SeaGlide_TEAM	Engineering Design Process Overview	Lesson #2 (60 minutes)

Description:

Students will learn about the engineering design process by becoming Civil Engineers. As a Civil Engineer, students will take on the challenge of helping a growing community decide where four bridges should be placed. This lesson is the first lesson of a six lesson unit project. Students will use the engineering design process to formulate a solution that fulfills the needs of the community. They will record their process in their engineering notebooks (worksheet handouts) in order to learn the importance of maintaining an organized record of their progress, which is essential for scientific communication.

Students will be able to:

- Define the engineering design process and its steps
- Use the engineering design process to formulate a solution to a problem
- Access prior knowledge to solve a real-world problem
- Research and collect evidence
- Communicate and defend solutions based on evidence
- Keep an organized record of their progress using their engineering notebook

Students will understand:

Engineering projects are hands-on, creative, and problem-solving based. The engineering design process is a process used to generate a solution to an existing problem. A process - like the engineering design process - that involves steps that can be repeated is called an iterative process. In addition, the engineering notebook is an important tool engineers use to keep organized records of every detail of their project. Students will use the steps of the engineering design process and the engineering notebook to tackle challenges and formulate solutions.

Key Definitions & Concepts: [1]

- **Compression**: the act, process, or result of applying power or pressure against an object, causing it to reduce in size, quantity, or volume.
- **Engineer**: a person who is trained in or follows as a profession a branch of engineering and designs and builds things in order to solve problems.
- **Engineering Design Process**: series of steps engineers follow to come up with a solution to a problem [2].
- **Force**:strength or energy exerted to press, drive, pass, or effect against resistance or inertia.
- **Load**: the mass or weight exerted on a surface or body.
- **Prototype**: an early model of a product built to test a concept or process; to act as model on which something is patterned.
- **Suspension**: a force applied that causes an object to stop temporarily.

Standards: [Copied from: 3]

HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

HS-ETS1-4. Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

	Background Information	

Prior Knowledge:

- Using iterative processes
- Logical thinking
- Methodical thinking
- Organizational techniques

Science Practices: [Copied from: 4]	**Core Ideas: [Copied from: 5]**	**Cross Cutting Concepts: [Copied from: 6]**
● Asking Questions and Defining Problems ● Developing and Using Models ● Analyzing and Interpreting Data ● Constructing Explanations and Designing Solutions ● Engaging in Argument from Evidence ● Obtaining, Evaluating, and Communicating Information	● Defining and Delimiting Engineering Problems ● Developing Possible Solutions ● Optimizing the Design Solution	● Patterns ● Cause and Effect ● Systems and System Models ● Structure and Function ● Stability and Change ● Influence of Science, Engineering, and Technology on Society and the Natural World

Possible Preconceptions/Misconceptions:

Since this lesson is designed to be an introductory and overview lesson, instructors should not expect students to experience preconceptions. The lesson is designed in a way to help students thoroughly understand any associated concepts with the engineering notebook, engineering design process, and the implementation in formulating solutions. There should be no outstanding misconceptions with these topics.

	Lesson Plan - 5E(+) Model	

Engage: [7]

The instructor will hand out *The Engineering Design Process* half sheets. Students will watch a short video (Video Link) that talks about the engineering design process and the different ways engineers used this process to create tools that are used in modern society. The students will engage in a class discussion after completing the half-sheet that corresponds to the video. The purpose of this video is to introduce students to the engineering design process and engage them in a brief class discussion of what the process entails and why it is important in engineering. The instructor should mention that, unlike the scientific method, the steps of engineering design process can be described in different ways but follow the same pattern. This section should take about 10 minutes to complete.

Explore:

Part I: Introduction

Building on the discussion held in the engage portion of the lesson, the instructor will introduce the topic of the engineering design notebook. The instructor will pose a question along the lines of "Scientists keep records of their experiments using laboratory notebooks. How do engineers keep track of their ideas?" This will encourage students to think and discuss the different methods used to keep records. The instructor will conduct a class discussion talking about the engineering design notebook and the importance of maintaining a good notebook. This will carry students into the next activity, where they will receive the *Craggy Rock Bridge Challenge* worksheet. Students will work in pairs to complete the first section of the worksheet that involves taking the different steps of the engineering design process and categorizing them into simpler categorizes. The goal of this section is to have students see that the engineering design process does not follow a precise structure (and is often reworded) but follows the same overall goal as the scientific method. This section should take about 10 minutes to complete.

Part II: *Benchmark Lesson*: The Engineering Notebook [8-10]

Students will move on to the main section of the *Craggy Rock Bridge Challenge* worksheet. Students will work in pairs and take on the role of Civil Engineers to work through *The Bridge Challenge* (Website Link). Students will follow the steps of the engineering design process to learn about bridges and their structure. They should read through the *Bridge Basics* (Page Link) and *The Labs* (Labs Link) prior to tackling the challenge in order to learn this various bridge types and the different ways bridge structures are affected by nature and materials. Students will then apply these learned concepts to brainstorm and to choose the best fit bridge for the four different locations. Allow about 10 minutes for the students to read those documents individually. Students will be expected to follow the layout of the engineering design notebook and work through the engineering design process to help record their thinking process. The purpose of this activity is to have students become familiarized with the engineering design process and to assess their work in order to correct and mitigate mistakes. Each student should be responsible for learning how an engineering notebook can be organized through this activity, i.e. each student will be creating and updating their own engineering notebook throughout the Bridge Project (detailed through the next 5 lessons). This section should take about 20 minutes to complete.

Part III: *Investigation Lesson*: Expanding Test and Improve

Once the students have completed the primary section of the activity, they will be introduced to a new problem that has occurred with their bridges. They will be asked to go back to their original process to design a new bridge that meets the new requirements. Students should be able to use what they have learned in their background research to find a solution. The goal here is to have students understand that they can build upon their previous work to come up with a new and/or improved solution instead of starting from the beginning. This section should take about 10 minutes.

Explain:

Throughout the exploration, the students will engage in discussions that inquire their understanding and knowledge of the information at-hand. Teachers will be informally asking students to explain the topics and relevant connections throughout the entirely of this lesson. The worksheets ask questions that require students to engage in high-level thinking, allowing them to verbalize and self-assess their understanding of the material.

Elaborate:

The entirety of this lesson revolves around content that forms the base of engineering design. The students would be primed to understanding the importance of following an iterative process when assessing a problem and designing a solution. This allows the students to be challenged to implement what they have learned into a real-life activity and use the engineering design process to navigate towards a solution while being able to explain and document their thinking process. The exit ticket is designed to have students understand that the engineering design process is incorporated into all engineering projects.

Evaluate:

This lesson is designed to have both informal and formal evaluations throughout its entirety. The informal evaluations occur throughout the engage and exploration because of the leading and open-ended questions and class discussions. This allows instructors to gauge surface-level student understanding. This is done through listening to student conversations and observing how students work through the activity worksheets. During this time, the instructor has the ability to hear and address misconceptions or misunderstandings as necessary. The formal evaluations of this lesson are the *Craggy Rock Bridge Challenge* activity worksheet and the exit ticket. Although the bridge challenge activity gives students a lot of creative freedom, they are expected to explain their decisions. The exit ticket is a 5 minute, individual activity that assesses the students on what they have learned by prompting them to answer situational questions based on the engineering design process.

Enrich:

This lesson could be extended by having students write a scientific research paper. Since the engineering design process is an iterative process and focuses on organizational design, students should be familiarized with planning and conducting background research and primed to learning how to apply those skills to writing. Scientific research papers are the main form of communication in the

scientific community, and it is important to know how to properly conduct research and be able to communicate it.

All associated documents are attached below
Reference *Annotated Bibliography* on the very last page of this packet

Name: _____ Date: _____

The Engineering Design Process [7]

1. What are the steps of the engineering design process mentioned in the video?

   Step 1:

   Step 2:

   Step 3:

   Step 4:

   Step 5:

   Step 6:

   Step 7:

2. What is invention or advancement made by an engineer that used the engineering design process? (Include the name of the invention and the name of the engineer.)

Name: _____ Date: _____

The Engineering Design Process [7]

1. What are the steps of the engineering design process mentioned in the video?

   Step 1:

   Step 2:

   Step 3:

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   Step 6:

   Step 7:

2. What is invention or advancement made by an engineer that used the engineering design process? (Include the name of the invention and the name of the engineer.)

Name: _____ Date: _____
Engineering Partner Name: _____

Craggy Rock Bridge Challenge [8-10]

Introduction: The engineering notebook is an important tool engineers use when working on a project. It is intended to capture vital details of the engineering design process and is an ongoing record of a project. If done correctly, an engineering notebook can be recognized as a legal document that is used in patent activities. Today, you will become a Civil Engineer, and you have been contacted by the mayor of Craggy Rock to help their growing community decide where their four new bridges should be placed. You will use the engineering design process to formulate a solution that fulfills all their needs. You will record your process in your engineering notebook and communicate them to the mayor.

Directions: First, take the different steps of the engineering design process you learned about in the video and categorize them into the simpler categorizes shown below. Then, using the engineering design process, work through the virtual bridge challenge. Make sure to read through the bridge basics and labs in order to learn about the different types of bridges and the several aspects that engineers must consider when designing a bridge. Use the following engineering notebook pages to help guide you through your design process.

The Engineering Design Process Overview

Ask

Identify the Problem:

Specifications: Read through description of each location and identify any important specifications of each location.

- Location 1: Multi-lane bridge for commuters and tourists
- Location 2: Footbridge across a stream
- Location 3: Highway bridge across a busy shipping port
- Location 4: Railroad bridge in a national park

Background Research: Conduct background research by reading through the Bridge Basics and list any important aspect of the different bridge type. Then, work through the four labs to learn about how forces, loads, materials, and shapes affect structures like bridges.

Bridge Basics:

Forces:	Materials:
Loads:	Shapes:

Imagine

Brainstorm: Based on your work in the ask section, brainstorm where each bridge should be placed without testing it. Defend your answers.	
Beam:	Suspension:
Arch:	Drawbridge:

Plan and Create

Directions: Based on your brainstorming, sketch a quick prototype of what the bridge would look like at your chosen location. Make sure to label your sketches!	
Beam:	Suspension:
Arch:	Drawbridge:

Test and Improve

Directions: Test out your plan design and record the results. If your bridge is not the correct match, improve your plan by identifying the mistake and assigning a new bridge for that location. Make sure to write out your entire process.	
Location 1:	Location 2:
Location 3:	Location 4:

But there's a problem...

Directions: Congratulations! You made the best choice for each location. However, a new problem has occurred. It is your job to go back to the drawing board and design a new bridge that solves the new problem.	
Location 1:	Location 2:
Location 3:	Location 4:

Name: _____ Date: _____

Exit Ticket: Engineering Design Process Assessment

1. **In engineering, the design process begins when…**
    a. Information about an existing product is gathered by an engineer.
    b. An engineering design team comes up with ideas for a new product.
    c. A design engineer recognizes the need for a solution to a problem.

2. **The engineering design process is iterative. This allows engineers to…**
    a. Become proficient at different engineering software applications.
    b. Find the most optimal solution to a design problem.
    c. Incorporate both math and science concepts into a design problem.

3. **When engineers develop a model, which step in the engineering design process is taking place?**
    a. Test
    b. Imagine
    c. Plan
    d. Ask

4. **Dany has designed and built a prototype to improve the brake system of her car. What is the next step she should take in the process?**
    a. Test the working prototype.
    b. Evaluate the design for improvement.
    c. Make sketches of the prototype.
    d. Collect and analyze the test results.

5. **Winston has noticed that, when he opens his bedroom door, the door knob hits the wall. He decides to design something to absorb the force of the opening door. He has identified the problem. What is the next step in his engineering design process?**
    a. Set a purpose.
    b. Take notes on his design.
    c. Brainstorm solutions.
    d. Sketch a possible solution.

Name: _____ANSWER KEY_____ Date: _____

The Engineering Design Process [7]

1. What are the steps of the engineering design process mentioned in the video?

   Step 1: define the problem

   Step 2: do your research

   Step 3: develop a possible solution

   Step 4: design your solution

   Step 5: build a prototype

   Step 6: test it

   Step 7: evaluate your solutions

2. What is invention or advancement made by an engineer that used the engineering design process? (Include the name of the invention and the name of the engineer.)

   **Answers will vary but can include any of the following:

   - Alexander Graham Bell - the telephone
   - Alfred Nobel - dynamite
   - Gustave Eiffel - Eiffel Tower
   - Willis Carrier - Air Conditioner

Name: _____ANSWER KEY_____ Date: _____
Engineering Partner Name: _____

Craggy Rock Bridge Challenge [8-10]

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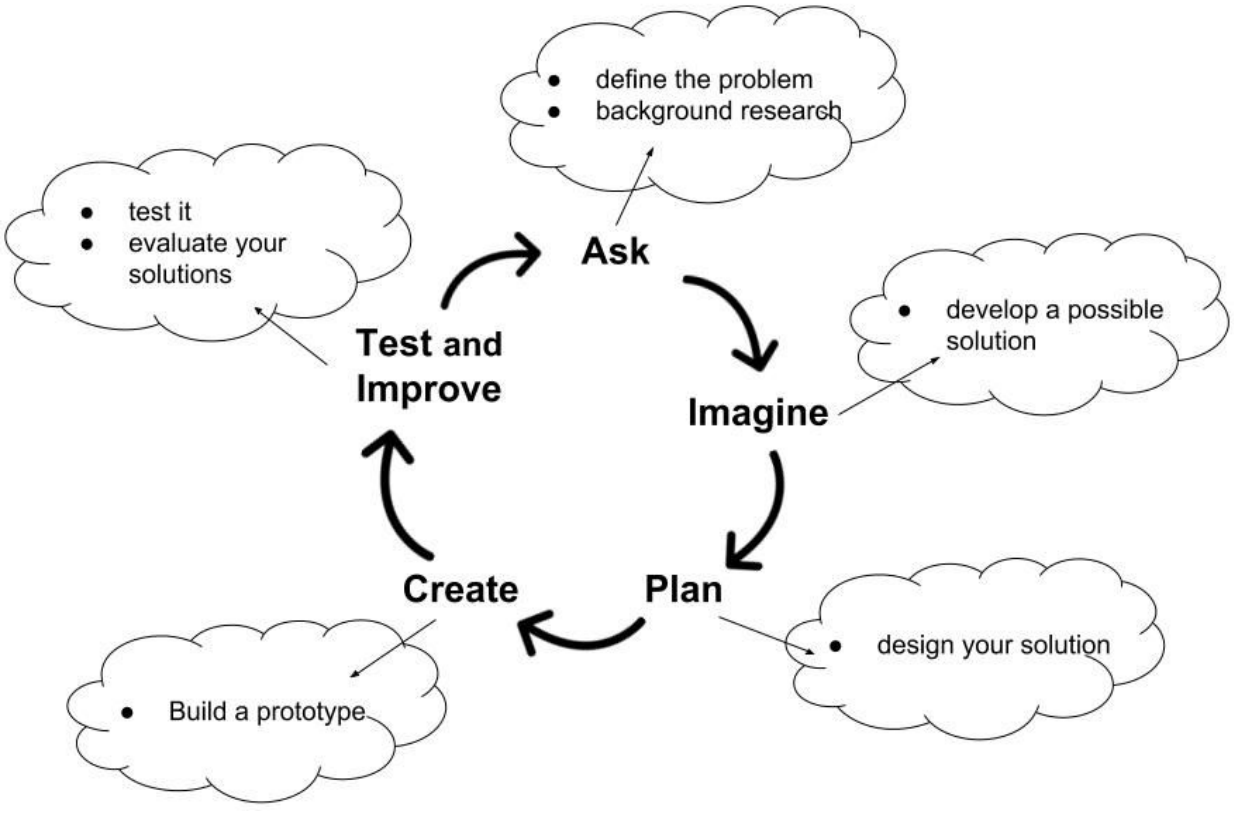
The Engineering Design Process Overview



Ask

Identify the Problem:

The community needs four new bridges that must fulfill all of their picky needs. Each bridge type can only be used once.

Specifications: Read through description of each location and identify any important specifications of each location.

- Location 1: Multi-lane bridge for commuters and tourists
  - 2000 ft span, crosses a river
  - Must leave enough room for sailboats
  - Cannot look like the Golden Gate Bridge or Brooklyn Bridge
- Location 2: Footbridge across a stream
  - 100 ft span, crosses a stream
  - Must be simple and connects 2 bike paths
  - Low cost
- Location 3: Highway bridge across a busy shipping port
  - 5000 ft span, crosses the ocean bay
  - Cannot block water traffic flow
- Location 4: Railroad bridge in a national park
  - 500 ft span, crosses a deep river
  - Must be simple and elegant
  - Cannot have towers or piers

Background Research: Conduct background research by reading through the Bridge Basics and list any important aspect of the different bridge type. Then, work through the four labs to learn about how forces, loads, materials, and shapes affect structures like bridges.

Bridge Basics:

- Considerations: span distance, types of materials
- Beam bridge: horizontal beam supported at end by piers, should not span more than 250 ft.
- Truss bridge: steel bars made into triangles, supported by rigid arms and piers
- Arch bridge: natural strength, made of steel or concrete, can span up to 800 ft.
- Suspension bridge: can span 2000-7000 ft, use a truss system beneath the roadway to prevent twisting and bending

Forces: Students should take notes on compression, squeezing, stretching, bending, sliding and twisting.	Materials: Students should take notes on wood, plastic, aluminum, brick, concrete, reinforced concrete, cast iron, and steel.
Loads: Students should take notes on weight of structures and objects, soft soil, temperature, earthquakes, wind, and vibrations.	Shapes: Students should take notes on how the shape of a structure affects the strength of that structure.

Imagine

Brainstorm: Based on your work in the ask section, brainstorm where each bridge should be placed without testing it. Defend your answers.	
Beam: Answers will vary, focus on supporting details to back up their responses.	Suspension: Answers will vary, focus on supporting details to back up their responses.
Arch: Answers will vary, focus on supporting details to back up their responses.	Drawbridge: Answers will vary, focus on supporting details to back up their responses.

Plan and Create

Directions: Based on your brainstorming, sketch a quick prototype of what the bridge would look like at your chosen location. Make sure to label your sketches!	
Beam: Sketches will vary, focus on labeling.	Suspension: Sketches will vary, focus on labeling.
Arch: Sketches will vary, focus on labeling.	Drawbridge: Sketches will vary, focus on labeling.

Test and Improve

Directions: Test out your plan design and record the results. If your bridge is not the correct match, improve your plan by identifying the mistake and assigning a new bridge for that location. Make sure to write out your entire process.	
Location 1: Results will vary, focus on their reassessment, and following the engineering design process. The final answer should be a drawbridge.	Location 2 Results will vary, focus on their reassessment, and following the engineering design process. The final answer should be a beam bridge.
Location 3: Results will vary, focus on their reassessment, and following the engineering design process. The final answer should be a suspension bridge.	Location 4: Results will vary, focus on their reassessment, and following the engineering design process. The final answer should be an arch bridge.

But there's a problem...

Directions: Congratulations! You made the best choice for each location. However, a new problem has occurred. It is your job to go back to the drawing board and design a new bridge that solves the new problem.	
Location 1: Results will vary, focus on their reassessment process. The final answer should be a cable-stayed bridge.	Location 2 Results will vary, focus on their reassessment process. The final answer should be building deeper piers.
Location 3: Results will vary, focus on their reassessment process. The final answer should be a stiffening/open truss.	Location 4: Results will vary, focus on their reassessment process. The final answer should be steel material.

Name: _____ANSWER KEY_____ Date: _____

Exit Ticket: Engineering Design Process Assessment

1. **In engineering, the design process begins when…**
    a. Information about an existing product is gathered by an engineer.
    b. An engineering design team comes up with ideas for a new product.
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5. **Winston has noticed that, when he opens his bedroom door, the door knob hits the wall. He decides to design something to absorb the force of the opening door. He has identified the problem. What is the next step in his engineering design process?**
    a. Set a purpose.
    b. Take notes on his design.
    c. Brainstorm solutions.
    d. Sketch a possible solution.

Annotated Bibliography

[1] Dictionary by Merriam-Webster: America's most-trusted online dictionary. (n.d.). Retrieved from https://www.merriam-webster.com/

This website was used for adaptation within the Engineering Design Process: Overview lesson plan as part of the Engineering Design Principles module. This reference aided in the completion of providing definitions for the key concepts and definitions sections and for associated worksheets. The key concepts and definitions were adapted based on the grade and activities at-hand.

[2] Science Buddies. (2019). The Engineering Design Process. Retrieved from https://www.sciencebuddies.org/science-fair-projects/engineering-design-process/engineering-design-process-steps

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[3] Nsta. (n.d.). Access the Next Generation Science Standards by Topic. Retrieved from https://ngss.nsta.org/AccessStandardsByTopic.aspx

This website was used in each lesson in the Engineering Design Principles module to select proper national set standards for science subjects that each lesson is centered around.

[4] Nsta. (n.d.). Science and Engineering Practices. Retrieved from https://ngss.nsta.org/PracticesFull.aspx

This website used in every lesson in the Engineering Design Principles module to find Standards for Science and Engineering Practices that are applicable in each lesson.

[5] Nsta. (n.d.). Disciplinary Core Ideas. Retrieved from https://ngss.nsta.org/DisciplinaryCoreIdeasTop.aspx

This website was used in each lesson in the Engineering Design Principles module to select appropriate disciplinary core ideas set forth by the NSTA that are at the center of each lesson.

[6] Nsta. (n.d.). Crosscutting Concepts. Retrieved from https://ngss.nsta.org/CrosscuttingConceptsFull.aspx

This website was used in each lesson in the Engineering Design Principles module to selecting appropriate crosscutting concepts set forth by the NSTA that apply to each science lesson.

[7] Kids, C. C. (2015). The Engineering Process: Crash Course Kids #12.2. Retrieved from https://www.youtube.com/watch?v=fxJWin195kU

This video was used for adaptation within the Engineering Design Process: Overview lesson plan as part of the Engineering Design Principles module. Questions were developed based on this video for students to answer within the engagement and exploration portions of the lesson.

[8] The Bridge Challenge. (2001). Retrieved from https://www.pbs.org/wgbh/buildingbig/bridge/challenge/

This website is an online tool used within the Engineering Design Process: Overview lesson plan as part of the Engineering Design Principles module for students to learn about bridge types and the process used to design a bridge based on location. This reference aided as a resource and used as inspiration for analysis questions designed to correlate with the activity on the website.

[9] Bridge Basics. (2001). Retrieved from https://www.pbs.org/wgbh/buildingbig/bridge/basics.html
This website is an online tool used within the Engineering Design Process: Overview less plan as part of the Engineering Design Principles module for students to learn about examples of various bridge types around the world and gain experience in the process of conducting background research. This reference aided as a resource and used as inspiration for analysis questions.

[10] Labs. (2001). Retrieved from https://www.pbs.org/wgbh/buildingbig/lab/index.html
This website is an online tool used within the Engineering Design Process: Overview less plan as part of the Engineering Design Principles module for students to learn about the various factors that affect the structure of a bridge and gain experience in the process of conducting background research. This reference aided as a resource and used as inspiration for analysis questions.