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INTRODUCTION

PURPOSE

Thinking Like an Engineer is designed to engage students in design thinking while teaching them about multiple engineering career options. The activities in this book use the engineering design process (Engineering is Elementary, 2018a) as an instructional approach to teaching science.

Using the five-step engineering design process (i.e. Ask, Imagine, Plan, Create, Improve; see Figure 1) as an instructional strategy puts a focus on real-world problem solving while students actively engage in learning content across multiple disciplines (Dailey, 2017; Engineering is Elementary, 2018a). Teachers often assume that engineering is most appropriate when integrated with mathematics or science, but the engineering design process can be used with any learning area to engage students in critical and creative problem-solving. For example, students can use the engineering design process to solve problems found in fiction or nonfiction stories in an English lesson or unit. In a Humanities and Social Sciences lesson, students might use the steps to design a plan to improve living conditions in an impoverished area. Furthermore, "knowledge is built as students progress through the challenges and content is provided on a *need to know basis*; thereby, differentiating instruction based on learner needs" (Dailey, 2017, p. 138).

Using the engineering design process as an instructional approach or model prepares students for problem-solving outside the context of the classroom. With ever-changing technologies, students need to be active and practised problem-solvers and innovative thinkers. Utilising this approach with real-world problems helps students prepare for advances in the future. In a world where content is at their fingertips, teaching students to critically and creatively solve problems is vital.

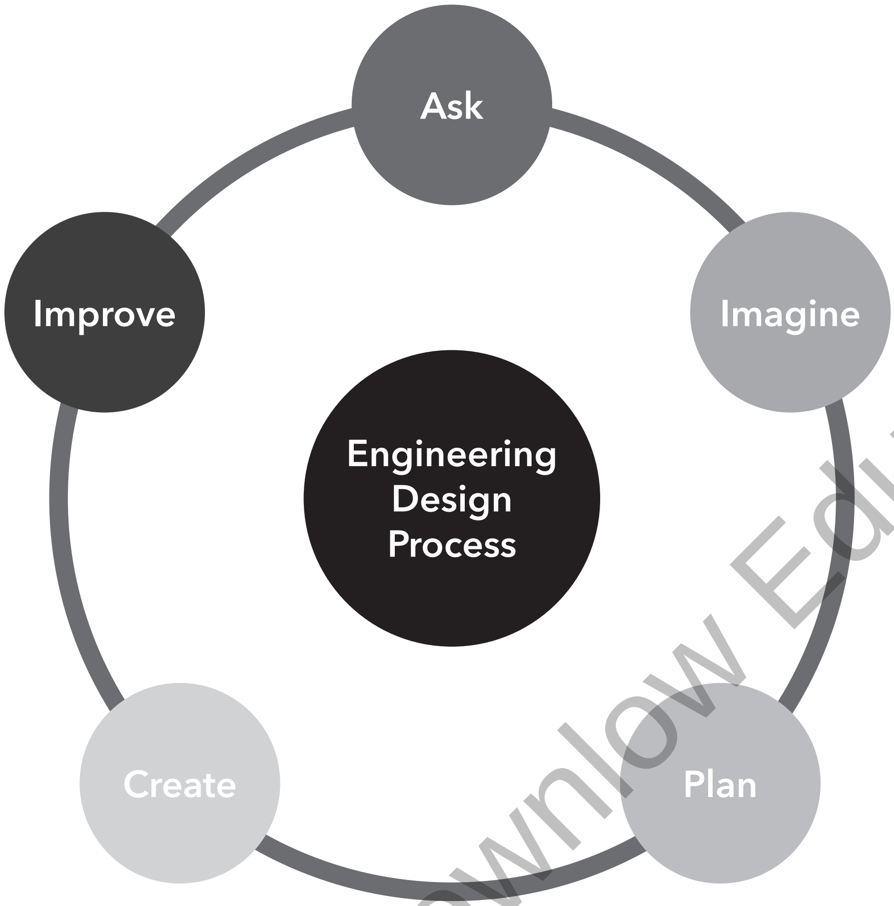

Figure 1. Engineering design process. Adapted from Engineering is Elementary, 2018a.

ORGANISATION OF THE BOOK

Unit 1 introduces students to engineers and their characteristics, job roles and careers. The unit concludes with a challenge to engage students in design thinking using the engineering design process.

Unit 2 provides students opportunities to learn about the branches of engineering and how to become an engineer. A focus in this unit is granting students opportunities to interact with practising engineers through virtual or face-to-face excursion, guest speakers or video (e.g. Skype) sessions.

Units 3–5 immerse students in the practices of engineers. Each unit is based on a theme: Design Cities Like an Engineer, Care for Your World Like an Engineer and Explore Beyond Your World Like an Engineer. In each unit, students will solve real-world problems using the engineering design process: Ask, Imagine, Plan, Create and Improve. There are eight challenges included in these units. You may elect to complete each challenge (or unit), select particular challenges for the class to complete or allow groups of students to choose which challenges they would like to do.

Introduction

Unit 6 gives students the opportunity to demonstrate their learning. Students are encouraged to share and communicate their engineering solutions to a formal audience in the format of their choice. Students will then complete and present activities chosen from a noughts and crosses board to represent their learning progress. Unit 6 concludes with students organising and presenting a living museum. Each student will embody an engineer from one of the branches of engineering.

ASSESSMENTS

I encourage the use of pre- and post-assessments to guide instructional paths for students and measure student progress. Engineering is Elementary (2018b) has developed instruments to measure students' interest and attitudes about engineering as well as their knowledge of engineering (see https://www.eie.org/engineering-elementary/research/research-instruments). I recommend that teachers review these instruments.

Figure 2 is a sample checklist that can be used by teachers during the design challenges. This checklist could easily be converted to a rubric to assess different levels of proficiency. Additionally, each lesson in each unit has a set of Assessment Observations to guide formative assessment strategies.

	Requirements	Yes/No
Ask	Students asked questions to determine the constraints and criteria of the challenge.	
Imagine	Students brainstormed in their groups to discuss possible solutions to their problem. Students listened to other group members' ideas and did not dominate the conversation.	
Plan	Students produced a detailed plan of their proposed design, utilising ideas from all group members.	
Create	Students utilised available resources to construct a prototype or model for their design. Students conducted controlled experiments when appropriate to determine the effectiveness of their design.	
Improve	Students improved their design using data from fair tests and recommendations from others. Students presented their completed designs to formal audiences.	

Figure 2. Engineering design process checklist.

THINKING LIKE AN ENGINEER

When possible, students should conduct controlled experiments when testing their products. Controlled experiments involve the experimenter controlling for other factors that may affect the results. Everything is treated exactly the same except for the substance being tested. The following definitions should be used.

- **Independent Variable:** The variable that is changed by the experimenter.
- **Dependent Variable:** The variable that is changed as a result of the independent variable.
- **Control:** When the independent variable is not changed; the experimenter compares what happens in the control with what happens in the experiment.
- **Constant:** What is kept the same in the experiment.

THINKING LIKE SERIES

This book is one in a series, developed in conjunction with the Center for Gifted Education at William & Mary, intended to develop process skills in various learning areas and enhance discipline-specific thinking and habits of mind through hands-on activities. Each book in the series focuses on a specific discipline.

- In *Thinking Like a Geographer*, students in Years 2–3 develop and practise geography skills, such as reading and creating maps, graphs and charts; examine primary and secondary sources; and think spatially on a variety of scales.
- In *Thinking Like a Mathematician*, students in Years 3–4 engage in exploration activities, complete mathematical challenges and then apply what they have learned by making real-world connections.
- In *Thinking Like an Engineer*, students in Years 4–5 complete design challenges, visit with an engineer and investigate real-world problems to plan feasible engineering solutions.
- In *Thinking Like a Scientist*, students in Years 5–6 use inquiry-based investigations to explore what scientists do, engage in critical thinking, learn about scientific tools and research, and examine careers in scientific fields.

UNIT 1

WHAT IS AN ENGINEER?

RATIONALE

The unit will familiarise students with engineers and their characteristics, job roles and careers. The unit concludes with an introduction to design thinking using the engineering design process.

PLAN

In Lesson 1.1, students will complete a Draw an Engineer Test. This assessment should be readministered after Unit 6 is completed to examine the progress made by students. After completing the test, students will complete a Frayer model in order to develop a definition of an engineer.

In Lesson 1.2, students will read a biography about an engineer. Throughout the unit, students should remember and compare the characteristics of the real-life engineer to their own characteristics as they solve various problems.

In Lesson 1.3, students will be introduced to the engineering design process on a "need to know" basis. Students will be given a challenge to solve before they are provided information about the engineering design process. After completing the challenge, students will reflect on and discuss how their design/solution could be better and what they need to improve it.

LESSON 1.1

WHAT IS AN ENGINEER?

RESOURCES AND MATERIALS

- Lesson 1.1 Draw an Engineer Test
- Sticky notes
- Flipchart paper with blank Frayer model
- Video: "Solve Problems: Be an Engineer!" (https://www.youtube.com/watch?v=D9I35Rqo04E)

ESTIMATED TIME

60–75 minutes

OBJECTIVES

In this lesson students will:

- illustrate an engineer
- compare and contrast various illustrations of engineers
- evaluate roles and characteristics of engineers
- develop a definition of an engineer.

CONTENT

The purpose of the Draw an Engineer Test (Knight & Cunningham, 2004) is to understand and use students' preconceived ideas to help guide instruction. Typically, students will draw engineers as men who fix things.

Working with the Frayer model will allow students to examine the roles and characteristics of engineers through brainstorming, discussion and structured argument.

PRIOR KNOWLEDGE

Skills: compare and contrast, data collection, presentation tools
Vocabulary: engineer, characteristics, example, non-example, career

INSTRUCTIONAL SEQUENCE

1. Distribute Lesson 1.1 Draw an Engineer Test to determine students' existing perceptions of engineers. Instruct students to draw an engineer in an engineer's work environment. You may ask: *What does an engineer do? What does an engineer look like?*
2. After students complete the drawing, divide them into groups of 3–4. Instruct students to compare and contrast their drawings with their group members' by completing the graphic organiser included in Lesson 1.1 Draw an Engineer Test.
3. Have students create a list of shared characteristics that they can all agree on. Students should then develop a new drawing based on their group's consensus. These revised drawings could be completed using regular paper or poster-sized paper. Alternately, students could complete this exercise using a computer or tablet drawing application, such as Sketchpad.
4. Display the new drawings, and ask groups to participate in a gallery walk, noting how other groups' drawings are similar and different.
5. As an alternative to creating a new drawing, students could use an app such as HP Reveal to create a video about an engineer. The original drawing would launch the video; during the gallery walk, students could access the video through the app.
6. Once students have completed their gallery walk, present the video "Solve Problems: Be an Engineer".
7. Present a class Frayer model created on flipchart paper or projected on the board (see Figure 3). In groups of 3–4, students should list roles and tasks of an engineer on sticky notes. Have students add their sticky notes to the class Frayer model.
8. As a class, have students categorise engineering roles and tasks based on identified and agreed-upon criteria. Although students have not yet learned about the engineering design process, look for students to form criteria such as "engineers ask questions", "engineers create and improve", etc.
9. In their groups, have students list examples of engineering titles or jobs (e.g. chemical engineer, electrical engineer, etc.). Have students add their examples to the class Frayer model.
10. Conduct a debate in which students discuss whether or not the examples are correct. For example, students might ask, "Is there an engineer called a virtual reality engineer?" (A virtual reality engineer is a software engineer specialising in virtual reality.)
11. In their groups, instruct students to list non-examples of engineer jobs, such as accountants, bankers and actors. Have students add their non-examples to the class Frayer model poster or drawing.

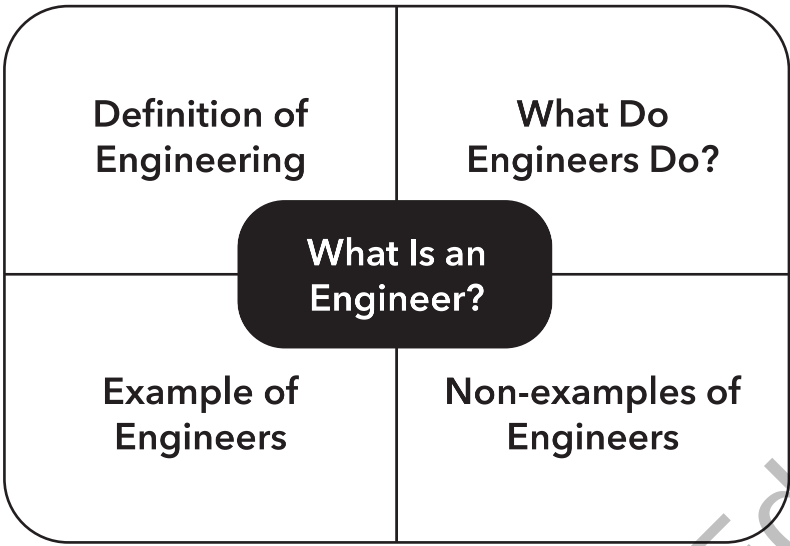

Figure 3. Frayer model example.

12. Then, have students debate whether or not the non-examples are correct. Students may mention that even though certain jobs are limited to engineering, all jobs require problem-solving. They require workers to ask questions, imagine, plan, create and improve solutions. Because students have not yet been formally instructed on the engineering design process, they may not use this specific language, but try to direct them towards this idea.
13. Based on information collected on the Frayer model, have students construct a definition of an engineer (e.g. "a person who uses scientific knowledge to ask and address complex problems and design and create solutions to those problems").

EXTENSION ACTIVITIES

- Conduct an engineering scavenger hunt. Have students hunt for items in the classroom that were engineered to solve problems. Students should list each item and the problem that the product solved.
- Have students work with a partner to brainstorm a problem that could be solved through engineering. Guide students to create a prototype or description of the solution.

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