throughout the course; therefore emphasis is put on establishing group norms and how to effectively brainstorm.

Unit 2: Building Bridges - Teaching Strategies
Use lecture or guided discussion through PowerPoint presentation with note-taking to illustrate how important bridges are in our everyday lives. Show students the design failure brief "Tacoma Narrows Bridge" on engineering.com posted on October 24, 2006 to demonstrate this. Form student teams for hands-on lab using materials lab procedure. Use destructive tests of the bridge to evaluate the quality of the bridge design as a metric of student understanding. Friendly competition among teams may be used to add fun and motivation.

Unit 3: Solar Energy - Teaching Strategies
The principle teaching strategy of this unit is thematic. Throughout the unit the students make connections to solar energy past, present, and future and comparing indirect uses of solar energy, such as bio-fuels to the efficiencies of those explored in the unit. Show students the article "Passive Solar Systems and Solar Hot Water" to illustrate this.

Unit 4: Windmills - Teaching Strategies
Students use active listening and a common rubric to evaluate their peers on the delivery and construction of the presentation of their design decisions. By this time in the course, the students are familiar the design/build/test process, so the teams are self-directed. Near the end of this unit show the video from National Science Foundation about Professor Charles Meneveau and Raul Cal on their research of wind turbines in a wind tunnel: nsf.gov/discoveries.

Unit 5: Archimedes Screw - Teaching Strategies
Use the video from engineering.com "Screw Pumps - Modern Twists on a Classic Device" to illustrate screw pumps and their simplicity. Also use the design brief on engineering.com "Buoyant Forces and Archimedes' Principle" posted on November 10, 2006 to teach the buoyant force of the Archimedes' principle. This unit uses problem based and cooperative learning. Compare and contrast paper from data.

Unit 6: Telescopes - Teaching Strategies
Thematic Instruction: The role of the telescope overlays the process of designing and construction the telescope. For example, design constraint through history is considered in the students' designs. Teachers may wish to use the design brief posted on November 09, 2006 on engineering.com "Telescope," to show the basic construction of a telescope. The telescope is demonstrated to a wider audience (on a clear evening), so that the Galileo experience can be had by all.

Unit 7: Roller Coasters - Teaching Strategies
Kick off this unit with a video of rollercoaster physics technology, such as the one from the Discovery Channel's Time Warp program: http://dsc.discovery.com/videos/time-warp-roller-coaster-science.htm or Build it Bigger program "Roller Coasters" http://science.discovery.com/videos/build-it-bigger-coasters. Another resource is "All About G Forces" from Nova. Because of the complexity of the project, the students work in groups and determine who owns special tasks, for example, marketing/business, systems design, product aesthetics, experimental design, documentation, and fabrication. The students develop and document the project plan with a graphical timeline and resource allocation, gain teacher approval, and demonstrate on time delivery of tasks.

Unit 8: The Energy Efficient House - Teaching Strategies
This principle teaching strategy of this unit is integrating technology into the design/build/test cycle. The students use their computers to collect and analyze data, prepare drawings with CAD software, make graphs, and communicate with presentation software, video, wiki's, etc. In addition to the Graphisoft EcoDesigner video, there are several educational videos available online to supplement teaching this unit, for example, videos found on planetgreen.com.

Unit 9: Building An Instrument - Teaching Strategies
Lecture or guided discussion through PowerPoint presentation with note-taking. Form student teams for hands-on lab using standard materials lab procedures. A design review serves as both an assessment and a method for the student to learn the design review process. Use Nova's "Pitch Perfect" online article to demonstrate how various shapes and materials affect sound. Alternatively, use planetgreen.com's "Instrumental: Elemental Design" video.

Unit 10: Vehicle Efficiency - Teaching Strategies
Class discussion, writing a technical paper from diagram to implementation of design, group work with discussion and modification, business skills, team building, analysis with data and presentation.

- Cooperative learning in groups
- Guided and independent practice
- Students prepare and present oral presentations to class
- Students prepare and present long term project report to the teacher
- Scaffolded discussion and guided practice of technical writing as outlined at the beginning of this section

Assessment Including Methods and/or Tools:

Course Assessments by Unit

Unit 1: Introduction to Engineering Geometry & Physics

- Written proposal: describing initial design of a catapult including a scale drawing, a cost spreadsheet, and justification as to why the design works.
- Benchmark competition: students test their prototype catapults and write reflections on how to improve their design.
- Final product: students redesign and build final catapult.
- Oral presentation: students describe their initial thoughts their observations, and how they improved their designs.
- Written report: explaining, showing calculations, and drawings of the design and how it changed over time.

Unit 2: Building Bridges

- Written proposal: describing initial design of a truss bridge, including a scale drawing, calculations of the amount and weight of the material used, and justification as to why the design works.
- Quizzes: on identifying action/reaction forces and congruent angles.
- Working drawings: full-size sketch of bridge on grid-paper showing angles in each triangle and use of deductive reasoning and theorems to prove that top and bottom chords are parallel.
- Interim presentation: oral presentation on great civil structures explaining the geometry and forces involved three structures of students' choice. Also, oral presentation skills a focus.
- Oral presentation: students describe the approach they took to designing their bridge, using geometry and physics vocabulary to justify their designs.
- Final product: manila file folder bridge students build using their working drawings. Students weigh their bridges, record the maximum loads, and calculate the strength to weight ratio.
- Written report: students reflect on their designs, their initial thoughts, what physics and geometry they used, what contributed to its collapse, and how they would change it if they were to build it again.

Unit 3: Unit 3 Solar Energy

- Written proposal: describing initial design of a solar water heater, including a scale drawing, a cost spreadsheet, and justification as to why the design works.
- Interim presentation: oral presentation investigating the past, present, and future of solar energy. Oral presentation skills are a focus.
- Benchmark competition: students test their initial designs and measure water temperature over time.
- Reflection: after graphing their results from the benchmark competition and discussing the results as a class, students describe what they learned from comparing their water heaters to those of their classmates.
- Working drawings: students redesign their solar water heaters and sketch a scaled drawing with lengths and angles labeled.
- Final product: students build and test their new solar water heaters and graph the results.
- Oral presentation: students describe their design, using physics and geometry vocabulary to describe its advantages. Also, students show their results to the class.

- Written report: students describe the process they went through in designing their solar water heaters, the physics and geometry used, and how they would change it if they were to redesign them.

Unit 4: Windmills

- Journal: online blog chronicles the students' experience through design process, including text, drawings, and photos.
- Quizzes: on Ohm's law, rotational kinematics, and arc lengths.
- Benchmark competition: students design, build, and test a turbine to raise a light weight and a heavy weight.
- Final product: students redesign their turbines to create the most electric current.
- Interim presentation: students describe the process they went through to come up with their final design and the physics and geometry learned along the way.
- Oral presentation: students describe the winning design in terms real-life application, and what feature could be improved upon.

Unit 5: Archimedes Screw

- Quizzes: on potential energy, similar triangles, and trig functions.
- Written report: students research the historical context, present applications, and future possibilities of the screw pump.
- Written proposal: students justify their designs, including scaled drawings and a list of materials and costs.
- Final product: students build a working screw pump model.
- Oral presentation: students describe their initial thoughts in designing their screw pumps, the geometry and physics considered, and how they could improve their designs.

Unit 6: Telescopes

- Quizzes: on sectors, arc lengths, similar triangles, and ray-tracing.
- Benchmark competition: students build a single lens or mirror device.
- Written proposal: students describe their designs for an optical instrument and its purpose, includingude scaled drawings and a materials list.
- Final product: students build their proposed optical instrument.
- Oral presentation: students describe the purpose of their designs and the physics and geometry involved.
- Written report: students compare and contrast the various optical instrument inventions constructed by the class.

Unit 7: Roller Coaster

- Written proposal: students describe the roller coaster they have designed, including sketches and material lists.
- Benchmark competition: students build prototype roller coasters and display them.
- Written report: students compare their designs to a peer's and record the differences, advantages, and disadvantages.
- Interim presentation: students give a brief history of roller coaster designs and tie it together with current technology of roller coasters.
- Final product: students redesign roller coasters and build a new model.
- Oral presentation: students describe their roller coasters, what physics and geometry is involved, and why the roller coaster should be built.

Unit 8: The Energy Efficient House

- Written proposal: include scaled drawings, justification of model, and materials and cost spreadsheet for full-size construction of an energy efficient home.
- Benchmark competition: students construct a model house with a single layer of insulation and measure the temperature inside and out.
- Working drawings: students redesign the house based upon findings of lab activities.
- Final product: students construct a model showcasing the energy efficient design of a home.
- Oral presentation: students present a website or power-point advertising an energy efficient home they have designed.
- Written report: students explain the features of the home they designed and the physics and geometry contributing to the energy efficiency.

Unit 9: Building an Instrument

- Quizzes: n harmonics, volume, and surface area.
- Written proposal: students define the function, design, and type of instrument they are building. Also, they must include detailed drawings and a materials/cost analysis.
- Benchmark competition: students build a prototype instrument.
- Written report: students analyze their initial designs and propose improvements to the designs, relating it to physics and geometry concepts.
- Final product: students re-build their instruments after testing their prototypes.
- Oral presentation: the final presentation of their instruments and a discussion of how their instruments function in terms of physics and geometry.

Unit 10: Vehicle Efficiency

- Journal: students record their findings throughout this unit.
- Quizzes: on perimeter, proofs, and torque.
- Benchmark competition: students build and test a mousetrap car.
- Written proposal: students describe how they can improve their mousetrap cars, including scaled drawings and a materials list.
- Final product: students build and test their re-designed mousetrap cars.
- Oral presentation: students describe their car designs and the physics and geometry involved.
- Written report: students describe their design processes and the physics and geometry involved.
- Course assessments by type
- Formative written proposal (for Units 1, 2, 3, 5, 6, 7, 8, 9, and 10)
- Benchmark competition (for Units 1, 3, 4, 6, 7, 8, 9, and 10)

- Quizzes (for Units 2, 4, 5, 6, 9, and 10)
- Working drawings (for Units 2, 3, and 8)
- Interim presentation (for Units 2, 3, 4, and 7)
- Reflection (for Unit 3)
- Journal (for Units 4 and 10)
- Written report (for Units 5, 7, and 9)
- Summative
- Final product (for each unit)
- Oral presentation (for each unit)
- Written report (for Units 1, 2, 3, 6, 8, and 10)