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Introducing Optimization in Elementary Education: a Precursor to Multibody Dynamics (Resource Exchange)

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I am an early-career engineering education scholar and educator. I hold a B.S. in Chemical Engineering (with Genetics minor) from Iowa State University, and an M.S. and Ph.D. in Chemical Engineering from The Ohio State University. My early Ph.D. work focused on the development of bacterial biosensors capable of screening pesticides for specifically targeting the malaria vector mosquito, Anopheles gambiae. As a result, my diverse background also includes experience in infectious disease and epidemiology, providing crucial exposure to the broader context of engineering problems and their subsequent solutions. These diverse experiences and a growing passion for improving engineering education prompted me to change career paths and become a scholar of engineering education. As an educator, I am committed to challenging my students to uncover new perspectives and dig deeper into the context of the societal problems engineering is intended to solve. As a scholar, I seek to not only contribute original theoretical research to the field, but work to bridge the theory-to-practice gap in engineering education by serving as an ambassador for empirically driven educational practices.

Kaela M Martin

Kaela Martin is an Associate Professor of Aerospace Engineering at Embry-Riddle Aeronautical University, Prescott Campus. She holds a B.S. in Aerospace Engineering from Iowa State University, a B.S. in Mathematics from Iowa State University, and a M.S. and Ph.D. in Aeronautical and Astronautical Engineering from Purdue University. Her research focuses on bridging the theory-to-practice gap in engineering education through new educational techniques.

Davide Guzzetti

Since 2019, Dr. Davide Guzzetti is an assistant professor in the Department of Aerospace Engineering at Auburn University. Dr. Guzzetti's research focus is astrodynamics and space mission design in complex space environments. He obtained a PhD in astrodynamics from Purdue University in 2016, and he holds a Master degree in space engineering from Politecnico di Milano, Italy. He is also an alumnus of the Italian honor society Alta Scuola Politecnica.

Introducing Optimization: Quarter Activity

Grade Level: 3-5

NGSS ED 3-5 ETS1 v-5

Time for Activity ~20 minutes

Teacher/Adult Supervision Required

Optimization is the process of creating the most effective design under certain constraints and conditions. Engineers use the concept of optimization to create functional and successful designs that also save money and use the least amount of materials. The concept of optimization can also be seen in fields such as computer science, medicine, marketing, and architecture! In this activity, participants experiment with optimizing the design of an aluminum foil "boat" to hold as many quarters as possible before the weight causes it to sink. The necessary supplies can be found around the house!

Introduction: Soup Thought Experiment

To better understand the concept of optimization, imagine that you are about to eat a bowl of your favorite soup. What utensil do you choose to eat with? Most would choose a spoon. But why is it more efficient to eat soup with a spoon than a fork? What sorts of traits does a spoon have that a fork or a knife does not? Logically, the spoon does not have gaps for the soup to fall through and can hold the most liquid. It is the best tool for the task of eating soup.

Now imagine that there are two sizes of spoon to choose from: a teaspoon or a ladle. Which tool would be most effective for eating a bowl of soup? The teaspoon would be the more reasonable choice, as you probably couldn't fit the ladle in your mouth. However, the ladle would be the best tool for transferring your serving of soup from the pot on the stove to your bowl. Using a small teaspoon would take much too long. The two tools are suited best for different tasks.

Although this thought experiment may seem silly, these are the types of questions that engineers must investigate when creating designs and choosing materials to work with. They must be able to determine what tool will complete their desired task in the most efficient way; just like choosing the most efficient utensil to eat your favorite soup. In this activity, you will determine which tool will be the most effective at completing your task: to create a boat that is the most effective at holding weight above water.

Next Generation Science Standards

3-5-ETS1 Engineering Design:

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.

Note for Teachers!

For some added fun, allow your students to try "scooping" the water used in the activity with spoons, forks, butter knives, or other classroom tools!

Quarter Activity

Materials

- Water
- 8x10'' piece of printer paper
- Pen, pencil and paper (to keep tally)
- Aluminum Foil
- Quarters (2 rolls)
- Deep bowl or container
- Invisible Tape

Procedure: Part One

1. With your piece of paper and invisible tape, construct a boat that you believe will be able to float on the water and hold weight. An example design can be seen in the upper right corner. Feel free to get creative with your structure!
2. Place the paper boat in the bowl and allow it to float on the surface of the water. Gently place a quarter in the center of the boat and observe what happens.
3. Continue adding quarters, one at a time, and keep a tally on a separate piece of paper of how many quarters the boat can hold before sinking.
4. Once the boat sinks, remove everything from the water. Make observations as to what worked well in your design and what went wrong.

Part Two: Switching Materials

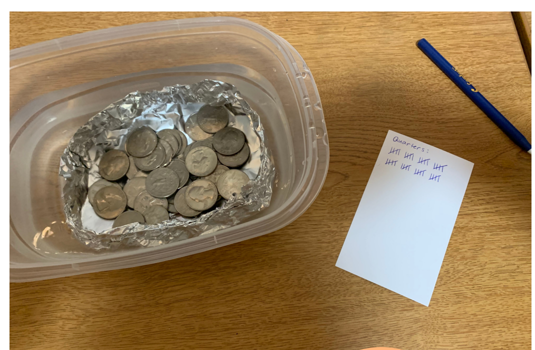
1. This time, build your boat with an 8x11" piece of aluminum foil (about the same size as the piece of paper you used in Part One) and the invisible tape. Think back to the strengths of your paper boat structure as you make your design.
2. Repeat the same steps as above, floating the boat on the surface of the water and tallying the number of quarters that can lay inside until it sinks.

Wrap-up Thoughts

Compare the number of quarters that each of the boats were able to hold. Was one more successful than the other?
Did the material used in Part Two behave differently in the water than the material in Part One?
After observing how the paper and aluminum foil boats behaved during the test, using what you now know about optimization, which material would you consider to be the best tool for this task?

Bad Boat Alert

More than likely, your boat from Part One looks a little bit like the one below: soggy and sunk. The sheet of paper begins to disintegrate in the water, making it not a very effective "tool" for the task. In Part Two, you'll investigate whether a different material is up to the test.



Extensions!

Brainstorm some other materials that would be effective at holding the quarters above water. What types of qualities are important for the materials used in making boats in real life?