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Is It Engineering or Not?

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To bring engineering tasks into the classroom, know what qualifies—and what doesn't

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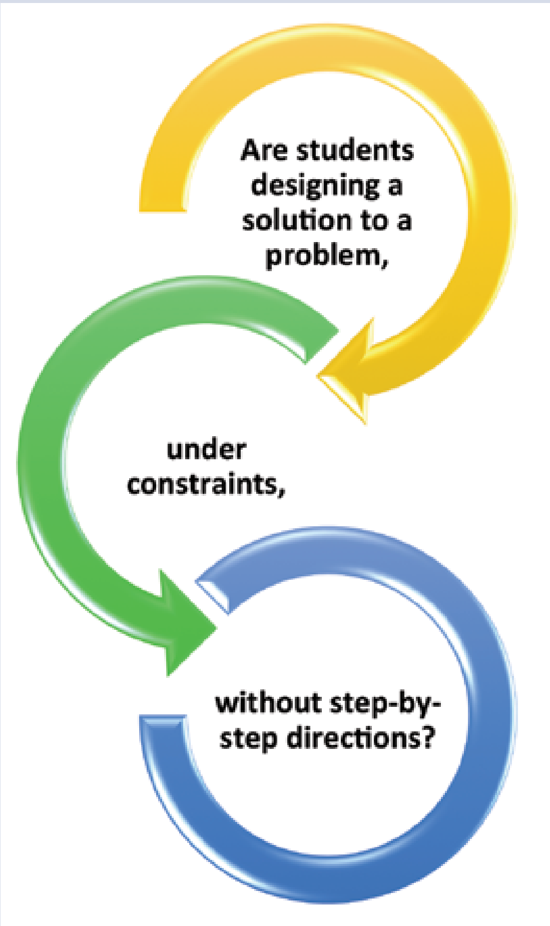
With the widespread adoption of the *Next Generation Science Standards* (NGSS Lead States 2013), science teachers now aspire to integrate engineering into science instruction, as the standards suggest, yet many don't know how. The first steps are to define engineering and identify tasks that incorporate engineering, which can be difficult and confusing. This article presents a simple explanation of engineering and offers a framework to help teachers determine whether a task is based on engineering. We also offer examples of how to integrate engineering in Earth science, chemistry, biology, and physics.

What is engineering?

Engineering and science are distinct fields with different goals: Engineers focus on modifying the world to meet human needs and wants, and scientists focus on studying the natural world to more deeply understand how things work (Katehi, Pearson, and Feder 2009).

FIGURE 1

Is it engineering or not?



Despite these differences, engineering and science share similar practices in reaching their goals (Bybee 2011). Both engineers and scientists conduct research to better understand problems, use models to understand complex systems, argue from evidence to support design plans or hypotheses, conduct investigations, interpret and analyze data, use math to analyze data, and communicate results and outcomes to others (Crismond 2013).

While scientists pose questions and generate hypotheses, engineers define and solve problems. Scientists interpret data and construct explanations. Engineers design solutions and troubleshoot. Engineering designs are informed by scientific knowledge, and advances in science are made feasible by technology developed by engineers (Katehi, Pearson, and Feder 2009).

The *NGSS* call for students to develop understanding of the engineering design process through eight practices to be integrated into science instruction:

- defining problems,
- developing and using models,
- planning and carrying out investigations,
- analyzing and interpreting data,
- using mathematics and computational thinking,
- designing solutions,
- engaging in argument from evidence, and
- obtaining, evaluating, and communicating information.

The standards also recognize that the design process is an iterative, cyclical process during which students may engage in these practices multiple times.

A National Research Council report defines engineering like this: "Engineering is both a body of knowledge—about the design and creation of human-made products—and a process for solving problems" (Katehi, Pearson, and Feder 2009, p. 17).

Is it engineering?

When deciding whether a task is engineering based, first ask: "Are students designing a solution to a problem under constraints without step-by-step directions?" (Figure 1). Many valuable tasks performed in the science classroom don't involve solving a problem under constraints or through a design process. For example, constructing physical or conceptual models of cells, atoms, or the solar system, or building circuits, airplanes, or weather instruments can all be worthwhile classroom tasks. However, because they don't typically involve solving a problem under constraints, they aren't engineering tasks.

Engineering-based tasks must start with a problem students can solve. Engineering-based tasks must also involve

FIGURE 2

Self-check. Which of these are engineering tasks?

1a. Students investigate potential and kinetic energy by: • building a model roller coaster as described on a handout, • taking measurements of a car's movement on the roller coaster, and • identifying the areas of most and least potential and kinetic energy.	1b. Students are told the amusement park nearby needs a new roller coaster. The teacher provides a multitude of materials for students to build and test their own roller coaster. Materials are associated with varied costs, and students are restricted by how much they may spend on the roller coaster as well as other safety and space restrictions. Students design, build, test, and modify their roller coasters before developing a presentation for the amusement park CEO.	1c. The teacher begins with the problem: "How can you safely design a roller coaster so the cars don't run off the tracks?" Following a brainstorming session of the problem, the teacher demonstrates several different roller coasters using a computer simulation. The teacher then facilitates a discussion as the class decides how it might safely design a roller coaster within the given constraints.
2a. Students research and describe how to build a circuit by using the text and images they find on the internet.	2b. Students participate in several investigations of electric circuits. Students are then tasked to build a creative sign. Students design, build, test, and modify their signs before sharing them with the class.	2c. Students are told a major electronics company is developing a new pinball game to be installed in every Pizza Shack around the country. A variety of materials available for the task are described, and students are given size, engagement, and sound restrictions for the pinball game. Students then use their knowledge of electric circuits to plan and draw their pinball machine. They then share their designs in groups to receive feedback and make modifications before turning in a final design.

designing a solution to that problem under constraints, so having students simply follow step-by-step directions to build or construct a product or simply researching others' ideas and plans does not qualify as engineering.

Arguably, to be authentically engaged in engineering, students must design, build, test, and redesign a product prototype. On the other hand, not all engineering-based tasks require students to build a prototype. Students could draw or write a plan to solve a problem as long as they are given specifications or constraints for the design or plan. Constraints may include time, money, available materials, environmental regulations, laws of nature, ability to manufacture, repairability, and so on (Katehi, Pearson, and Feder 2009).

Test your understanding

Teachers can check their understanding of engineering-based tasks against the examples in Figure 2. Examples 1a, 2a, and 2b are not based on engineering:

- Example 1a does not involve solving a problem.
- Example 2a may imply a problem, but students aren't given constraints and aren't designing the solution on their own.
- In example 2b, students are not solving a problem nor working within any constraints.

However, simple modification of these activities—developing a problem, removing the step-by-step directions, and providing constraints—could transform these activities into engineering-based tasks. Examples 1b, 1c, and 2c qualify as engineering tasks because they incorporate a problem to be solved, require students to design a solution, and must be solved under constraints.

- In Example 1b, students solve an authentic problem with realistic constraints by designing a roller coaster.

FIGURE 3

Engineering examples in biology, chemistry, Earth science, and physics.

Discipline	Problem	Possible constraints
Biology	Artificial heart valves are critical for individuals with various heart issues. To function properly, the valve needs to withstand different levels of blood pressure. How would you design a heart valve for a patient in need?	• Valve needs to be made with materials that are compatible with the body. • Valve should function from low to high blood-pressure ranges. • Valve should not allow for return blood flow.
Chemistry	Properly functioning air bags are important to driving safety. Recently, 34 million vehicles were identified as having defective air bags. How can you create a chemical reaction that will effectively fill a car air bag to the appropriate fullness needed to keep a passenger safe?	• Air bag should inflate to specified volume. • Chemical components should be as nontoxic as possible. • Reaction should occur in the smallest amount of time. • Air bag should be cost effective.
Earth science	Many communities around the world have increasing pollution in their water sources. Clean water is necessary for bathing, drinking, and cooking. How would you develop a household filtration system for a community in need?	• Filter should use only certain provided materials. • Rate of water filtered should fall within certain range of ml/min. • Filtered water should have certain level of cleanliness.
Physics	Thermostats are essential to keep automobiles from overheating and depend on electricity to function properly. How would you design a scale model of a circuit used in an automobile's thermostat?	• Scale model should be a particular size. • Thermostat should turn on and off within a particular temperature range. • Design should contain both parallel and series circuits.

- In example 1c, the teacher facilitates the design using a computer simulation, but students are responsible for the design of the roller coaster within given constraints.
- In example 2c, even though students don't build a prototype, they solve a problem under constraints without step-by-step directions.

Implementing engineering in your classroom

When integrating an engineering task in science instruction, the task should lead students to a deeper understanding of the ideas being studied. Ideally, the task should grab students' attention and involve an authentic, real-world problem. Such problems can be introduced through readings, videos, or news reports. Other approaches are to present design challenges or to integrate an engineering task into a project-based or problem-based learning unit. For example, the design of a voltaic cell–powered fan may be the culminating project for a problem-based learning unit on electrochemistry.

Engineering is not, as some teachers may think, only for the physics classroom. It can be integrated into any content area. Figure 3 presents an engineering problem and constraints for several content areas: biology, chemistry, Earth science, and physics.

The chemistry and Earth science engineering problems in Figure 3 were drawn from recent news stories (e.g., automobile air bag recall and lead-tainted water problems in Flint, Michigan). This is a great way to motivate students to address relevant and real-world problems. The possible constraints listed are suggestions to spur thinking about other types of constraints that could be appropriate, such as laws of nature, time, available materials, environmental regulations, usability, and range of function. Resources for developing engineering investigations are provided at the end of this article.

Structuring engineering for success

Teachers should scaffold and support students as they begin to engage with engineering practices. One approach is to use an Engineering Design Log described in a previous article (Wheeler, Whitworth, and Gonczi 2014). The log offers students prompts to thoroughly engage in the engineering practices. Students often want to skip the research, brainstorming, and planning phases to go straight to designing and building, yet these earlier phases are important to the engineering design process.

Another way to offer structure is through mini-investigations of concepts needed to complete an engineering design challenge (Schnittka and Richards 2016). This method makes more explicit the connections between engineering design and science concepts. Providing scaffolds and accountability for students as they participate in engineering tasks allows for smoother implementation overall.

Finally, it is important to make the engineering practices explicit to students. Students do not always realize they are participating in engineering activities nor see how engineering differs from science. During a short discussion at the end of a lesson or project, ask students to reflect about the work they've completed. Or, ask students to add a written reflection to any report given about the product they designed.

Conclusion

Incorporating engineering into the science classroom may increase student interest in STEM careers and increase STEM literacy. It can also help make science and math relevant to students (Katehi, Pearson, and Feder 2009). Furthermore, embedding engineering into science instruction can help students develop 21st Century Learning Skills (2015), including critical thinking, communication, collaboration, and creativity. Engineering in the classroom allows students to learn that failure can be an opportunity to learn, an important life lesson (Cunningham and Carlsen 2014).

As teachers implement the *NGSS* engineering practices in their classrooms, it's important for them to design engineering tasks that are worthwhile and meaningful for students. We hope this article's definition of engineering and framework for determining whether a task is based on engineering will help teachers enhance their engineering instruction. ■

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On the web

Center for Innovation in Engineering and Science Education: *http://ciese.org/materials/k12/*

Engineering Design through Media (PBS): *http://bit.ly/PBS-engineering*

Engineering, Go For It! (lesson plans): *http://bit.ly/engin-lessons*

Engineer Your World, a high-school curriculum: *www.engineeryourworld.org*

Link Engineering, educator exchange: *www.linkengineering.org*

Materials World, inquiry and design-based units: *www.materialsworldmodules.org*

National Science Foundation, engineering classroom resources: *www.nsf.gov/news/classroom/engineering.jsp*

Teach Engineering, curriculum: *http://bit.ly/teach-engineering*

The Engineering Place, resources for teachers: *http://bit.ly/NC-resources*

Try Engineering: *http://tryengineering.org/lesson-plans*

WISE Engineering: *http://wisengineering.org/*

Resources

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