Guide Lites

Comparing Science and Engineering Practices Using Black Box Models

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nasaeclips.arc.nasa.gov

National Education Standards

Next Generation Science Standards

SEP1: Asking Questions and Defining Problems

SEP2: Developing and Using Models

SEP3: Planning and Carrying Out Investigations

SEP4: Analyzing and Interpreting Data

SEP5: Using Mathematics and Computational Thinking

SEP6: Constructing Explanations and Designing Solutions

SEP7: Engaging in Argument from Evidence

SEP8: Obtaining, Evaluating, and Communicating Information

Partner

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Universal Systems – Black Boxes

Systems Thinking, the first of eight *Technology and Engineering Practices* (*TEP*) framed by the 2020 Standards for Technological and Engineering Literacy (STEL), describes how parts or components may work together to create an entity that is different from its individual pieces. As described by ITEEA (2020), this systems-way of thinking can be used to solve problems and consider how the big picture may be broken into smaller parts. The ***universal systems model*** is one useful tool for analyzing systems. This approach identifies the impact of inputs, processes, outputs, and feedback mechanisms within the system.

Engineers and scientists routinely represent aspects of the universal systems model as black box models that visualize, from the outside, how the system performs as a whole. The inner workings, or the system inside the box, remains unknown and is described as opaque or "black." Observers try to determine what is happening within the black box based only on visible inputs and outputs.

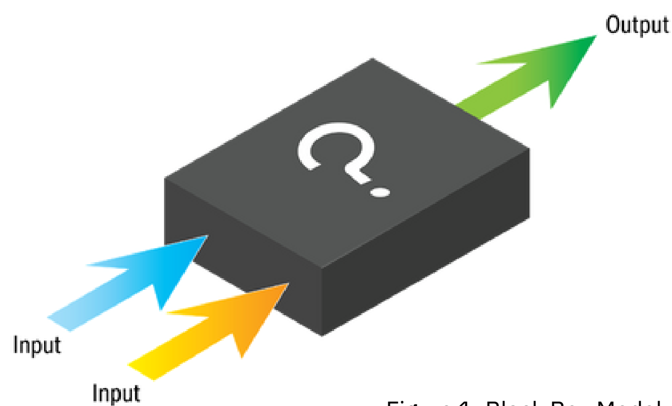


Figure 1: Black Box Model

Did You Know?

The black box models are not to be confused with an aircraft's black box or flight data recorder. As described by the Pilot Institute (2022), an aircraft's black box records an aircraft's flight performance and condition during flight.

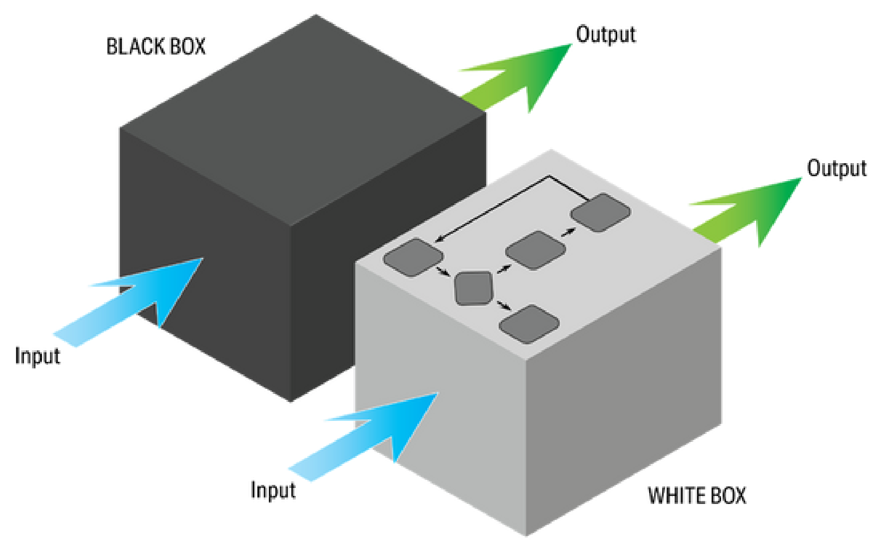


Figure 2: Comparing Black Box and White Box Models

White box models, the opposite of black box models, contain ideas and systems that are more easily understood and transparent. Both types of models may be used in the worlds of science, economics, and engineering.

Create Your Own Black Box

The concept of systems thinking within opaque black boxes is the basis for this activity that compares two black box manipulatives. The simple paper models are used to compare and contrast the different processes inherent to science inquiry and engineering design.

Objective

To build a conceptual understanding of the disciplines and practices of science and engineering using simple black box models as manipulatives.

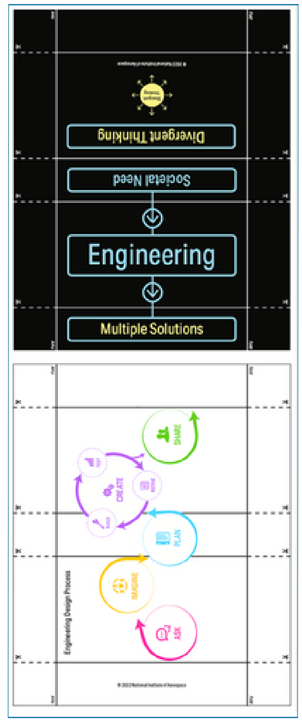
Materials

- Science black box template
- Engineering black box template
- Scissors
- Tape

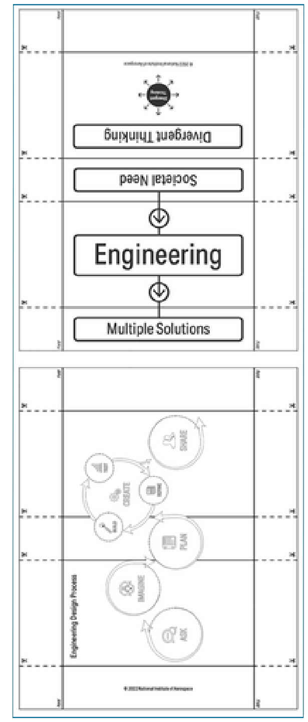
Preparation

1. Create the black box manipulatives using the templates.
    a. Two versions of each template can be found at the end of this Guide Lite.
    b. Blackline versions are included to reduce the use of ink in printing.
2. Print the templates front-to-back so the graphic is on one side and the labels for the box on the other.
    a. If you don't have a printer that prints on both sides of the paper, you will need to print one-sided and tape the templates together.
3. Follow the instructions for cutting and folding the lines of the template.
4. Tape all corners to create a small paper box with the graphic inside the labeled black box.

Engineering Black Box Template



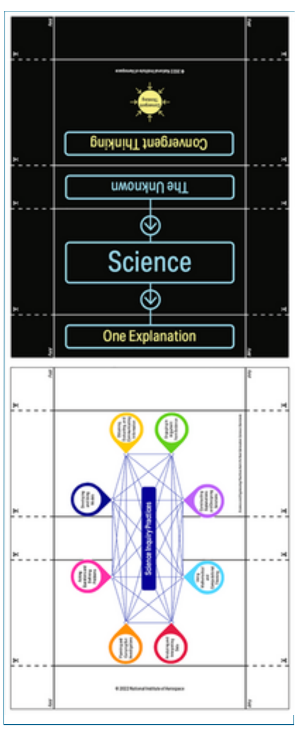
Engineering Template
With Color



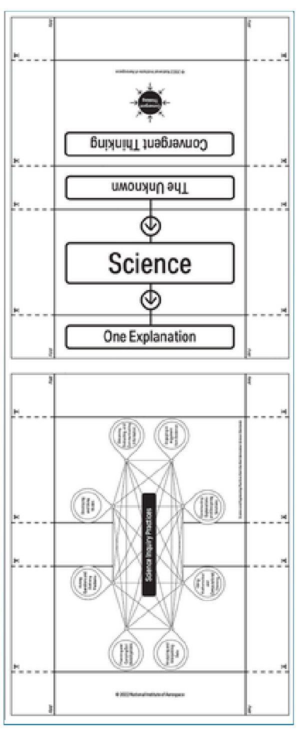
Engineering Template
Blackline

Figure 3: Engineering Black Box Templates

Science Black Box Template



Science Template
With Color



Science Template
Blackline

Figure 4: Science Black Box Templates

Engage

NASA Launchpad "Engineering Design to Support Scientific Discovery"

This video was produced before the launch of the James Webb Space Telescope December 25, 2021 and features a discussion between Stefanie Milam, the Deputy Project Scientist for the Webb Telescope and Begona Vila, one of the Webb Instrument Systems engineers.

https://nasaeclips.arc.nasa.gov/video/launchpad/launchpad-engineering-design-to-support-scientific-discovery

After watching the video, lead a discussion about attributes of scientists and engineers. Discuss how scientists and engineers collaborate. *How is their work similar and different?*

Explore

Continue the discussion using the paper black boxes. Hold up the two black boxes and compare the top panel. One box has "Science" on top. The other has "Engineering" on top.

Inputs: Ask the group to describe what "drives" science and what "drives" engineering. These are inputs for each system. The inputs are on one side of each box.

One input, or driving force for science is the quest to *discover* the unknown; to find answers for questions about the natural world and the unknown. *Are there other possible inputs that drive science?*

One input or impetus for engineering is working to find solutions for a *societal need*. *Are there other possible inputs driving engineering?*

Outputs: Ask learners to describe the *outputs* for each system. Each box has a different output marked on one side. One output for the process of science is synthesizing discoveries into *one explanation*. Science seeks to explain the unknown. This kind of thinking is *convergent thinking*; thinking that tries to focus on finding one explanation. Convergent thinking is marked on the bottom of the science black box.

One output for engineering is generating *multiple solutions*. Engineering design is fueled by *divergent thinking*; thinking that creates many possible solutions. Divergent thinking is marked on the bottom of the engineering black box.

Explain

The two black boxes can be used to help frame a conversation about the processes and conceptual similarities and differences between science and engineering.

The manipulatives are not road maps or guides, but tools to open doors for discussion.

From the outside of each box, learners see:

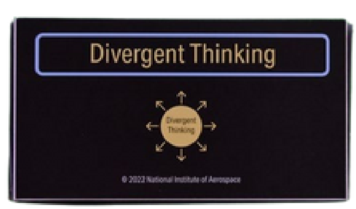
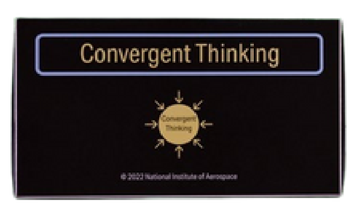
	Boxes	
	Engineering	Science
Inputs	 Societal Need	 The Unknown
Outputs	 Multiple Solutions	 One Explanation
Thinking	 Divergent Thinking	 Convergent Thinking

Figure 5: Comparing the Black Boxes

The logical next question is *what processes, or systems, are hidden inside the boxes? What happens between the inputs that leads to the observable outputs?*

The eight Science and Engineering Practices (SEP) outlined within the Next Generation Science Standards (NGSS) are graphically depicted inside the science black box. An engineering design process is graphically represented within the engineering black box.

Hold the open boxes, side-by-side, to discuss how NGSS SEP and the engineering design process are similar and different.

- *What are similar skills or practices?*
- *How do these processes differ?*
- *Why are both important?*

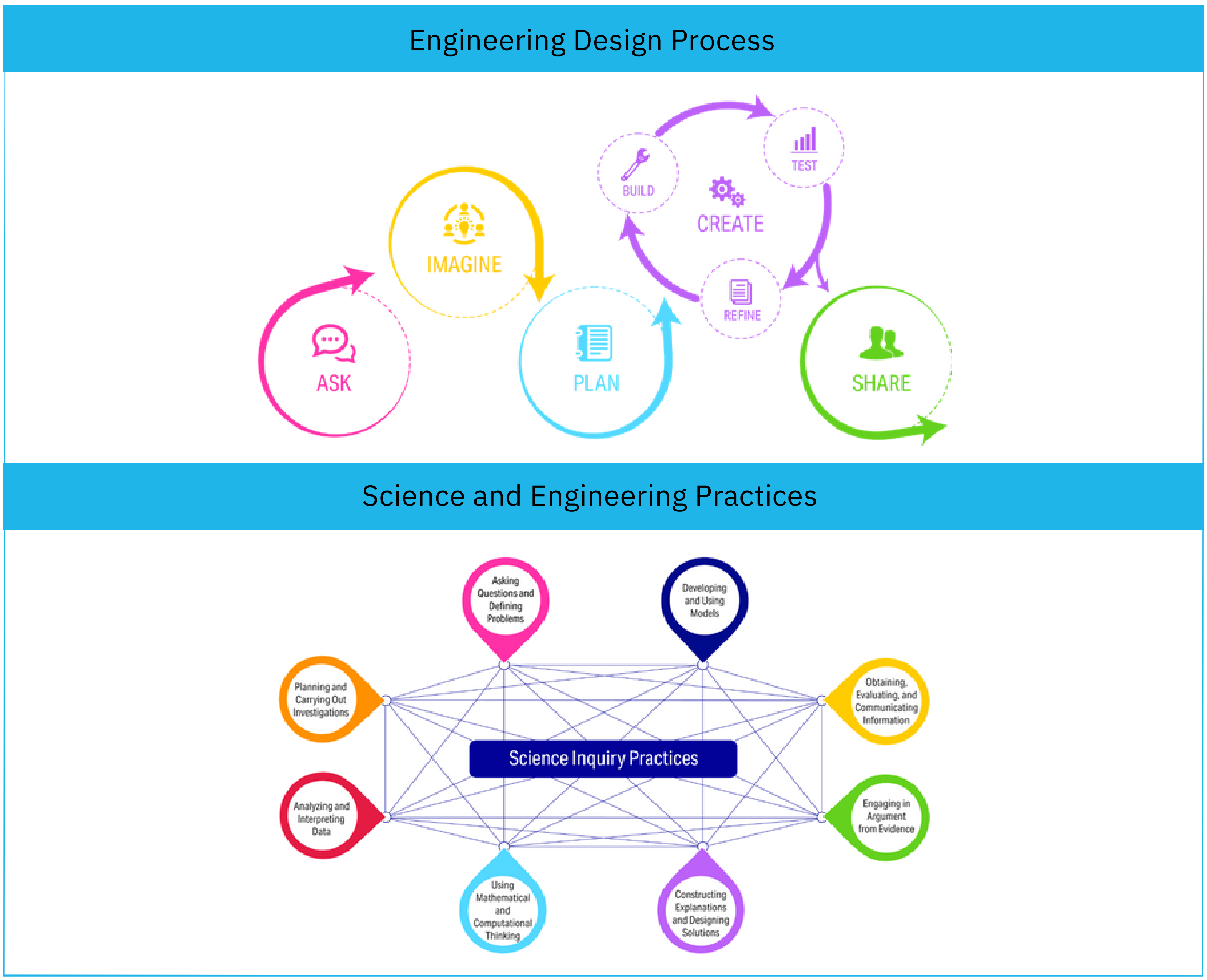


Figure 6: Comparing Engineering Design to Science Inquiry

Elaborate

Our World “Systems to Grow Plants in Space”

Gioia Massa, a Life Sciences Project Scientist, and Jacob Torres, a Technical & Horticultural Scientist, discuss the science and engineering intertwined within systems that help plants grow in space.

https://nasaeclips.arc.nasa.gov/video/ourworld/our-world-systems-to-grow-plants-in-space

After watching the video, lead a discussion comparing science and engineering. Discuss how science and engineering work together to help NASA and others solve problems and meet challenges.

Evaluate

Ask learners to apply the universal systems model, as demonstrated through the science and engineering black boxes, to a recent science or engineering experience.

For example, ask learners to identify a recent science inquiry experience, such as wanting to grow healthy plants and experimenting to see how different soils impact plant growth.

The discussion could reinforce this kind of thinking:

- Input for Science (The Unknown): What is needed to grow a healthy plant? One variable is soils.

- Hidden Practices for Science (NGSS Practices): Create an experiment to test different soils. NGSS Practices might include:
    - Asking Questions and Defining Problems
    - Planning and Carrying Out Investigations
    - Analyzing and Interpreting Data
    - Constructing Explanations and Designing Solutions
    - Engaging in Argument from Evidence
    - Obtaining, Evaluating, and Communicating Information
- Output for Science (One Explanation): After testing several different soils, what evidence do you have that results in identifying the best soil for plant growth?

Lead a similar discussion around a recent engineering experience. For example, ask learners to design the best portable plant growth chamber.

The discussion could reinforce this kind of thinking:

- Input for Engineering (Societal Need): Design a portable plant growth chamber that could sit on a small desk.
- Hidden Practices for Engineering: Work through this process to design and build a prototype:
    - Ask: What are we trying to design? What has been created by others already?
    - Imagine: Brainstorm ideas.
    - Plan: Select the best ideas based upon criteria (what does the plant growth chamber need to do) and constraints (what are your limitations).
    - Create: Build, test, and refine your design.
    - Share: Share your design with peers.
- Output for Science (Multiple Solutions): Share the different designs for the portable plant growth chamber.

With practice, learners will build their conceptual understanding of science inquiry and engineering design. The black box manipulatives may be used within learning environments addressing interdisciplinary technology, engineering, and science. The models help learners compare and contrast the processes inherent to each discipline.

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Divergent Thinking

Societal Need

Divergent Thinking

Engineering

Multiple Solutions

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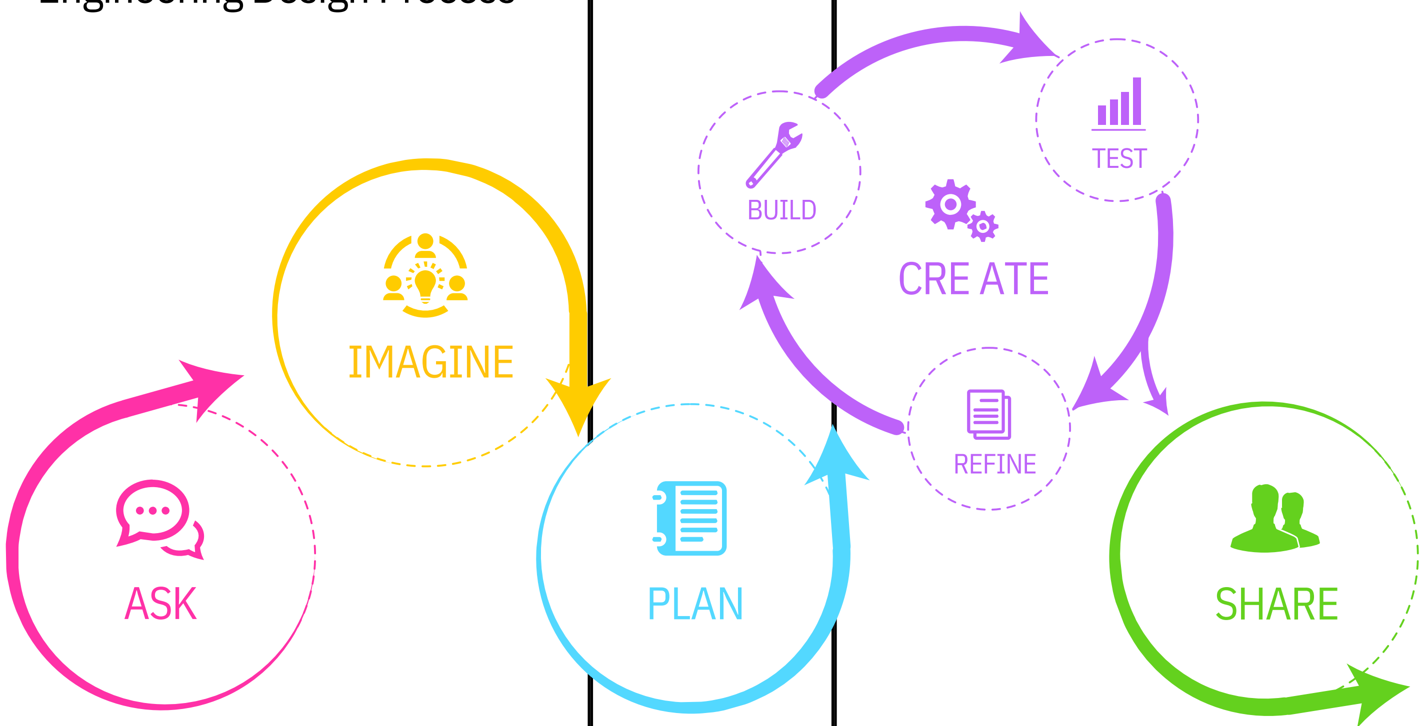
Engineering Design Process



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Divergent Thinking

Societal Need

Divergent Thinking

Engineering

Multiple Solutions

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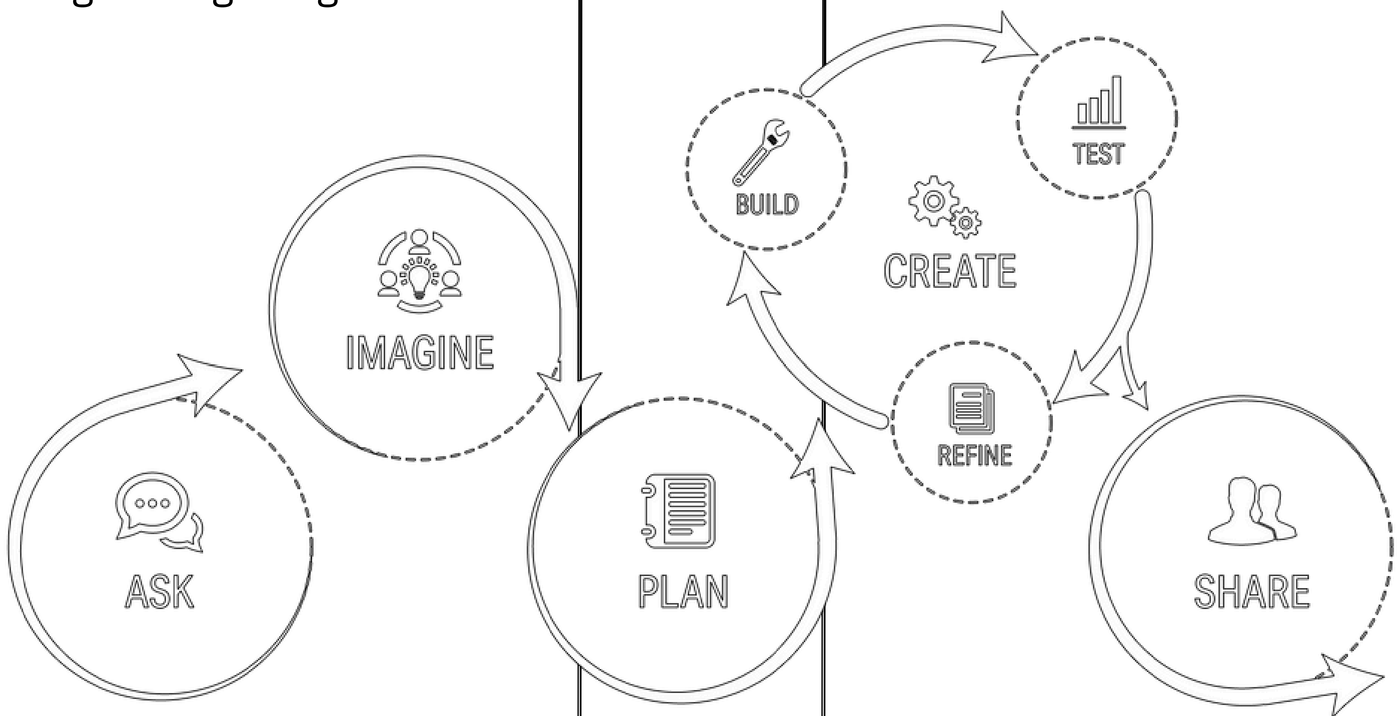
Engineering Design Process



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Convergent Thinking

The Unknown

Convergent Thinking

Science

One Explanation

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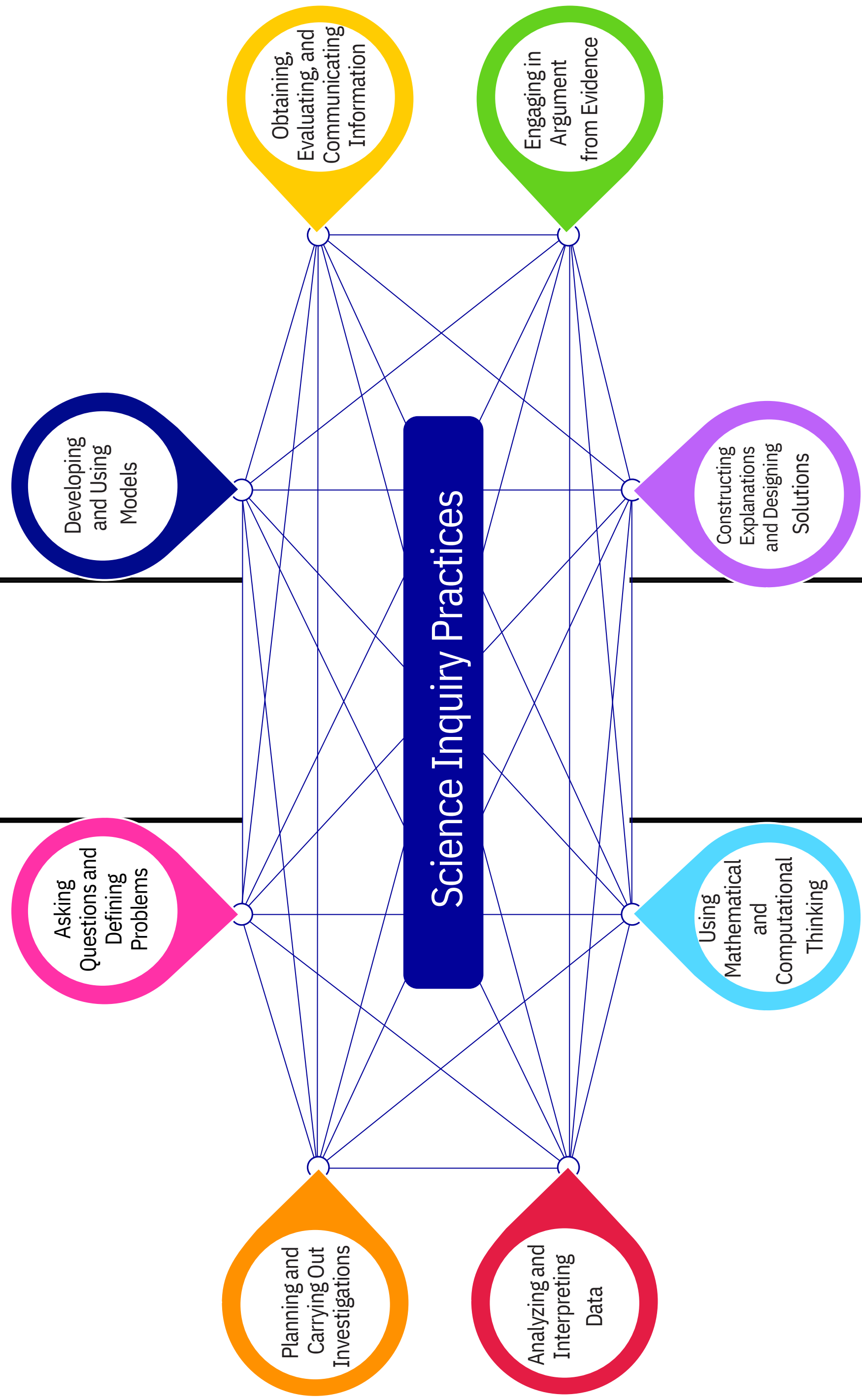

Science and Engineering Practices from the Next Generation Science Standards

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The Unknown

Convergent Thinking

Science

One Explanation

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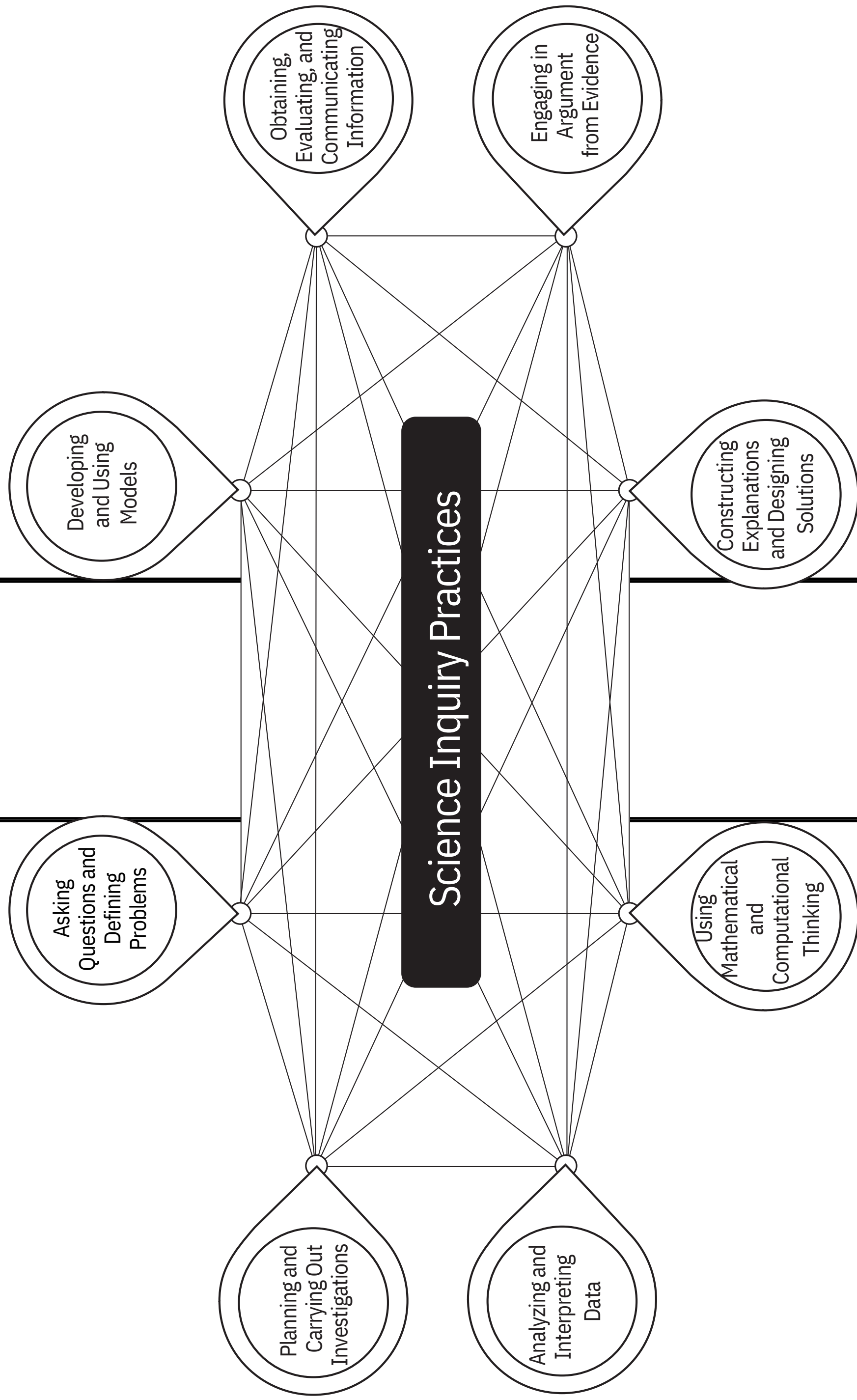

Science and Engineering Practices from the Next Generation Science Standards

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