Next Gen PET

Teaching and Learning Extension B

Reading: Engineering and the Next Generation Science Standards

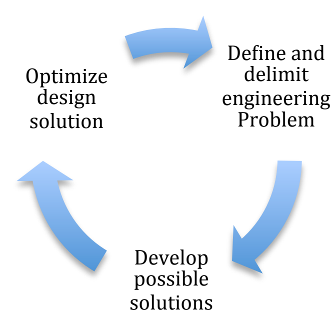
Engineering design is the process by which engineers develop innovative solutions to problems. The process involves understanding the problem; generating ideas; selecting an idea based on multiple constraints; and improving the idea. Even before you entered school, you have been using the process of engineering design to help you solve problems.

Consider a child who let go of the string of a helium-filled balloon in her kitchen. The balloon floated to the ceiling and was too high for her to reach. This presented a problem to solve: How can she reach the balloon? She considered the many resources available to her right in her kitchen. There were chairs and cooking utensils. First, she tried using a chair to stand on. However, the chair was not high enough. She then tried holding a wooden spoon in her hand to extend her reach while standing on the chair, but she could not grasp the string. Finally, she tried standing on the chair holding a set of tongs. This solution allowed her to reach and grasp the string.

We encounter these sorts of engineering problems and engage in this sort of problem solving or design thinking every day. In this activity we will look at the processes of engineering more carefully.

The Next Generation Science Standards (NGSS) and Engineering Design

The Next Generation Science Standards (NGSS) breaks engineering design into three stages: 1) Defining and delimiting an Engineering Problem, 2) Developing Possible Solutions, and 3) Optimizing the Design Solution The table below describes what students in grades 3-5 should be able to do to demonstrate understanding of these three stages.



Define/Delimit Problem.	Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
Develop solutions.	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.
Optimize	Plan and carry out fair tests in which variables are controlled and failure

design solution	points are considered to identify aspects of a model or prototype that can be improved.

The first step is to **define the problem**. An engineering problem includes **goals** (or **criteria for success)** for what should be done (e.g., build a bridge that spans a stream 5 meters wide and can support the weight of 5 adults) and **constraints** (e.g., a specified budget, limit on materials or time limits). The first step to solving any engineering problem is to fully understand the problem including the goals and constraints.

The second step is to **develop solutions**. This step includes brainstorming or generating several different possible solutions and then considering how well each solution is likely to meet the problem goals and take the constraints into account. Each promising solution should then be tested to determine how well it actually meets goals and stays within constraints.

The third step is to **optimize the solution.** Once an engineer has selected a solution, the next step is to optimize that solution. Optimize means to take a possible solution and make it as good as possible, so it best meets the goals and stays within the constraints. In engineering, there is usually not a perfect solution and multiple factors are involved. Sometimes as one tries to increase optimization along one factor (e.g., using less material), it may mean decreasing performance along another (e.g., speed).

The Next Generation Science Standards (NGSS) and engineering practices

The Next Generation Science Standards (NGSS) describe eight practices of science and engineering. These are things that scientists and engineers do when they are doing science. The chart below (NRC, 2012) describes how the practices look in science and engineering. The goals of science and engineering are different. The goal of science is to explain natural phenomenon and to support these explanations with evidence. The goal of engineering is to identify problems that humans face and to solve these problems through the invention and development of objects or processes. The processes by which these goals are met are similar.

Scientific and Engineering Practices

Asking Questions and Defining Problems

A basic practice of the **scientist** is the ability to formulate empirically answerable questions about phenomena to establish what is already known, and to determine what questions have yet to be satisfactorily answered.	**Engineering** begins with a problem that needs to be solved, such as "How can we reduce the nation's dependence on fossil fuels?" or "What can be done to reduce a particular disease?" or "How can we improve the fuel efficiency of automobiles?"

Developing and Using Models

Science often involves the construction and use of models and simulations to help develop explanations about natural phenomena.	**Engineering** makes use of models and simulations to analyze systems to identify flaws that might occur or to test possible solutions to a new problem.

Planning and Carrying Out Investigations

A major practice of **scientists** is planning and carrying out systematic scientific investigations that require identifying variables and clarifying what counts as data.	**Engineering** investigations are conducted to gain data essential for specifying criteria or parameters and to test proposed designs.

Analyzing and Interpreting Data

Scientific investigations produce data that must be analyzed to derive meaning. Scientists use a range of tools to identify significant features and patterns in the data.	**Engineering** investigations include analysis of data collected in the tests of designs. This allows comparison of different solutions and determines how well each meets specific design criteria.

Using Mathematics, Information and Computer Technology, and Computational Thinking

In **science,** mathematics and computation are fundamental tools for representing physical variables and their relationships.	In **engineering,** mathematical and computational representations of established relationships and principles are an integral part of the design process.

Constructing Explanations and Designing Solutions

The goal of **science** is the construction of theories that provide explanatory accounts of the material world.	The goal of **engineering** design is a systematic approach to solving engineering problems that is based on scientific knowledge and models of the material world.

Engaging in Argument From Evidence

In **science,** reasoning and argument are essential for clarifying strengths and weaknesses of a line of evidence and for identifying the best explanation for a natural phenomenon.	In **engineering,** reasoning and argument are essential for finding the best solution to a problem. Engineers collaborate with their peers throughout the design process.

Obtaining, Evaluating, and Communicating Information

Science cannot advance if scientists are unable to communicate their findings clearly and persuasively or learn about the findings of others.	**Engineering** cannot produce new or improved technologies if the advantages of their designs are not communicated clearly and persuasively.

References

National Research Council. (2012). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Washington, DC: The National Academies Press.

Achieve (2012). *Next Generation Science Standards.* Available at http://www.nextgenscience.org/