What's our process?

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<th>High School</th>
<th>Standard(s): HS-ETS1-2, 1-3, 1-4, HS-PS2-1, CCS-ELA.SL.1,2,4 (Optional: CCS-ELA.IT.1,2, &amp; 4)</th>
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<tr>
<td>Topic: Engineering Design Process</td>
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<td>Developed by: ASNE with videos from NASA and Massachusetts DOE</td>
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Overview: A 5-minute warm-up activity has students talking about designing a process. Then, the class will discuss and create the engineering design process for this Club. You could use the optional materials in this plan (NASA videos, an educational diagram) or have a straightforward discussion to accomplish this goal. Students will then use this process to figure out how to work on the bottom of a ship.

Sample Lesson Flow:
- Warm-up (5 min), discussion engineering process (20 min), use engineering process (15 min), exit discussion (5 min)
- Warm-up (5 min), discussion engineering process (25 min), create artifact to document the engineering design process (20 min), use engineering process (40 min), exit discussion (5 min)

Prior Student Knowledge Needed:
- None, but there is an option for literacy-focused schools to assign a reading activity the night before: Massachusetts Engineering Design process and associated literacy questions.

Student Learning Objective:
Understand the cyclical nature of the engineering design model.
Create/Adopt an engineering design model that works for your group.
Design an engineering solution to a complex, real-world problem.

Materials:
- Technology to play YouTube video
- Place for students to record thoughts (notebook/pencil, chalkboard/chalk, poster/art supplies, etc.)
- Permanent place to record your engineering design process (poster, webpage, PowerPoint slide, etc.)
- Access to FLEET Forums to store and share your engineering design plan.
  (Optional, Prior Knowledge Print Massachusetts Engineering Design process and associated literacy questions.)
  (Optional, Step #19 Computers with FLEET installed.)
  (Optional, Step #20 Poster, video, diagram, etc. to document the engineering design process.)

LESSON PLAN – (5-E Model)

Engage
1. Start with a 5-minute Think-Pair-Share:

   How would you engineer a solution to this problem?

Choose one of the big engineering challenges below to spark student’s imagination. You can choose one below or highlight a problem that is local or timely (there is a slide online and a handout on the last page of this lesson that lists these challenges):

   a. The U.S. government paid $13 billion for the most recent aircraft carrier, the USS Gerald Ford. Describe your plan to create an aircraft carrier that could earn you $13 billion!
   b. Sometimes ships have to go across the Arctic Ocean through the ice. They use ice breakers like the Coast Guard Cutter Healy. Create a plan to build a new and improved icebreaker that can travel across the Arctic Ocean.
   c. A local marine biologist wants to explore dolphins that usually swim a couple miles off the coast. She wants to have a glass-bottom boat so that she can watch the dolphins swim and interact. Create a plan that will convince her that you can build the perfect glass-bottom boat for dolphin watching (You may choose to play this glass-bottom boat video on mute while
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students work: https://www.youtube.com/watch?v=XKAU1zoT3WM).

   d. There were no bridges over the Mississippi River until 1856 (literary resource). Using tools and materials available in the 1850s, create a plan to build the first bridge across the Mississippi River.

   e. Imagine NASA will pay someone $25 million to create a machine to gather rocks on Mars. Create a plan that shows how you would get the job done.

   f. NOTE: There is a slide with this information that you could show to students on the computer screen(s) as they enter.

2. These problems are case studies. The goal is to engage students in an engineering process and these experiences will be the heart of the final conversation (Step #15). Circulate the room and remind them they are designing the process to solve the problem, they are not directly solving the problem yet.

Explore

3. Now that everyone has considered designing a process. The conversation will now focus on, How will your group design solutions to problems this year? If your students worry about being incorrect, you could start with a process as outlined in Step #4-12. Or, you could let them brainstorm and research on their topic in small groups.

4. NASA released a series of videos that use 6 simple words to describe a basic engineering design process:
   a. Ask questions
   b. Imagine solutions
   c. Plan possible designs
   d. Create models
   e. Experiment and try out the model
   f. Improve the model by revising it

5. There are six videos below; one for each engineering design process. After each video, ask if students have any questions and then ask them the discussion questions provided (possible answers in parentheses).
   a. Note: If you think these videos will not entertain your students, consider using the optional literary activity about the engineering design process. There is an optional worksheet with guiding questions as well.

6. Ask

   a. Class Discussion Questions:
      i. What engineering question is asked in this video? (how to build a rocket, and lots of sub questions)
      ii. What does “ask” mean to an engineer? (clarifying the problem)
      iii. What is a “limitation” in finding a solution? (things we want to use but don’t have infinite amount of)

7. Imagine

   a. Class Discussion Questions:
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i. What is the “spirit of imagining”? (having a wide range of possible solutions)
ii. What does it mean that ideas are “synergistic”? (they work together)
iii. What does it mean that ideas “build on each other”? (you may hear someone’s idea and add something to it to make it better)
iv. What does it mean that “there are no bad ideas”? (we need to come up with many different ideas that are wildly different)

8. Planning
Link: https://youtu.be/bYxO3iXfu-Y (Length: 2:18)

a. Class Discussion Questions:
   i. Why do we plan? (because time and other resources are limited; to make sure teams work together well)
   ii. How does the video suggest you plan? (sketching)
   iii. Do you agree sketching is the best way for you and your group to plan? (no correct response here)
   iv. What do you change during the experiment phase? (one variable)
   v. What is a test of a sketch? What makes it a “good” sketch? (You can draw something from it)

9. Creating
Link: https://youtu.be/VzVJbGucZw8 (Length: 0:49)

a. Class Discussion Questions:
   i. What is a limitation that you need to work in? (a certain amount of time)
   ii. What should you use from the Planning phase? (sketch)

10. Experiment
Link: https://youtu.be/lCXIhe66pfs (Length: 1:26)

a. Class Discussion Question:
   i. What does experimenting involve? (changing one variable)
   ii. What do you use to compare experiments? (data, measurements)

11. Improve
Link: https://youtu.be/Kt1oVv2D_n (Length: 1:22)

a. Class Discussion Questions:
   i. What are questions that you should ask after the experiment? (What didn’t work? What could work better?)

12. Now discuss the entire engineering design process. How does this process match the plans created in the student case studies? Are there steps in NASA’s design process that a group skipped? Is there a group that designed a plan that does not fit into the NASA model?

13. Tell your class: **Now it is time to decide our club’s engineering process.**
Someone will need to lead the conversation and write down the ideas. The notetaker could be you or a student.
Tell the class the time allotted for this activity (20-30 minutes is recommended). The activity is to
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decide on our engineering process.

a. If there is a disagreement without resolution, remind them that most engineers work in teams and cooperate closely together. If there is still disagreement after 5 more minutes, suggest the class tests out two competing models.

b. If your students quickly choose to adopt the NASA process, ask them to create a definition for each step. Then, ask them how the “Ask” step is different the second time through the engineering process (the goal here is to emphasize the cyclical nature of the process.)

14. Your class has now decided on its own engineering design process to use for the investigations. This could be one of three results:

a. Adopted the NASA model as the process for your group going forward.

b. Modified the NASA model so that it incorporates any new ideas from the group.

c. Created a new model using the students’ language that encapsulates the ideas of being creative, testing and iteratively improving designs.

Explore

15. Now students will explore something they just created, their engineering design process. Hold up a “boat” (the boat could be a coffee cup, a plastic cup, recyclable, etc.). Explain the activity:

This cup represents an aircraft carrier. We need to work on the bottom of it but it’s in water now. You will work together in groups to design a solution so that we can work on the bottom of the aircraft carrier.

16. Possible engineering solutions students may design with probing questions for you to use:

a. Using a crane to lift the boat. Although not cost effective or realistic, this is one solution but not a good one. If a group quickly reaches this decision, ask them to find a more cost-effective solution. (Cost is a common design concern in life and in FLEET).

b. Creating a device that lifts the boat out of the water. (This has been done historically. For example, floating drydocks empty ballast tanks to lift ships.) Groups reaching this decision quickly could be asked to refine their design and consider what is needed to lift the full weight of the aircraft carrier could be lifted using their design.

c. Scuba equipment could be used for small jobs, but the group should consider how this solution affects the tools used and the jobs that could be performed. and steel a scuba diver could handle.

d. Pulling the drain in the sink is an ideal solution—these groups have discovered the drydock. Groups that quickly reach this solution should consider weighs that the sink could be drained in real life.

i. Most drydocks rely on pumps to actively remove the water. Like most sinks the drydocks are designed.

ii. Tides could be used in some harbors to control the amount of water in the drydock, but usually this is not sufficient to completely drain the drydock.

Explain

17. As you circulate, ask groups to explain to you how they are using the engineering design process.

a. You can reinforce the name and goals of each step during these discussions.

18. If you have time, there are two more design considerations that groups will most likely not consider (they can repeat the process in Steps #15-17):

a. What else does the drydock need to ensure the boat is not damaged?

i. Possible answers that mimic real-life solutions:
**What’s our process?**

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<td>A.</td>
<td>The bottom of the sink needs something to hold the ship. Drydocks use structures that center and support the ship.</td>
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<tr>
<td>B.</td>
<td>The water should re-enter the drydock from the bottom (rather than from the faucet above). By slowly filling the drydock with water, ships can be carefully returned to the sea.</td>
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19. (Optional) If your group is excited by the **FLEET** video game, open up the game and show the opening cut screen. This is the drydock where naval engineers work on ships.

20. (Optional) You may wish to create a poster, video, diagram, or any other artifact to record the engineering design process.
   - Students could work together to create one artifact for the class, or work in small groups to create one artifact for their team.

**Evaluate**

21. Summarize today’s work: On Day 1, you talked about plans for million-dollar engineering projects, agreed to an engineering design process, and solved an engineering process. Wow! Ask students to discuss:
   - How does the engineering design process **feel** now that you have used it? (e.g., Did they ask lots of questions? Did they test out each other’s ideas to see if they would reach the goal? Did they create a plan and then go back and improve it?)
   - This final conversation will help students become metacognitively aware when they are addressing engineering design principles in the future.

**Additional Resources**

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| A. | If you want another closing activity, or want to give a hint, play this amazing time lapse video of a real drydock being flooded and the ship returning to sea.  
   - [https://www.youtube.com/watch?v=dw8kvPN0oK0](https://www.youtube.com/watch?v=dw8kvPN0oK0) |
| B. | Throughout your teaching, please use the **FLEET** Forum called “**FLEET** Discussion” as a place to share what works and what you had trouble with ([http://www.navalengineers.org/Membership/Forum](http://www.navalengineers.org/Membership/Forum)). Also, feel free to use that space to list your ideas as a safe space to try out ideas amongst other educators thinking about the same issues. |
| C. | NASA also has an educator-facing overview video of this process (2:45):  
   - [https://www.youtube.com/watch?v=c0wh4GxoL28&list=PLiuUQ9asub3TqAiPRqhOjudMTPeMzwPt&index=6](https://www.youtube.com/watch?v=c0wh4GxoL28&list=PLiuUQ9asub3TqAiPRqhOjudMTPeMzwPt&index=6) |
| D. | If you are interested in a survey of different engineering design principles, see this article published by NASA and Texas researchers: [https://www.asee.org/public/conferences/8/papers/4130/view](https://www.asee.org/public/conferences/8/papers/4130/view) |
| E. | Discovery has a five-minute video about the drydock for Building Maersk’s largest container ship. The simulations are nice, the video discusses the concept of ballast, and the narrator describes the role of the pumps and supports very well: [https://youtu.be/RUfGCngF9DI?t=5m1s](https://youtu.be/RUfGCngF9DI?t=5m1s) |
| F. | At times the U.S. has built floating drydocks that uses some of the same principles. There is a great article on drydocks with pictures at: [http://www.msc.navy.mil/sealift/2005/August/drydock.htm](http://www.msc.navy.mil/sealift/2005/August/drydock.htm) |

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5 Minutes! Think-Pair-Share

Describe a **plan** you would use to accomplish **one** of these tasks:

A. The U.S. government paid $13 billion for the most recent aircraft carrier, the *USS Gerald Ford*. Describe your plan to create an aircraft carrier that could earn you $13 billion!

B. Sometimes ships have to go across the Arctic Ocean through the ice. They use ice breakers like the Coast Guard Cutter *Healy*. Create a plan to build a new and improved icebreaker that can travel across the Arctic Ocean.

C. A local marine biologist wants to explore dolphins that usually swim a couple miles off the coast. She wants to have a glass-bottom boat so that she can watch the dolphins swim and interact. Create a plan that will convince her that you can build the perfect glass-bottom boat for dolphin watching (You may choose to play this glass-bottom boat video on mute while you work: [https://www.youtube.com/watch?v=XKAUlzoT3WM](https://www.youtube.com/watch?v=XKAUlzoT3WM)).

D. Imagine NASA will pay someone $25 million to create a machine to gather rocks on Mars. Create a plan that shows you would get the job done.

E. There were no bridges over the Mississippi River until 1856 ([literary resource](https://www.fleetengineering.org)). Using tools and materials available in the 1850s, create a plan to build the first bridge across the Mississippi River.