An Engineering Design Process

Engineering is a systematic method for solving problems. On the left side are several different parts of an engineering design process. Draw a line from each box on the left to the number on the right to show what you think might be a useful order of steps for solving a problem.

Improve the design by studying test results.	**1st**
Research the problem.	**2nd**
Define the problem.	**3rd**
Test the solution to see if it solves the problem.	**4th**
Brainstorm solutions.	**5th**
Choose the best idea to make a physical model (prototype).	**6th**
Communicate the final solution.	**7th**
Build a prototype for testing.	**8th**

Explain why you chose this sequence of steps.

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Teacher Notes

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Purpose

The purpose of this assessment probe is to elicit students' ideas about an engineering design process. The probe is designed to show how students think of engineering design as a logical sequence.

Type of Probe

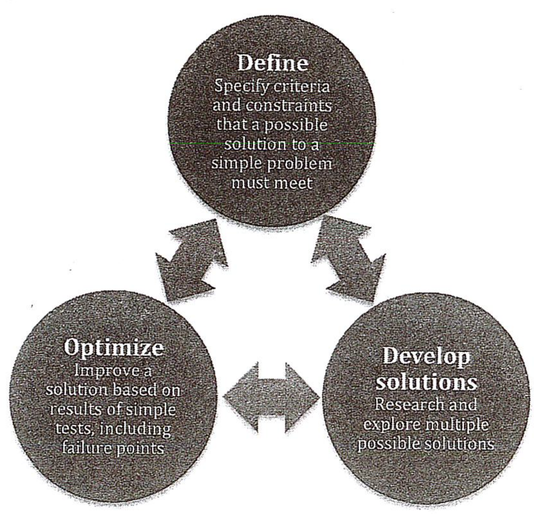
Sequencing

Related Key Idea

- An engineering design process (EDP) is a systematic method for defining and solving problems.

Explanation

There is no single best answer that puts all the steps in a correct order. The sequence students select and their explanation should show how they think about what they would do first, second, and so on when solving a problem, and that they realize that a systematic approach is really just a way of thinking logically and carefully—not rushing to the first solution that comes to mind or believing that there is a fixed set of steps that must always be followed in a definite sequence. The *NGSS* development team recognized that a wide variety of interpretations of an EDP are acceptable; so rather than choosing one vision of the process over another, the *NGSS* included a diagram of an EDP (below) that consists of three phases: define the problem, develop solutions, and optimize (NGSS Lead States 2013). These three broad phases encompass many versions of an EDP associated with various sets of standards and curricula.



Administering the Probe

This probe is best used with students in grades 3–12. The probe can be used as a card sort. Provide pairs or small groups of students with a set of cards, with each part of the design process listed on a card. Students sort the cards, putting them into a logical sequence and explaining why they put them in that order.

Connections to the Three Dimensions (NRC 2012; NGSS Lead States 2013)

In the *NGSS*, an EDP is both a disciplinary core idea (DCI) and a science and engineering practice (SEP). That means students should be able to both describe an EDP and use it to define and solve problems.

There are three broad DCIs for understanding an EDP in grades K–12:

- ETS1.A: Defining and Delimiting Engineering Problems
- ETS1.B: Developing Possible Solutions
- ETS1.C: Optimizing the Design Solution

The K–12 SEPs often found to be useful in an EDP are as follows:

- Asking Questions (for science) and Defining Problems (for engineering)
- Developing and Using Models
- Planning and Carrying Out Investigations
- Analyzing and Interpreting Data
- Using Mathematics and Computational Thinking
- Constructing Explanations (for science) and Designing Solutions (for engineering)
- Engaging in Argument From Evidence
- Obtaining, Evaluating, and Communicating Information

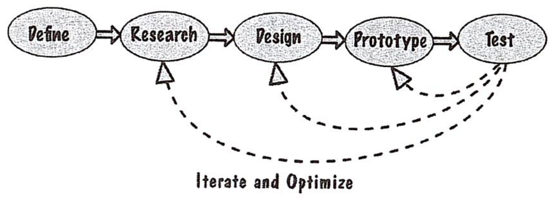
Related Research

- Alemdar et al. (2017) developed an assessment of middle school students' understanding of an EDP that used 18 multiple-choice questions. The purpose of the assessment was to identify the extent of common misconceptions, such as the idea that an EDP is a step-by-step fixed process rather than an iterative process, in which students continually revise and improve prior designs. The researchers tested their assessment instrument with 44 middle school students by comparing the results of the multiple-choice assessment with individual interviews, and refined the instrument based on their findings. The researchers commented that students were more familiar with some phases of an EDP than with others. For example, they were better at evaluating existing designs than they were at initially creating designs, possibly because evaluation of designs was emphasized in their engineering curriculum.

Suggestions for Instruction and Assessment

- This probe can be used as a starting point to assess and discuss students' initial ideas about an EDP. The subsequent probes in this book are intended to assess students' understanding of each phase of an EDP, and to deepen the sophistication with which they consider and solve problems.
- There is a rich and vibrant literature on the history and nature of engineering design, including the popular writings of Henry Petroski, such as *Invention by Design: How Engineers Get From Thought to Thing* (Petroski 1996). Excerpts from these books can be used with students to provide them with a real-life, engaging glimpse into engineering design.
- For students in grades 6–12 (and possibly also grades 3–5 if vocabulary is made an early part of the discussion), the following diagram is a simple and dynamic view of an EDP that abstracts the key features of

many EDP models and uses the typical terminology used by engineering practitioners.



- **Define:** The first step involves developing a clear statement of the problem in terms of criteria for success, and constraints or limits of possible solutions. A unique aspect of engineering is the presence of a *client*—an individual or group of people who have a problem or need, and who can help identify the criteria and constraints.
- **Research:** Research should include exploring how similar problems have been solved in the past, and may include other kinds of studies, such as marketing, to see who would use the solution and what additional criteria or constraints should be considered.
- **Design:** This phase usually begins by considering many different possible solutions, synthesizing various ideas, and determining which idea is most likely to solve the problem. This phase also usually includes creating a model of the solution, which may be as simple as a paper sketch, a detailed two- or three-dimensional model using computer-aided design, or a full mathematical computer simulation model.
- **Prototype:** A prototype is a physical or software model that can be tested to determine how well the design meets the criteria and constraints of the problem. It can also be shown to potential users to see if they agree it meets their needs. Early prototypes can also be "virtual prototypes" that are detailed functional simulation models.
- **Test and Revise:** In many cases the first attempt will not completely solve the problem, leading to further research. The dotted arrows indicate that further research may or may not be needed. If improvements are obvious, the designers might construct and test a new prototype right away. If not, they may need to return to the design phase and think of new solutions. Or, if the test shows they are on the wrong track, they may need to conduct further research to learn more about what will solve the problem. This iterative process continues until the problem is solved. Once it is solved, students can continue to optimize the solution—that is, to improve it as much as possible.
- **Communicate:** Although not shown in the diagram, the final stage of an EDP is often a presentation describing the new design with a summary of the process so that the audience understands how the design was arrived at and why it is the best way to solve the problem.

- For K–5 grades, you may wish to consider a diagram with fewer steps and more daily language, such as the diagram of an EDP developed for use in the Engineering is Elementary curriculum by the Museum of Science in Boston. See *www.eie.org/overview/engineering-design-process*.
- A different way to think about an EDP for 6–12 students was developed as part of the *Design Squad* television program (Wolsky 2015). A clickable version of *Design Squad*'s EDP diagram can be found

online at *https://pbskids.org/designsquad/parentseducators/workshop/process.html.*

- The Massachusetts Department of Elementary and Secondary Education has included an EDP in its standards since 2001. Each subsequent improvement of the standards has included a modified diagram of an EDP. The most recent version of the state's EDP diagram and its relationship to science inquiry can be found in the *Massachusetts Science and Technology/Engineering Framework* (2016, pp. 98–100). The document can be downloaded at *www.doe.mass.edu/frameworks/scitech/2016-04.pdf.*
- Regardless of which EDP representation you use with your students, it is important to emphasize that engineering design is both logical and creative, and uses a systematic and iterative process. There is no firmly set official starting point or end point. Depending on the problem and what has been done so far, you can begin at any step, move back and forth between steps, or even repeat the entire cycle. The important point is that it is methodical and involves following a sequence of steps.

References

Alemdar, M., J. A. Lingle, S. A. Wind, and R. A. Moore. 2017. Developing an engineering design process assessment using think-aloud interviews. *International Journal for Engineering Education* 33 (1): 441–452.

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