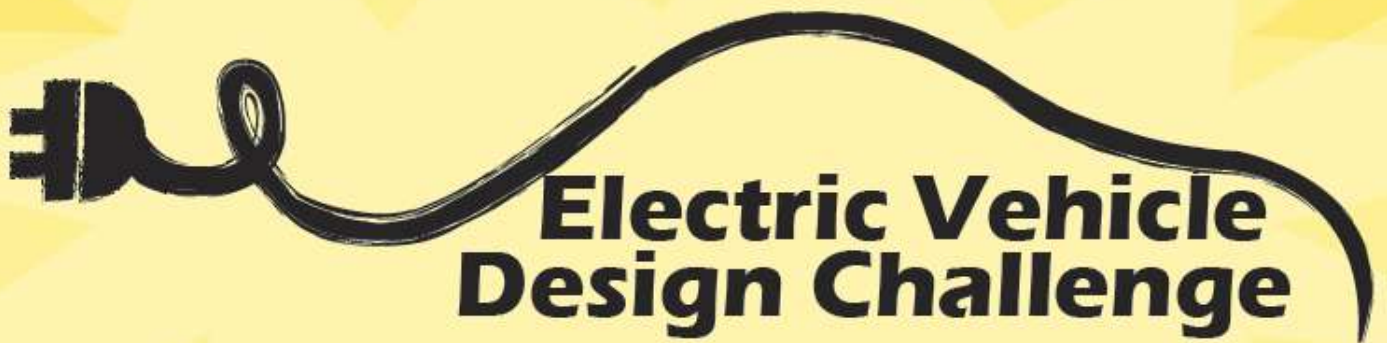


Engineering Design



Teacher Edition



**ENERGY LEARNING
EXCHANGE**
Illinois State University



**CENTER FOR
MATHEMATICS, SCIENCE,
AND TECHNOLOGY**
Illinois State University

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Experience the Engineering Design Process

Design an Electric Vehicle

What is Engineering Design?

Science is the study of the natural world. This study often identifies patterns. The study and use of patterns is basically the definition of “mathematics.” What is discovered can be applied “to solve problems and extend human capabilities.” That is the definition of “technology.” The process of developing technology is called “engineering.”

Engineering Design is the process of applying knowledge of the natural world and its patterns to solve a problem. It is not just “math” or just “science” or limited to a particular age group or gender. It is a skill that all students should have, regardless of academic ability or career goals. Engineering Design can be as simple as making a schedule to get ready for school in the morning and arriving on time. It can be as complex as operating a rover on Mars.

For the past several decades, most people think that a better understanding of mathematics and science will improve our ability to solve problems leading to new inventions and innovations. The intended outcome is a stronger economy, increased national security, and an elevated standard of living. That explains the current interest in STEM (science, technology, engineering, mathematics) classes at your school.

Why is Engineering Design Important?

Over the past several years, the need for engineers has grown faster than the supply. Simply stated, our technological society requires lots of engineers. The Bureau of Labor Statistics estimates that the United States will see an 11% increase in jobs for engineers by 2018. Contributing to this situation is fact that over 60% of the engineering students currently enrolled in post-graduate degrees in the United States are from other countries and most of them will return to their own country after graduation.

By the way, engineers make some serious money. Most start out around \$40,000 per year and their salaries quickly increase.

But what if you never plan to be an engineer? Should you still learn how to do the engineering process? Yes. The *Common Core State Standards for Mathematics* and the *Next Generation Science Standards* (NGSS) list what ALL students should know and be able to do to be ready for careers or college. In math, all students should be able to do the following:

1. Make sense of problems and persevere in solving them.
2. Reason abstractly and quantitatively.
3. Construct viable arguments and critique the reasoning of others.
4. Model with mathematics.
5. Use appropriate tools strategically.
6. Attend to precision.
7. Look for and make use of structure.
8. Look for and express regularity in repeated reasoning.

All science students are supposed to be able to do the things on this list:

1. Asking questions and defining problems
2. Planning and carrying out investigations
3. Analyzing and interpreting data
4. Constructing explanations and designing solutions
5. Obtaining, evaluating, and communicating information
6. Developing and using models
7. Engaging in argument from evidence
8. Using mathematical and computational thinking

Education experts think these skills are so important that they are repeated at every grade level, K-12.

Be certain that all vehicle models are aligned lengthwise with the board and are placed approximately in the middle. There must be at least 6 inches or so of empty board immediately ahead of the vehicle.

Some teams may try to make a hollow model. This is unnecessary and is a waste of valuable time.

Think About It

The immediate concern of any experienced teacher is how to control the use of clay in the classroom. It is just too messy with the potential of little clay balls flying across the room. Yes, some of that is likely. Please consider, however, behaviors of children when they are bored as compared to when they are interested. There will be a few students who take advantage of the opportunity to disrupt, but peer pressure can be used to keep them in line. All students will prefer making a clay model over listening to another lecture or doing another worksheet. Most will realize that too much goofing off will jeopardize the likelihood of ever getting to do this again and will pressure their less-mature classmates to straighten up.

There are several reasons why it is important to make the clay model. First, it allows the students to see their sketches in 3 dimensions. Second, it provides an avenue for ratios and proportion calculations. It also is the basis for experimentation and data collection later. It puts the student in the role of “car designer.” They have probably seen images of engineers carving full size mockup of car bodies. This process looks similar. Finally, making the model provides an opportunity for the more artistic student to contribute to the project.

With all that said, if making the clay model is the “deal breaker” it can be omitted. The data collected from the model can be estimated. Doing so, however, greatly reduces the experience called for in NGSS Processes 2, 3, and 6.

With the proper set up, it is possible to make the clay model in a clean environment (like a school library). Just keep the clay away from the computers and books.

2. Determine the scale of the clay model

- a. Compare a standard component of the model to an actual vehicle. Most cars are about 52 inches tall. Most automotive tires are between 24 and 32 inches in diameter. For example: if your model is 5 inches tall and you want it to be about standard height, you have a scale of about 1 inch = 10 inches.
- b. You may wish to go to the parking lot to gather specifications from various cars or research dimensions of similar vehicles.
- c. Build a “model person” to the same scale as your vehicle. Compare your clay vehicle to the model person, making sure your vehicle would be able to accommodate a person/people inside. Revise your clay model as necessary. Remember, the occupants can recline to a comfortable angle.



Think About It

A scale model is simply a ratio. Understanding ratios is critical to the ability to use mathematics as a tool. Fractions and percents are often used to describe ratios. Although your students have been instructed on ratios, fractions, and percents for several years, they may still not understand the concept to the point of being able to do it. They will now come to you, asking for instruction. This is the difference between the traditional “just in case” instruction and “just in time” instruction. Students will learn when the skill is needed to complete a task that they want to do.

Encourage the teams to gather their own data. They will ask you for dimensions, but avoid giving them precise numbers. Instead, tell them to take a tape measure or meter stick to the parking lot and measure a few cars. Do not allow them to search for dimensions on the internet. They will spend far too much time and will come up with much more data than necessary. It is very likely that the car models made will have to be adjusted once the dimensions are calculated. Often the wheels are too small.

3. Refer to your design goals and original sketches. Perhaps the goals and original designs are no longer feasible or you have abandoned some ideas in favor of others. These modifications are a natural part of the process, but one that some find frustrating. The engineering process involves making the best decisions possible based on the available data. As more data becomes available, designs evolve.

Record changes to your design goals in Section 1 and add sketches to Section 2 of your Engineering Journal. Be sure to indicate the reason for each decision.

Think About It

You are probably accustomed to “one right answer” especially in mathematics. In the engineering process however, there is seldom a single right answer. When more information is discovered, designs change. This constant updating and revising can be frustrating.



The students probably will not have to be encouraged to make the vehicle look as nice as possible (doors, windows, wheels, etc.) In fact, you may have to tell them “that is good enough.” Some will be quite artistic. What really matters is that it must be functional for the aerodynamic drag test to be conducted later.