float your boat:

making instant design challenges meaningful and relevant

Using instant design challenges to introduce new concepts can lead to a more student-centered learning environment.

Introduction

Engineering design is a core component of technology and engineering education, and although not every student will become an engineer following high school, all students can profit from having engineering design experiences in high school (Apedoe, Reynolds, Ellefson, & Schunn, 2008; Denson & Lammi, 2014; Grubbs & Strimel, 2015; National Academy of Engineering and National Research Council, 2009; Wicklein, 2006). For example, a fundamental purpose of using engineering design is to help students develop critical thinking and team-working skills (Wicklein, 2006), specifically, engineering design that takes the form of an open-ended challenge that requires problem solving. Although there are many types of open-ended design challenges available to cultivate students' cognitive ability, instant design challenges may be employed in technology and engineering education classrooms to contextualize learning for real-world problems. Furthermore, instant design challenges are a quick way of introducing new topics through simulated real-world problems. The purpose of this article is to illustrate how an instant design challenge can be employed in the context of transportation technology.

Instant Design Challenges: Meaningful and Relevant

In an instant design challenge, students are expected to utilize the engineering design process to solve a design problem in a condensed format. Most instant design challenges are formatted to be completed within a single class period—though it is questionable as to whether frequently employed challenges currently being implemented in technology and engineering education classrooms are being delivered in the most effective way possible. Moreover, have these instant design challenges effectively addressed the standards and objectives the instructor sought to meet? Lastly, how could these challenges be adapted to improve student-centered learning in the classroom? Typically, current instant design challenges may only be used to develop a basic set of problem-solving skills or to reinforce a principle that a student has already mastered. Furthermore, the design challenges could also be used to introduce a topic through a student-centered approach without much additional

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effort in terms of intentional planning. For example, consider constructing a straw tower. The objective of the straw tower design challenge should not necessarily be to build the tallest tower possible using the given resources, but rather for students to use their observations to predictably determine how a specific structure can fail, or to see what shapes may best hold the most load. Subsequently, immersing students in an environment that allows them to observe and document the results of testing their prototype provides the first step of feedback necessary to develop their cognition. The second step is for instructors to provide descriptive feedback that informs their learning progression.

Instant Design Challenge: Float Your Boat

The instant design challenge that will be discussed here was created to challenge student thinking regarding the underlying causes of buoyancy. Some high school students have probably heard of buoyancy at some point in their lives, but do not know the factors that influence it. By the end of this activity, students will be able to explain which physical properties of a material or compound structure affect how an object floats.

In the Float Your Boat Challenge, teams of two to three students will design a watercraft capable of holding the most weight possible using only two feet of plastic wrap, ten drinking straws, and a foot of masking tape. It is best to use smaller weights, such as pennies or washers, to help students understand why objects float because it will assist them in understanding that both the surface area of the watercraft and the distribution of the weight relative to the center of gravity are key. At the end of the class period, students will collect and analyze data from their watercraft in order to better understand how characteristics such as surface area and weight affect buoyancy. The Float Your Boat Challenge can comfortably be done in a 90-minute class period or two 45-minute class periods. During the class period(s), students should complete the design process, including at least three tests of their prototype. Table 1 shows an outline of the class period. The standards that align with this instant design challenge are listed in Table 2.

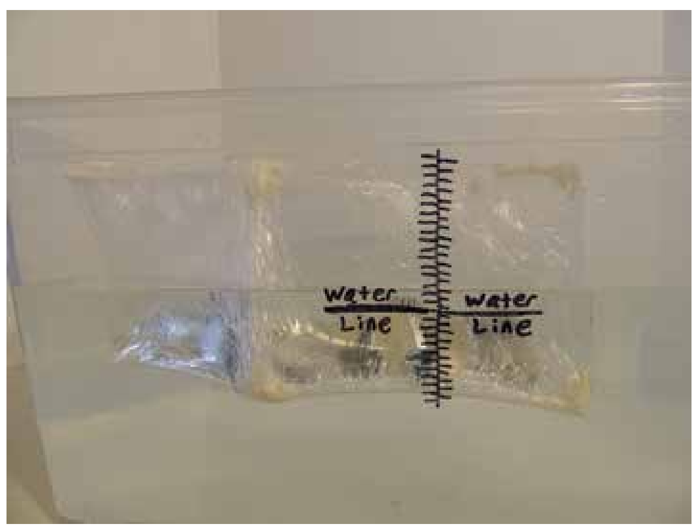
Table 1
Outline of class period. *For two 45-minute class periods, end the first day after one official round of testing.*

Task	Time
Design Challenge Introduction	5 Minutes
Brainstorming	7 Minutes
Selecting the Best Design	5 Minutes
Construction/Testing	23 Minutes
Testing (Official Rounds)	20 Minutes
Analyze Data	8 Minutes
Think-Pair-Share	17 Minutes

Table 2
***Standards Addressed Related to* Standards for Technological Literacy**

***STL* 8.H:** The design process includes defining a problem, brainstorming, researching and generating ideas, identifying criteria and specifying constraints, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype, testing and evaluating the design using specifications, refining the design, creating or making it, and communicating processes and results.
***STL* 8.J** The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.
***STL* 9.K** A prototype is a working model used to test a design concept by making actual observations and necessary adjustments.
***STL* 11.Q** Develop and produce a product or system using a design process.

Before the class period begins, the instructor should ensure that the student materials and testing tanks are ready to go. For the testing tanks, it is recommended to use any clear plastic container that is at least one-foot square. A larger container works best so the watercraft does not accidentally bump the side of the tank. Make graduation marks on the side of the container in sixteenths of an inch increments and fill up the container with at least 3 to 4 inches of water. An easy way to distribute materials to students is to place the straws in a plastic zipper bag. Next, precut the tape and attach it to the outside of the bag. Students will be able to easily remove the tape from the bag, and this will speed up the process of distributing materials to a large number of groups.



The first step in any good engineering design challenge should be the same regardless of whether the task is to build a paper bridge or to develop the next iteration of the Falcon 9 Rocket. No matter how small the challenge, always start by having students brainstorm several different ideas on how they plan to approach

the challenge and select their best idea before receiving any materials. During the concept generation phase of the design process some students will crank out a few ideas in a matter of minutes, and others will slowly consider solutions. To help all students stay on track, one approach is to have a set amount of time for brainstorming instead of a minimum number of ideas to develop. Remind students that the brainstorming phase is not the time to be critical of each other's ideas, but rather, to try to come up with many potential solutions as quickly as possible. As an educator, encourage students to think outside the box, as often these ideas can lead to the best solutions.

Now it is time for the most hands-on part of the design process, creating a prototype. Give students about twenty-three minutes to build and test their designs. During this time give students the opportunity to test their designs and make sure they are watertight. Due to the properties of the plastic wrap once it becomes wet, it may become necessary for some groups to replace their plastic wrap if major design modifications are necessary. Students should not be allowed to trade in any other materials except for the plastic wrap. Not allowing students to trade in materials makes them plan out the design more thoughtfully and forces them to follow the design process to ensure that they will have enough materials for the prototype.

Now that each team has a prototype, they should begin testing their designs and recording the data in their design notebooks. They should perform both a quantitative and qualitative analysis of their watercraft for each of the three trial runs. In any STEM-related field, it is good practice to have multiple data points in an experiment in case one of the trial runs is an anomaly and skews the data. From an engineering standpoint, it is important to show that the prototype can effectively and consistently meet the criteria set forth in the design statement. Data that should be recorded in the student's engineering design journal is listed in Table 3.

Table 3

Topics for Data Analysis

Data Collected	Type of Data
Surface Area of Boat Bottom	Quantitative
Number of Washers Held	Quantitative
Initial Height of Water	Quantitative
Final Height of Water	Quantitative
Height of Boat	Quantitative
Volume of Boat	Quantitative
Describe the placement of the washers in the boat.	Qualitative
How did the boat start to sink/take on water?	Qualitative
What is the geometric shape of the bottom of your boat?	Qualitative

As students are recording the data in their own journals, a master list of data should be written in the front of the classroom; this can be done by hand on the chalkboard or by using an Excel-like program. This will allow students to see how different designs produce different results and come to their own conclusion about what factors influence the watercraft's ability to float.

Once all of the watercraft have been tested, give each group a few minutes to make sure they all have the same data written down in their design journals. As students begin analyzing the raw data, have students use some guiding questions in order to narrow their search on how the quantitative and qualitative data points are related to each other. Some examples of guiding questions can be found in Table 4.

Table 4

Sample Guiding Questions

Which variables have a proportional relationship?
Which variables have an inversely proportional relationship?
Are there any variables that do not have a correlation?
Why do you think the water level rises when more weight is added to the boat?

It is important for students to have time to analyze the information on their own before sharing with their group or the rest of the class. Using this Think-Pair-Share method ensures that all students have time to develop their own ideas before conforming to "groupthink" and destroying some potentially good ideas. Students should be encouraged to journal their ideas so they have something written down before they share and their idea does not get influenced by groupthink. After approximately five minutes, allow students to return to their groups to discuss their ideas.

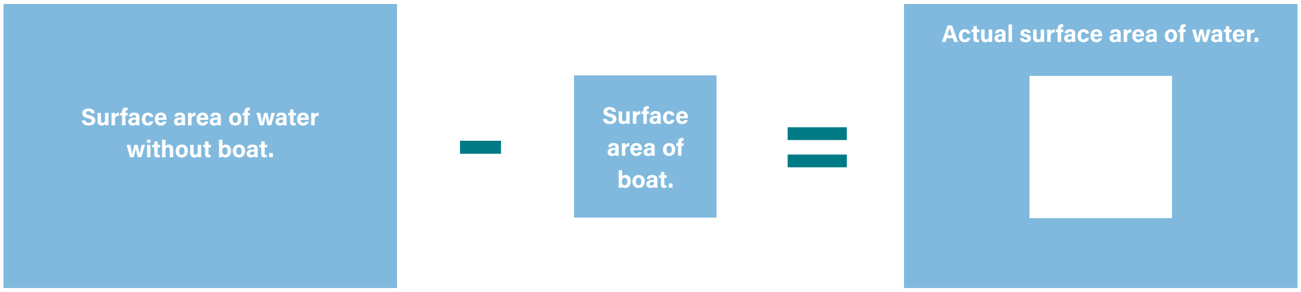


Figure 1: How to calculate the actual surface area of water.

Drawing a Conclusion

By the time students get to group discussion they should see some basic patterns arising from the data they are analyzing. For example, by looking at the class set of data, students should see a proportional pattern between the volume of the boat and the amount of weight that the watercraft can hold. Some groups might only look at the surface area of the hull versus the weight, but that is not the entire relationship. Ultimately, the amount of weight a boat can carry is proportional to the amount of water it can displace, meaning that the weight of the water displaced is equal to the total weight in the boat. The amount of water displaced can be calculated by multiplying the height of the water rise by the surface area of the water. An example of how to calculate the surface area of the water can be found in Figure 1.

If a student's group is convinced that only the surface area matters, have them revisit and build two watercraft with identical hulls. Have them add sides to one of the watercraft and leave the other as a flat raft, and have the students discuss the outcome of the secondary experiment. The students should notice that the watercraft with sides was able to displace more water and therefore hold more weight.

Students may also see a small pattern where a few boats with a large volume could not hold a lot of weight. This is due to the placement of the weight relative to the watercraft's center of gravity. The offset of the weight will cause a rotation to occur near the center of gravity—where one side of the watercraft will dip into the water, and the other side will begin to rise. This will ultimately cause water to start flowing into the boat before it has displaced an amount of water equal to the volume of the watercraft—making the boat less efficient than some of the other designs. This scenario can also be considered an outlier in the data set. If the students ask questions about whether or not the placement of the weight matters, have them attempt to balance a pencil on one finger. Then have them think about where they could add a weight to the pencil without it falling off. Students should conclude that placing the weight in the center above their finger will not cause the pencil to fall. This is because placing the weight in this particular location does not generate a rotational force and keeps the pencil level. Ultimately the top of the watercraft needs to remain level relative to the water in order

to operate efficiently and displace the maximum amount of water possible.

Conclusion

Although design challenges are used in a multitude of situations, using instant design challenges to introduce new concepts can lead to a more student-centered learning environment. Additionally, when implemented thoughtfully, specific concepts and experiences can be drawn out for students to encounter. Although this approach may take more time implementing both in and out of the classroom, it will ultimately lead to an increase in student understanding and make the class more engaging. Allowing the students to think critically with guided questions is the key to success in using instant design challenges to introduce topics using a more-student centered approach (rather than having a teacher-led lesson). As current design challenges—used as anticipatory sets or to deliver core content—are implemented in the classroom, they can easily be reconfigured to intentionally immerse students in an authentic learning experience.

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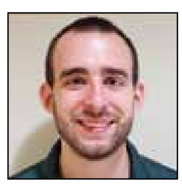

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