FLINN STEM

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IMSA Fusion — Engineering: Design & Build STEM Curriculum Module

Table of Contents

Curriculum Overview

Notes

Engineering: Design & Build focuses on investigating engineering. Student led teams conceptualize, build, test and acquire knowledge while becoming familiar with the engineering design process. Using an open-ended inquiry approach students are able to foster their creativity. Students learn to apply multiple skills and develop the habits of innovators.

Students are encouraged to think about needs, requirements, and alternatives as they progress throughout the curriculum. Additionally, students consider materials, energy, inputs and outputs. Unit lessons combine generative, analytical, synthesis, and evaluative thinking to allow students to finalize their design choice and initiate construction.

Curriculum Objectives

The students will:

- identify a problem, materials and constraints
- brainstorm solutions
- research and share solutions
- design and construct a prototype
- modify and retest a design
- reflect and discuss results

Logistics

Class age/size: All lessons are designed for twenty 4th-5th grade students.

Materials: See insert for each individual activity within this unit.

Time: See individual activities for suggested times.

Location: All activities may be taught in a classroom. There may be a few instances where it may be advantageous to take a walking tour of the school. Water will be used in the Build-A-Boat lesson.

Notes

Standards

Next Generation Science Standards Scientific and Engineering Practices

1. Asking questions and defining problems (SEP1)
2. Developing and using models (SEP2)
3. Planning and carrying out investigations (SEP3)
4. Analyzing and interpreting data (SEP4)
5. Using mathematics and computational thinking (SEP5)
6. Constructing explanations and designing solutions (SEP6)
7. Engaging in argument from evidence (SEP7)
8. Obtaining, evaluating, and communicating information (SEP8)

Next Generation Science Standards

4-PS3-1. Use evidence to construct an explanation relating the speed of an object to the energy of that object.
4-PS3-4. Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.
5-PS2-1. Support an argument that the gravitational force exerted by Earth on objects is directed down.
3-5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
3-5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.
MS-PS2-2. Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.
MS-PS3-2. Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.
MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.
MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

Notes

Common Core State Standards Mathematical Practices

MP1 Make sense of problems and persevere in solving them.
MP2 Reason abstractly and quantitatively.
MP4 Model with mathematics.
MP5 Use appropriate tools strategically.
MP6 Attend to precision.

Common Core State Standards

4.MD. A2 Use the four operations to solve word problems involving distances, intervals of time, liquid volumes, masses of objects, and money, including problems involving simple fractions or decimals, and problems that require expressing measurements given in a larger unit in terms of a smaller unit. Represent measurement quantities using diagrams such as number line diagrams that feature a measurement scale.
5.G.A.2 Represent real world and mathematical problems by graphing points in the first quadrant of the coordinate plane, and interpret coordinate values of points in the context of the situation.
6.NS.C.5 Understand a rational number as a point on the number line. Extend number line diagrams and coordinate axes familiar from previous grades to represent points on the line and in the plane with negative number coordinates.
6.RP.A2 Understand the concept of a unit rate a/b associated with a ratio a:b with $b \neq 0$, and use rate language in the context of a ratio relationship. *For example, "This recipe has a ratio of 3 cups of flour to 4 cups of sugar, so there is 3/4 cup of flour for each cup of sugar." "We paid $75 for 15 hamburgers, which is a rate of $5 per hamburger."*[1]
6.RP.A3.B Solve unit rate problems including those involving unit pricing and constant speed. *For example, if it took 7 hours to mow 4 lawns, then at that rate, how many lawns could be mowed in 35 hours? At what rate were lawns being mowed?*
6.SP.A3 Recognize that a measure of center for a numerical data set summarizes all of its values with a single number, while a measure of variation describes how its values vary with a single number.
6.SP.B5.C Giving quantitative measures of center (median and/or mean) and variability (interquartile range and/or mean absolute deviation), as well as describing any overall pattern and any striking deviations from the overall pattern with reference to the context in which the data were gathered
8.SP.A.1 Construct and interpret scatter plots for bivariate measurement data to investigate patterns of association between two quantities. Describe patterns such as clustering, outliers, positive or negative association, linear association, and nonlinear association.
RI.5.4 Determine the meaning of general academic and domain-specific words and phrases in a text relevant to a *grade 5 topic or subject area*.
RI.5.10 By the end of the year, read and comprehend informational texts, including history/social studies, science, and technical texts, at the high end of the grades 4-5 text complexity band independently and proficiently.

Notes

W.5.10 Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.
W.6.1 Write arguments to support claims with clear reasons and relevant evidence.
SL.5.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on *grade 5 topics and texts*, building on others' ideas and expressing their own clearly.
RST.6-8.3 Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.
RST.6-8.7 Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

Unit Summaries and Objectives

Notes

The ***Introductory Activity*** gets at students perceptions and understanding of the field of engineering, what engineers do at work, and what tools they use.

Build-A-Boat is a lesson that focuses on the scientific inquiry process. Students experience the concept of buoyancy. They explain why some objects sink and other objects float. Ultimately, they design and build an aluminum foil boat to hold a maximum load.
The students will:

- **understand and practice scientific inquiry: questioning, predicting, observing, recording and interpreting data, and communicating results**
- **experience the concept of buoyancy**
- **explain in their own words why some objects sink and other objects float**
- **design and construct an aluminum foil boat to hold a maximum load**

You've Got Mail is designed to enhance students' problem solving skills and team work. This lesson specifically focuses on the understanding of package design: planning, construction, testing and evaluation. Students play the role of "engineers" as they design and safely ship a package.
The students will:

- **gain knowledge of product planning**
- **practice the engineering design process**
- **explore and experiment with ideas, materials, technologies and techniques**
- **assess solutions to a design challenge**
- **experience working in groups and problem solving**

Hot Rod Hamster is a lesson that focuses on the scientific inquiry process. Students become familiar with the engineering design process by using it to brainstorm solutions to a problem and then build, test, and refine their prototype.
The students will:

- **become familiar with the design process by using it to brainstorm solutions to a problem and then build, test, and refine their prototype**
- **communicate design strategies for efficient, gravity powered cars including size, mass, and speed**
- **be financially responsible and purchase materials for their car within predetermined budget constraints**

Let It Roll is a lesson where students design and build a ski jump to launch a ball that will travel a maximum distance to a target. In addition, students design and build a foam insulation roller coaster track that demonstrates the laws of motion.
The students will:

- **design and build a ski jump to launch a ball that will travel a maximum distance to a target**
- **design and build a foam insulation roller coaster track that demonstrates the laws of motion**
- **differentiate energy as potential or kinetic**

Notes

Catapult Wars is a lesson where students design and build a catapult. Students test, evaluate and discuss possible improvements to their designs. This lesson focuses on student understanding of motion and forces. In addition, students become aware of accuracy and precision. Ultimately, students will understand that a catapult is a type of simple machine called a first-class lever.

The students will:

- **design and build a catapult**
- **test and evaluate effectiveness of their designs**
- **discuss possible improvements to their designs**
- **communicate experimental results**
- **understand motion and forces**
- **become aware of accuracy and precision**
- **understand that a catapult is a type of simple machine called a first class lever**

FUSION Five engages participants in a case study. A series of engineering challenges to be solved with limited supplies await students.

The students will:

- **identify relationships among the concepts of lever, fulcrum, load, and effort**
- **use simple machines to solve problems**
- **understand air resistance**
- **work in groups to design solutions to problems**

Something Borrowed explores a different aspect of engineering. Students test and assess materials' capabilities to repel water and stains while learning about the inspiration for these ideas – nature. After learning about biomimicry, students develop a new product.

The students will:

- **understand the concept of hydrophobic**
- **be introduced to the field of biomimetics**
- **preform water resistance and stain resistance tests**
- **design a nature inspired product**

In the culmination activity, ***Applications of Engineering Design***, students apply what they have learned about simple machines and engineering design to build a Rube Goldberg machine.

The students will:

- **apply what has been learned about simple machines and engineering design to build a Rube Goldberg machine**

Notes

For those wishing to extend the curriculum, ***Wheeling the Weight Around*** is a lesson where students physically construct a scale model of a working block and tackle system. They develop a deeper understanding of the way force can be multiplied at the expense of distance. Students use what was learned through simulation to answer challenging questions.

The students will:

- **physically construct a scale model that simulates the workings of a real block and tackle system**
- **develop a deeper understanding of the way force can be multiplied at the expense of distance**
- **use what was learned through simulation to answer the challenge question**

Another opportunity to extend learning is ***Topsy Turvy***--a lesson where students find the center of mass of a meter stick. In addition, students explore the use of a lever as a simple machine. Finally, students apply the dynamics of levers in real-world situations.

The students will:

- **find the center of mass of a meter stick**
- **explore the use of a lever as a simple machine**
- **apply the dynamics of levers in real-world situations**

Notes

Introductory Activity

Objectives
The students will:
- draw their perception of what an engineer is
- reflect on their perception versus actual engineering professions

Background Information
Introductory Activity is a lesson that focuses on the student's perception of what is an engineer.

Inquiry Overview
Students will depict their thoughts of what an "engineer" is by constructing a drawing. Students will reflect on their perceptions. At the end of the unit, students will revisit their drawings and you may choose to have them redraw "engineer" at the end.

Activity:
- 30 Minutes: Introduction and Drawing
- 40 Minutes: Sharing
- 20 Minutes: Debrief

Materials
For Each Student
- Student Handout

For Students to Share
- Colored Pencils/Markers

Students are asked to draw an "engineer doing engineering work."

By having students draw what they imagine an engineer to be and do you will employ an abstract method of determining what their perceptions are of the field.

After debrief, you may wish to display the drawings throughout the curriculum, revisit the drawings and initial perceptions, and have students modify or make new drawings at the end of the curriculum.

Debrief – Large Group
After the students have had ample time to complete their drawing, discuss the following points with the group.
- What are some similarities you noticed among the drawings?
- As a class, brainstorm a list of actions performed by an engineer.
- As a class, brainstorm a list of objects used by engineers
- What are some problems that engineers could help solve?

Build-A-Boat

Notes

Objectives

The students will:

- understand and practice scientific inquiry: questioning, predicting, observing, recording and interpreting data, and communicating results.
- experience the concept of buoyancy
- explain in their own words why some objects sink and other objects float
- design and construct an aluminum foil boat that can hold a maximum load

Standards

SEP1	SEP8
SEP2	MD.A.2
SEP3	G.A.2
SEP4	NS.C.5
SEP5	SP.A.1
SEP6	MP2
SEP7	MP5

Background Information

Build-A-Boat, is a lesson that focuses on the engineering design process and the concept of buoyancy.

Buoyancy is the upward force a fluid puts on an object less dense than the fluid itself. The buoyancy of any object in water depends on the amount of space the object takes up or its volume and density--how much mass it has per unit of volume--compared to the density of the water. Objects with large volumes and low densities tend to be quite buoyant. For example, ships are buoyant in spite of the fact they're often made out of metal. That's because the hulls of ships are usually filled with air, which is less dense than water

When an object is placed in water there is a buoyant force that pushes up on it. The strength of the upward force is equal to the weight of the water that was moved out of the way or displaced. As a result, if an object moves a small amount of water out of the way, then the weight of the small amount of water is small, thus the buoyant force is small. In contrast, if the object moves a large amount of water then the weight of the water is large and there is a large buoyant force pushing up on it.

Inquiry Overview

Throughout this lesson, students are learning how to question, predict, observe, record and interpret data, as well as communicate results, all the while learning and experiencing the effects of buoyant forces.

Notes

Advanced Preparation

Bring in tubs for water and decide how/where tubs will be set up for boat testing.

Activities:

Initial Exploration

- 10 Minutes: Introduction of Activity
- 40 Minutes: Design and Build
- 10 Minutes: Debrief

Big Load

- 10 Minutes: Introduction of Activity
- 40 Minutes: Design and Build
- 10 Minutes: Debrief

Biggest Load

- 10 Minutes: Introduction of Activity
- 90 Minutes: Design and Build
- 20 Minutes: Debrief

Materials

For the class

- Tub(s) of water
- Pennies
- Scissors
- Scale
- Dry rice
- Graduated Cylinder
- Graph paper
- Ruler
- Computer with Internet Access

For 2 students per group

- Aluminum foil
- Tape

Students are arranged in groups of two. Each pair will receive the same set of materials. Teams may only use the materials and quantities provided. Introduction activities provide students the opportunity to explore and experiment with density and buoyancy. Following the initial exploration activities, students will progress to designing their boats. Allow teams enough time to research, plan and construct their boats. Before testing, collect all boats (be sure that students label which boat is theirs') and have each team estimate how many pennies they think that their boat will hold. During testing select one student per team to add the pennies. Use your own judgment as to how long to wait in between adding more pennies. Do not allow students to just dump pennies on their boats as this may cause an unfair advantage.

Teacher tip: As the maximum load nears you may want to slow down the penny addition and allow more time for observations.

Teacher Suggestion: You may choose to have multiple "tubs" of water set up around the classroom. These tubs could have specific and/or creative names such as "Lake Michigan" or "Fusion BAY"

When the time is right you may choose to show the students the following video clip from PBS. The video clip describes in simple terms buoyancy and what happens to the buoyant force if the boat is sinking. Link:
http://www.pbs.org/media/wgbh/designsquad/animations/202_bouyancy_hi.mov

Notes

Debrief – Large Group

- How did you place the pennies in your boat? Did you have a strategy? Why did you use this strategy?
- What would you change if you had to do this challenge again?
- What was the most effective boat design? Why?

Extensions

- Build and test several styles of boats using the same amount of aluminum foil.
- Measure and record level of water displacement as pennies are added.
- Use other materials, such as, wax paper, plastic, or cardboard to construct the boat.
- Use other materials to place inside the boat, such as gummy bears or sour patch kids.
- Cardboard boat race: Use recycled cardboard to construct a boat that would hold a heavy object (for example: a brick or cinder block). Race them in a local pool.
- Wrap pennies with foil and drop them into containers of water with various temperatures. Watch as the pennies drop at different rates.
- Build a boat using straws and plastic wrap. Link: http://pbskids.org/designsquad/parentseducators/resources/watercraft.html

Resources

Interesting Article: http://www.sciencenewsforkids.org/2011/05/ants-aweigh/

Build-A-Boat

TRY IT & REPORT

Materials Needed: Two pieces of aluminum foil (15 centimeters by 15 centimeters) and one tub of water.

Shape a piece of aluminum foil into a design that will float. Draw the shape below.

Shape a piece of aluminum foil into a design that will sink. Draw the shape below.

When your team is ready, take the shapes to the tub and try them out.
What happened? Was it what you expected? Write your response below.

Build-A-Boat

PROCEDURE:

1. Shape a 15cm by 15cm piece of aluminum foil into the designs listed in the table.
2. Use a new 15cm by 15cm piece for each foil shape.
3. When your team is ready, take the shapes to the tub and observe the outcome.

TRY IT: Does it sink or float?

FOIL SHAPE	My Prediction!	What do you observe?		Why do you think that is happening?
		SINK	FLOAT	
FLAT				
FLAT WITH PENNY ON TOP				
BALL				
BALL WITH PENNY IN MIDDLE				

Build-A-Boat

DESIGN: Use the materials provided to design a boat that can hold **at least** 10 pennies.

MATERIALS:

For the class	For each student group
Tub (Clear)	Pennies
Water	1 Aluminum foil sheet (15cm by 15cm)
Scissors	

PLAN & SKETCH:

How will your boat look? Sketch your plan for building the boat in the space below.

RESULTS: When your team is ready, take the shape to the tub and test its performance. What happened? Was it what you expected? Write your responses below.

Build-A-Boat

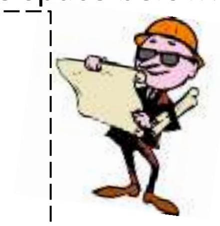
CHALLENGE: How can your team design a "boat" that will hold the **most** pennies using the materials provided?

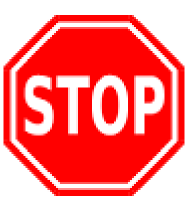
MATERIALS:

For the class	For each student group
Scale	Pennies
Tub (Clear)	1 Aluminum foil sheet (15cm by 15cm)
Water	Scissors

PLAN & SKETCH:

We will consider the following factors in our boat design. Sketch your boat in the space below.





WEIGHT: Your team needs to come up with a plan to answer the following question –
How much weight did the boat hold? Explain how your team will do this using pennies as cargo.

Build-A-Boat

RESULTS: When your team is ready, take the shape to the tub and test the boat. What did you notice as you added the pennies? Describe your results below.

CALCULATIONS:

Calculate the total weight of the pennies your boat held? Show your work!

Build-A-Boat

CLASS DATA TABLE:

Record your maximum capacity on the class data table below.
Collect data from the entire class. Use this data to help you decide

TEAM NAME	MAXIMUM # PENNIES HELD

Build-A-Boat

Class Observations and Data		
° Boat Drawing ° Number of Pennies ° Weight Held ° Other Observations	° Boat Drawing ° Number of Pennies ° Weight Held ° Other Observations	° Boat Drawing ° Number of Pennies ° Weight Held ° Other Observations

Build-A-Boat

DISCUSSION:

1. How did you place the pennies in your boat? Describe your strategy.

2. What would you change about your boat and/or penny placement strategy if you were able to do this challenge again? Explain your ideas.