INTEGRATING ENGINEERING + SCIENCE IN YOUR CLASSROOM

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EDUCATION

Contents

Part Two

Content Area Activities

LIFE AND ENVIRONMENTAL SCIENCE

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CHAPTER 1

The Engineering Design Process

By Eric Brunsell

Students need more than one chance to be successful at a task. So many times they are left thinking, "next time I would have…." The design process allows students to have that next time.

—Jonathon W. Gerlach
"Elementary Design Challenges"

Science and engineering are complementary, but they are not the same. In general, the purpose of science inquiry is to use evidence to explain the natural and designed world. The purpose of engineering is to solve specific problems related to needs or wants. Many different characterizations of the design process can be found in the articles in this book. However, they all share similar aspects that involve defining the problem, generating multiple possible solutions; analyzing these solutions; testing, evaluating, and refining solutions; and communicating ideas. Engineering design is messy—it is not a linear process. Additionally, engineering design is not a "one shot deal." Failure is a constant companion in the design process. By testing ideas to failure, we learn how to improve our ideas. In the classroom, testing of a solution should not be the end point. Instead, like in Gerlach's quote, students should be given opportunities to refine their solutions as many times as possible within the constraints of your curriculum.

Define the Problem

In Sumrall and Mott's *Science Scope* article, "Building Models to Better Understand the Importance of Cost Versus Safety in Engineering," students are asked to build a tower for a football field. Identifying parameters for a successful tower and identifying the need to balance safety and cost further define this problem. In this project, the balance between safety and cost helps students understand "trade-offs" inherent in the decision-making process.

Often, engineering projects are started with a design brief. A design brief includes the goal of the project, expectations, and limitations. The design brief can be introduced by the teacher (as in Sumrall and Mott's project) or collaboratively created by students and the teacher. An example design brief can be found in Sterling's "Science and engineering" article.

As part of this stage of the engineering design process, it is common for students to conduct research about the problem and what solutions have been used in the past.

Develop Possible Solutions

In any complex problem, there is no obvious right answer. In fact, there are often many solutions. At this stage of the design process, students should brainstorm as many possible ways to solve the problem. Good brainstorming involves rapidly generating ideas without passing judgment. If a problem is particularly challenging, it is often valuable to break the problem into smaller pieces and brainstorm solutions to each piece. For example, if the challenge is to create a robot that can move widgets from one assembly line to another, you might brainstorm solutions for moving the robot separate from solutions for grabbing widgets.

Brainstorming should be a social process. It may help to start the process if students identify a few possible solutions on their own, but most of the brainstorming time should be spent in small groups. To deemphasize competition, it is also beneficial to continue brainstorming as an entire class. As you facilitate this process, help students keep their focus on generating ideas, not evaluating the likelihood that the idea is suitable.

Analyze Solutions

Once a large number of possible solutions have been identified, students can begin analyzing solutions. In this process, students make judgment calls on how each solution meets the goals and constraints (specifications) in the design brief. Students should be encouraged to use a systematic approach for this analysis. For example, a simple matrix can be used to determine if a solution meets the required specifications. From this analysis, students select one (or a few) solution to prototype and test.

In Sakakeeney's article, "Repairing Femoral Fractures," students are challenged to find ways to mend a broken leg. Before getting their hands on a model leg, students are expected to create two possible design solutions. The design solution includes a description of how the solution works, how it matches the problem definition, and clear drawings. In small groups, students evaluate each of these design solutions by identifying pros and cons and then develop the solution that they plan on testing.

Optimize Solutions

The next step in the engineering design process is for students to test their solutions. Students should collect data on the performance of their solution and identify opportunities for improvement. In some cases, these tests can take the form of a "fair test," where single aspects of a design can be changed to determine how it impacts performance. At this stage, it is critical to reinforce that engineering design is an iterative process. Whenever possible, testing should lead students to refine their design. Students should be given the opportunity to retest those modifications as they improve their designs. This is time-consuming, but limiting testing to one attempt provides a distorted view of the engineering design process. Gerlach's "Elementary Design Challenges" illustrates this process of continual improvement as students work as a class to perfect airplane designs.

Solutions	Specifications		
	Criteria 1	Criteria 2	Criteria 3
Solution 1	X	+	+
Solution 2	–	X	–

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Communication

Throughout the engineering design process, students should be presented with opportunities to communicate their results to their peers and, when possible, to a larger audience. During each stage, students can share their thinking. For example, in the "Define the Problem" stage, students can share their understanding of the scenario, constraints, and indicators of success for solutions. During the "Test, Evaluate, and Refine" stage, students should share the results of their test, decisions that they made related to refining their solution, and evidence that supports those decisions. Finally, students should be given the opportunity to develop a presentation of their final solution, evidence of success, and their pathway to that solution.