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Thinking Like an Engineer

How all elementary students can learn to solve problems like an engineer

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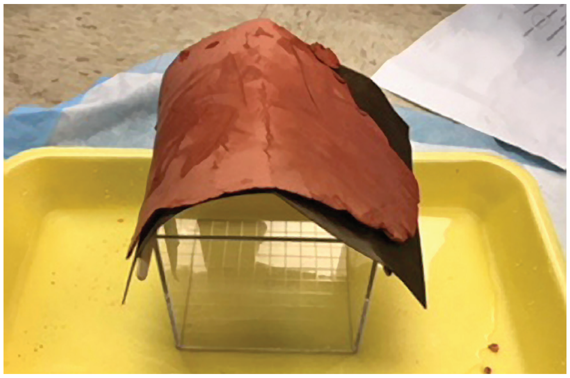
Engineers employ ways of thinking that help them solve problems, advancing technology and improving society. These ways of thinking can be introduced into elementary (grades K–5) classrooms to help all students think in ways that are similar to engineers and apply these ways of thinking to a range of problems.

Incorporating engineering into K–12 education can improve students' performance in science and mathematics; help students build their science, technology, engineering, and mathematics (STEM) literacy; and encourage all students to pursue engineering pathways (Katehi et al. 2009). Engaging students in the practices of engineering from a young age can help them become more familiar with what engineering is, what engineers do, and how engineers think about problems. If elementary science or mathematics curricula are designed to incorporate engineering concepts, practices, and ways of thinking, students' conceptual understanding of engineering content can be improved while also supporting their reading comprehension, vocabulary knowledge, and writing abilities (Cervetti et al. 2012). Supporting elementary students to think like engineers encourages them to use critical-thinking skills to ask questions about the world, make judgments about what constitutes a good solution to a problem, and learn how to effectively communicate their ideas with others.



Credit: Lisa Emerson, Marshall Road Elementary School, Vienna, Virginia

Elementary engineers design a building roof that drains water and keeps the building dry.

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Engineering: Part of STEM Learning

Engineering is not an isolated discipline; it is intertwined with science, technology, and mathematics. Engineers rely on scientific knowledge.

- They use scientific practices when they design and test their ideas.
- They use and improve different forms of technology to solve problems that the world encounters every day.
- They design systems that purify groundwater, devices that allow people to communicate over long distances, and buildings that are resistant to earthquakes.

Similarly, much of engineering is grounded in mathematical principles and requires the ability to use computational skills and algorithmic approaches to solve problems and analyze solutions.

Elementary students should be taught that, as engineers, they need to consider what is known from science, technology, and mathematics to be successful. Because of these interdependencies, engineering is best suited to be taught in conjunction with other content areas, such as science, rather than as a standalone subject. Students who engage in integrated science and engineering learning can have improved understandings of the relationship between these disciplines and their practices, and a greater interest in pursuing science and engineering in the future (NRC 2012).

Credit: Smithsonian Science Education Center

Students design an earthquake-resistant building.

Working Within Design Criteria and Constraints

When engineers encounter a problem or issue to solve, they usually are not told the best way to solve it or what the perfect solution will look like. The process of defining the context of a problem, testing a solution, and improving that solution is essential to engineering practice (Carr et al. 2012; Lucas & Hanson 2016; NRC 2012).

Students in K–5 can participate in defining problems, generating solutions, testing designs, and comparing solutions (Cunningham 2009; NAE 2010). Students can identify a problem that is relevant and engaging, such as animals being killed as they cross a road. They can use their prior knowledge, interests, or cultural perspectives to generate designs to help solve this problem. To determine the effectiveness of their designs, students can collect evidence showing whether their designs solved the engineering problem. They can then make claims based on this evidence about how well the designs solved the problem and compare their solutions to other students' designs.

Engineers also rarely have unlimited freedom when creating solutions. They must be able to consider certain criteria and constraints that depend on the situation. Elementary students can employ this type of engineering thinking by learning how engineers manage constraints when designing solutions in practice (Sneider & Rosen 2009). These constraints can include making choices from available materials and adhering to a budget. For example, students may be given a design challenge requiring them to design a tunnel to help an animal safely cross the road. The criteria and constraints for this challenge may include a budgetary limit, physical limitations, and that it must be suitable for the type of animal they are helping. Given a selection of materials available at different costs, students make choices about which materials to select to build a tunnel that meets the given criteria and constraints.

Budget Worksheet—
First Tunnel Design

Write down the cost of materials for your first tunnel design in the table.

Material	Price	How many?	Total
Long piece of wood	$20		
Half cardboard tube	$40		
Long piece of cardboard	$10		
Piece of black mesh (small holes)	$20		
Piece of white mesh (large holes)	$30		
Use of hole punch	$25		
Total cost			

Credit: Smithsonian Science Education Center

Sample budget worksheet for students building a design.

Elementary Engineers Work in Teams

Communication and collaboration are essential skills engineers must develop to effectively share knowledge, ideas, and results with others (Carr et al. 2012; NAE 2010; NRC 2012). Students in K–5 should start practicing these teamwork skills early in elementary school (Sneider & Rosen 2009). Elementary students can work individually or with other students to generate ideas and test solutions to engineering problems.

One approach is to have students engage in a Think-Pair-Share activity. For example, to solve an engineering challenge about how to pump freshwater to a city, students can first be prompted to individually think about where the water they use comes from. They can discuss their initial thoughts in pairs and then share their ideas with the rest of the class. The class can then discuss the various solution ideas and think about how to solve the engineering problem.

Alternatively, students can initially be divided into groups or teams to collaboratively generate solution ideas. This affords students the opportunity to learn from the diverse perspectives of their classmates and recognize that people approach problems in different ways.

Engineers must also be able to communicate and present their ideas so the ideas can be understood by others. Students can first choose a method for how they would like to document and communicate their ideas. Some examples may include drawings or written descriptions. Students then use these artifacts to communicate their ideas with a partner or a team when they are generating solution ideas together. Once each team has selected a final solution idea, student teams can present their solutions to the rest of the class. They would be able to justify their choices and explain how they believe their ideas solve the given engineering problem. Alternatively, the class could hold a gallery display of the student teams' design solutions to see how others approached solving the given problem.

Credit: Catherine Bambury, Council Rock Primary School, Rochester, New York

Students work together to generate and test ideas.

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How Smithsonian Science for the Classroom Supports Engineering Ways of Thinking

The Smithsonian Science Education Center (SSEC) designed the Smithsonian Science for the Classroom series for grades K–5. This modular series integrates engineering and science in at least two of four modules at each K–5 grade level, supporting students in developing engineering practices and ways of thinking. Students solve problems and complete design challenges that require them to ask questions, develop solutions, and make arguments about the effectiveness of their solutions based on evidence they collect through testing of their designs.

Learn more about Smithsonian Science for the Classroom.
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