T&E Express

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Course Introduction to Engineering Design (IED)

<u>Strand:</u> Nature of Science & Engineering

<u>Sub-strand:</u> "Engineering design is an analytical and creative process of devising a solution to meet a need or solve a specific problem."

Science Standard being addressed

9.1.2.2

Science Standard and Benchmarks

9.1.2.2.1 Constraints on Designs

9.1.2.2.2 Using Models in Designing

Math Strand and Substrand being addressed:

<u>Strand:</u> *Geometry & Measurement*

<u>Sub-Strand:</u> *"Calculate measurements of plane and solid geometric figures; including volume, mass, surface area and density*

Math Standard being addressed

9.3.1A

Math Standard and Benchmarks

9.3.1.1 Surface Area & Volume

9.3.1.5 Estimates & Accuracy

Correction to AAAS Atlas:

Science - 9.1.2.2

<u>AAAS Atlas Benchmark(s):</u>

The Mathematical World (Shapes):

- The more parts and connections a system has, the more ways it can go wrong. Complex systems usually have components to detect, back up, bypass, or compensate for minor failures. 3B/H5

Math - 9.3.1A

AAAS Atlas Benchmark(s):

The Nature of Technology (Design & Systems)

- The Mathematical World (Shapes):The position of any point on a surface can be specified by two numbers. 9C/H3b

Essential Understandings/Big Ideas:

- The Design Process- This is a "culminating unit" the students have learned the various parts of the design process in other units. They will now put them all together in this unit.
- Innovation vs. Invention - this unit is intended to have student practice innovation. It is okay if students have trouble being totally original, especially in how products and materials are generally put together. Encourage students to see what is out there for similar projects.
- 3D Printing-This unit will allow students the ability to fully realize step 4 (Construct and Test a Prototype) through the use of a 3D Printer

Misconceptions:

Student Misconceptions:

- *Students often have an abstract or simplified view of assembling and geometrically constraining components in a CAD assembly. Reviewing, demonstrating, and showing repeated reminders of how points, lines, and planes work together in 3D is critical.*
- *Locating holes mathematically, whether it be linear dimensions or concentric reference, is difficult and not natural for many students. Supplementing the project with some practice designs containing many holes with specs is helpful.*

Teacher Resources:

Teacher Notes

- This project is meant as a final project. This project can be broken down into smaller steps and also be taught as a unit, while applying a broader list of concepts like drawing types, the design process, etc.

- The following is a list of vocabulary terms that the student has been introduced to throughout the course.

Summary Vocabulary

Key Term	Definition
Annotate	To add explanatory notes to a drawing.

Assembly	A group of machined or handmade parts that fit together to form a self-contained unit.
Assembly Drawing	A drawing that shows parts of an item when assembled.
Cartesian Coordinate System	A rectangular coordinate system created by three mutually perpendicular coordinate axes, commonly labeled X, Y, and Z.
Component	A part or element of a larger whole.
Computer-Aided Design or Computer-Aided Drafting (CAD)	1. When used in the context of design: the use of a computer to assist in the process of designing a part, circuit, building, etc. 2. When used in the context of drafting: the use of a computer to assist in the process of creating, storing, retrieving, modifying, plotting, and communicating a technical drawing.
Degree of Freedom	The variables by which an object can move. In assemblies, an object floating free in space with no constraints to another object can be moved along three axes of translation and around three axes of rotation. Such a body is said to have six degrees of freedom.
Design Brief	A written plan that identifies a problem to be solved, its criteria, and its constraints. The design brief is used to encourage thinking of all aspects of a problem before attempting a solution.
Design Statement	A part of a design brief that challenges the designer, describes what a design solution should do without describing how to solve the problem, and identifies the degree to which the solution must be executed.
Extrusion	1. A manufacturing process that forces material through a shaped opening. 2. A modeling process that creates a three-dimensional form by defining a closed two-dimensional shape and a length.
Function	1. A relationship from one set (called the domain) to another set (called the range) that assigns to each element of the domain exactly one element

	of the range. 2. The action or actions that an item is designed to perform.
Geometric Constraint	Constant, non-numerical relationships between the parts of a geometric figure. Examples include parallelism, perpendicularity, and concentricity.
Marketing	The promotion and selling of products or services.
Mock-up	A model or replica of a machine or structure for instructional or experimental purposes. Also referred to as an Appearance Model.
Model	A visual, mathematical, or three-dimensional representation in detail of an object or design, often smaller than the original.
Origin	A fixed point from which coordinates are measured.
Physical Model	A physical representation of an object. Prototypes and appearance models are physical models.
Plane	A flat surface on which a straight line joining any two points would wholly lie.
Prototype	A full-scale working model used to test and improve a design concept by making actual observations and necessary adjustments.
Revolution	Creating a 3D solid or surface by revolving a 2D shape about an axis.
Rotation	Turning around an axis or center point.
Round	A rounded exterior blend between two surfaces.

Scale Model	An enlarged or reduced representation of an object that is usually intended for study purposes.
Solid	A three-dimensional body or geometric figure.
Solid Modeling	A type of 3D CAD modeling that represents the volume of an object, not just its lines and surfaces.
Subassembly	An assembled part that is a part of a larger assembly.
Translation	Motion in which all particles of a body move with the same velocity along parallel paths.
Working Drawings	Drawings that convey all of the information needed to manufacture and assemble a design.

Vignette:

Day(s) 1: Introduce Design Brief

Instructor will break students into teams of 3-4. Use any method you wish. Present the **Design Brief** and have each team establish "Team Norms". This should include everything from rules for brainstorming , how meetings are conducted to haw decisions will be made.

Day(s) 2-4: Generate Concepts

This is the research phase. Each student should do their own research of what is out there. All info found should be recorded in Engineering Notebooks. Include written notes, sketches, photos, printouts. Detailed measurements are vital. Students will also have to explore the world of standardized parts and fasteners available to anyone. Having a Grainger catalog on hand or assigning a trip to a hardware store is key. No teacher will have on hand samples of all the standard components and fasteners that exist.

- **http://littlegreatideas.com/stabilizer/diy/**
- **http://www.grainger.com/category/raw-materials/ecatalog/N-bis**
- **http://www.grainger.com/category/fasteners/ecatalog/N-bi6**
- **http://www.ted.com/talks/marcin_jakubowski.html**

Each team member will then Produce 2 designs to solve the problem. These designs can be completely original or innovate from an existing design. These designs should utilize Stock Parts and also have at least 1 part that is an original.

Day(s) 1-2: Reverse Engineering of Stock Parts

Students will reverse engineer all stock parts for at least one of their design solutions

Day(S) 1 Develop a Solution
Students will share their design ideas will the team. They put together a Decision Matrix to choose the solution they will fully develop.

Day(s) 3-5 3D CAD Lab Time - Parts, Assemblies, & Drawings

This step of the process is heavily based on resources, labs, comfort level of the instructor, cost, etc. At the very least, students should have their designs built with separate virtual 3D CAD parts and then assembled. Furthermore, if students can locate standard parts as downloads to speed up the process, then great! On the flip side, if the project is structured more hands-on, and stock parts can be brought in to be reverse-engineered, all the more better.

Days(s) 11-16 3D Printing and Project Assembly

According to the design brief, at least 1 or 2 parts of the design had to be entirely custom. These parts should be printed on the 3D printer. The printed parts and the stock parts will then be assembled.

- <u>Calculating Printing Cost's:</u> the 3D printer uses a cost per cubic unit. Students must calculate the volume of their parts to be printed. Structure appropriate activities to teach volumes/surface areas.
- <u>Coating's and Dipping's:</u> to teach surface areas, the practical application of having their custom part(s) either injection molded, machined, or cast would possibly require some sort of coating. This may be paint for coloring or a protective finish. Apply this concept by requiring the calculation of not only the surface area of 1 part, but if 100 or 1,000 parts were manufacturing. What would that coating cost?

Day(s) 4-6 Testing and Evaluating the Prototype

Students will observe and test the prototype and record the results**.** After evaluating the results, students will be able to make design revisions. And then modify the prototype.

Once this is done, they will retest the prototype, record the results and prepare a presentation for the class.

Day(S) 2 Team Presentations

The Water Sample Collector Design Brief

Client: Water and Wetland Restoration Inc. (WWRI)

Target Consumer: Companies and government agencies involved in the restoration of surface waters

Designer: ___________________________________

Problem Statement:

When polluted surface waters (wetlands, lakes, rivers etc.) are being cleaned up or restored to non polluted levels, water sample are taken frequently and tested. Samples have to be taken at various depths. The desire is to have a device that is simple to use and allows for sample to be taken form depths ranging from 0 to 30 feet.

Design Statement:

WWRI would like to create a water sample collector. Design, build, test, and document a product that is light, portable, and easy to use.

Design Constraints:

1. Must be able to collect sample from 0 to 30 feet deep.

2. Must be able to be stored in a 3 liter space.

3. Must not require tools, other than a pliers or screw driver, to assemble or use.

4. Must collect a sample size of 1 liter.

5. Must be easy to clean between samples.

Additional Instructional Resources

- These are embedded into the Vignette above….

Assessment:

An invaluable way for students to be assessed is to test their test their physical design, present their design, and then have them address whether or not their designed failed. If the design failed in its intended function, then how would they change it? What would they do differently? Any self reflection type of activities addressing these essential questions is ideal.

Differentiation:

Gifted and Talented:

These students can be invaluable as student helpers/mentors. Their level of understanding and ability is elevated when they have to explain to others how to do the more advanced operations, etc. Furthermore, if they are moving along quite quickly - having them demonstrate some items is great.

Special Education:

Creativity can be difficult for some of the brightest students in high school. If students are having difficulty with a starting point in their design, it may be worthwhile to simple change the design brief where their starting point is pre-determined. For example, you could provide them with a preset size of ¼" aluminum stock that the MUST build the chassis from instead of letting them do the chassis from scratch.

English Language Learners

The majority of the vocabulary can be difficult. Having multiple visuals or demo's is key, and taking time to stress those vocabulary words is good practice.

Parents and Administration:

Administrative/Peer Classroom Observation

Students Are: (descriptive list)	**Teachers Are:** (descriptive list)
Sketching & Brainstorming Designs	Facilitating brainstorming activities and presenting rules of brainstorming
Calculating volumes, surface areas, mass & density	Providing formulas and examples
Applying geometric constraints in 3D CAD	Demonstrating part/assembly interactions and geometric constraining
Building, Testing, and refining their designs	Teaching machine/tool safety, providing safety glasses, tool demo's, threading holes with taps, etc.
Researching designs, components, etc.	Assigning minimum research requirements of documentation, facilitating exploration of existing stock components and fasteners.

Parent Resources:

www.makerbot.com
www.stratasys.com
http://www.asee.org/
www.pltw.org
www.ted.com
www.ptc.com
www.autodesk.com
http://www.ptc.com/company/community/education/university/ptc-design-challenge/
http://www.solidworks.com/
http://www.stcloudstate.edu/teexpress/

References:

http://www.bhphotovideo.com/c/product/893611-REG/rigwheels_iw04_68mm_inline_skate.html

- Vendor for quality wheels with bearings at a reasonable price

http://autodeskmfg.typepad.com/blog/2011/02/standard-parts-content.html

- information on incorporating and obtaining pre-made stock CAD parts

http://grabcad.com/

- free source of stock CAD parts and community for sharing CAD parts