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Engineering Design Activity Guide

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Objectives

These activities will enable students to:

- Describe the steps of the Engineering Design Process
- Contrast the Scientific Method with the Engineering Design Process
- Apply the steps of the Engineering Design Process to the building of an item

Standards

This lesson aligns with the following National Science Content Standards (NGSS):

- MS-ETS1: Engineering Design
- MS-ETS1-1: Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution.
- MS-ETS1-2: Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

Related Standards

The extension activities may address Next Generation Science Standards:

- MS-ETS1-3: Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.
- MS-ETS1-4: Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

Throughout this document, black text indicates optional talking points, green text indicates actions/tasks for the instructor that support the talking points for the instructor.

Introduction

Welcome to this exciting journey through the world of engineering design! Whether you're a budding engineer, a curious individual, or just someone who enjoys tinkering with ideas, this lesson promises to be both enlightening and fun.

What Is Engineering Design?

At its core, engineering design is the art and science of creating solutions to real-world problems. It's like being handed a puzzle—a complex, three-dimensional puzzle with missing pieces—and your job is to invent those missing pieces. Think of it as the ultimate brain teaser, where creativity and logic collide.

How is Engineering Design different from the Scientific Method?

The purpose of the Scientific Method: To understand natural phenomena, uncover fundamental truths, and expand our knowledge. Scientists come up with a hypothesis, perform experiments, collect and analyze data through the steps of the scientific method to prove or disprove the hypothesis.

The purpose of Engineering Design: To create practical solutions for real-world problems. Engineers start asking "What is the problem?" brainstorm solutions, plan and build a solution, then improve upon that solution.

Scientists ask 'Why?' to seek understanding and expand their knowledge. Engineers ask, 'What or How?' to find solutions to real-world problems. Engineers are problem solvers.

Optional Activity

To support students' experiential understanding of the usefulness of the Engineering Design Process, you can have a hands-on building challenge accompany this. See the next section for the recommended process that could accompany this activity guide and slide deck. Choose an activity that involves building something with a set of limited materials, requires teamwork, and has a restricted amount of time. Two options are listed below.

Options for build task:

- Rubberband Racers - Rubber Band Racer — Rubber Band Car Activity – TeacherGeek
- Wigglebot - Art Bot: Build a Wobbly Robot That Creates Art | Science Project (sciencebuddies.org)

Phase 1: Pre-Engineering Design Challenge

1. **Group Formation**: Divide students into small groups.
2. **Limited Instructions**: Provide minimal guidance on the task. For example, “Build a bridge using only these materials: straws, tape, and paper.”
3. **Time Constraint:** Set a strict time limit, such as 30 minutes, to complete the build.
4. **Observation:** Allow students to work through the challenge, observing their problem-solving and teamwork skills.

Phase 2: Teaching Engineering Design – use the ‘Engineering Design Overview’ slide deck

1. **Introduction to Engineering Design:** Explain the steps of the engineering design process using the provided slide deck.
2. **Examples and Discussion:** Show real-world examples and discuss how engineers use this process.

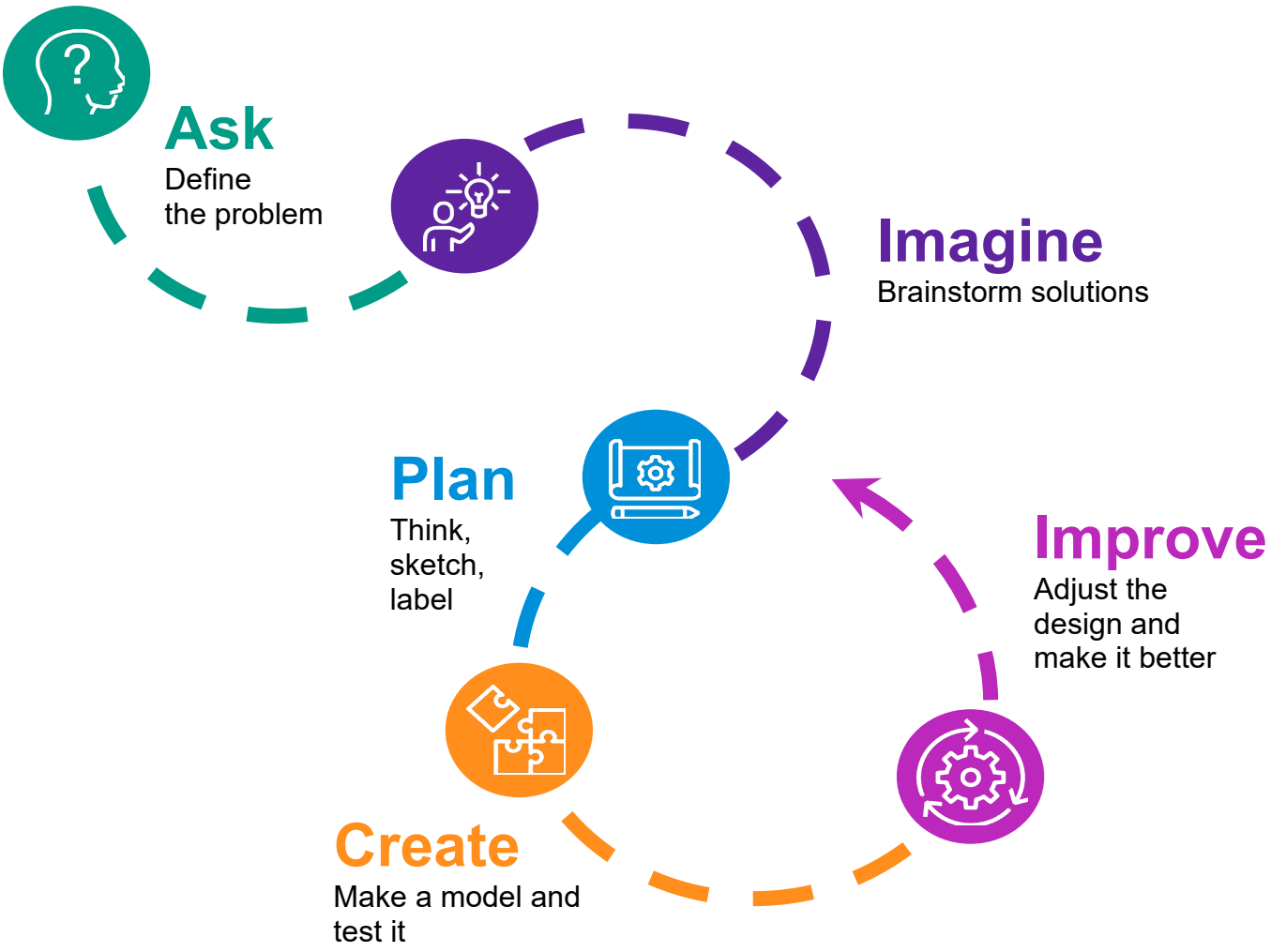
Phase 3: Post-Engineering Design Challenge – use the ‘Engineering Design WiggleBot’ slide deck

1. **Rebuild with Process:** Have the same groups rebuild the item, this time following the engineering design steps.
2. **Documentation:** Encourage students to document each step of their process.
3. **Presentation:** Have each group present their design, explaining how they applied the engineering design process.
4. **Reflection:** Facilitate a discussion on the differences between the two builds and what they learned.

Benefits of This Approach

- Hands-On Learning: Students engage actively with the material.
- Critical Thinking: Encourages problem-solving and iterative thinking.
- Teamwork: Promotes collaboration and communication skills.
- Real-World Application: Helps students understand how engineering principles are applied in real life.

Explore the Engineering Design Process



Engineers work in teams to solve problems, they rarely work alone. The steps in the diagram can be applied to a wide variety of technical and real-world problems and challenges. We will discuss how the teams will approach each step.

The following pages align with each slide for each step of the Engineering Design process. Engage students in discussion about how each step can be applied to a real-world example. Use one example throughout or consider multiple examples.

Ask "Define the problem"

The Ask step is where your team clearly defines the problem. It is important to clearly define the problem so everyone on your team understands what you are working together to accomplish. Take time to ensure everyone understands the problem the team needs to solve, or the challenge to be met.

Q: What will happen if just one person on your team does not understand the problem or challenge? Or each person has a different idea of what the problem, or challenge, is?
A: Pause, allow silence and space to think. Take enough time to get a number of different answers from the students. The teamwork will not work well, because not everyone is working toward the same goal

The first step is to have your team discuss all aspects of the problem or challenge. Be sure everyone on the team has the opportunity to contribute to the discussion.

Q: What is a requirement?
A: Something that is essential for the solution to a problem.

Q: What is a limitation?
A: A restriction or a rule.

Have some real-world examples of problems that have been solved.

One example is from the Apollo 13 mission, which was highlighted in the movie, when there was a leak that had to be plugged with a set of random materials.

Requirement: plug the hole to stop the leak of Oxygen
Limitations: time & materials

As your team discusses, be sure to ask questions of the activity leaders to clarify parts of the problem you or members of your team still don't understand. It may be necessary to ask your activity leaders to help resolve disagreements if members of the team are not able to come to agreement on what problem they are being asked to solve.

Imagine ”Brainstorm solutions”

The Image step is where your team brainstorms a bunch of solutions. This is the time to be creative and even come up with crazy ideas to address the problem or challenge. Brainstorm and discuss any and all possible solutions with your team. Have the team write down all the ideas with a brief description, so no ideas are lost. You can write one idea each on small pieces of paper or post it notes. Or capture everything on a larger paper.

Each person on the team should take some time to think about a similar problem they have solved in the past. Expand your thinking outside of the obvious to see where there might be some similar experiences. If someone on the team has a related experience, have them share and explain how it relates to the current problem or challenge.

Share some examples of solutions to similar challenges

- When the challenge involves building a circuit, think about when you have used a flashlight and what happens of one of the batteries is bad or installed in the wrong direction.
- When the challenge involves building a structure, such as a bridge or a tower, consider unique bridges or tall buildings you have seen around the world.

Q: Has anyone had an experience with brainstorming that went well?
A: Ask if any of those with hands raised would explain & take time for 2-3 to share.

Q: Has anyone had an experience with brainstorming that did not go well?
A: Ask if any of those with hands raised would explain & take time for 2-3 to share.

Bringing a diverse set of ideas together can help come up with a better overall solution. Build on ideas among members of the team to create new solutions. Team members should not be defensive if their idea is not embraced by the entire team.

Q: Has anyone had an experience where the ideas that came out of a group working together was better than the ideas of one specific person?
A: Ask if any of those with hands raised would explain & take time for 2-3 to share.

There is no need to limit the ideas during this step in the Engineering Design Process. This is the time to share all the ideas of the group. You will have to narrow down to one solution in the next step, so this is the time to let the creativity flow. That said, you can eliminate ideas that no longer make sense to the team.

Plan ”Think, sketch, label”

The Plan step is where your team thinks through and fully defines the solution. Now the team must get focused on how to solve the problem or challenge. The team can still be creative, but it may be time to drop the ‘crazy’ ideas. This is the time to narrow down to what the team believes are the most reasonable and effective solutions. It may be hard for your team to narrow down to one solution, so good communication skills, including listening, are important.

If the team is not in agreement on one or two solutions, encourage individuals sketch rough diagrams of the possible solutions. If sketching isn’t preferred, then help them create detailed written descriptions. Activity guides can help teams consider combining 2-3 ideas into a new concept that could address the problem or challenge. Team members may be very attached to their own idea, yet often some ideas can be very similar or can build on one another.

Q: What might happen if the team does not agree on one final solution before moving on to the create/build step?
A: There will be misunderstandings and wasted time. The team may not actually solve the problem or meet the challenge.

Once narrowed down to just one or two solutions, the team will list the necessary (or provided) materials and label how each item will be used. Be aware of the time available, as it may cost some valuable minutes for the team to spend too much time debating the details of more than one solution.

Ultimately your team agrees on one solution to build. Plan how everyone will be involved in the building process and write down the steps required to build the solution. Plan the proper order of the steps and write that detail down along with the steps.

If the team is having a hard time working together, it may require an adult leader to step in to direct some of the planning.

Q: What is the advantage of taking the time to plan out the steps and what each person will do before building?
A: It will allow the team to work smoothly and take less time to build the final solution.

Create ”Make a model and test it”

The Create step is where your team will finally build the solution. Consider the first build a model, because with the Engineering Design Process there will be opportunities to update and improve. Be sure to stick with the plan and roles agreed to by the team. While building there may be some changes to the plan, and it is important to document those changes and be sure all the team members understand the changes.

There can be a tendency for just one or two people on the team to take over most of the tasks. Leaders help to ensure everyone participates and contributes. If one member of the team decides not to participate in the build, then that person will be assigned the ‘quality control’ role to test out how the model works.

Consider how to test the model in a variety of ways. While some team members are building, other team members can be planning how to test the model. There are engineering jobs where people are tasked with creating conditions that would potentially break the model.

Once the model is built, it is time to test it and analyze the results. The purpose of testing the model is to confirm that it solves the problem. If the model breaks down, take steps to understand what went wrong. Allow the teammates that spent time planning the testing to try the model out in different ways. Document what could be changed, but don’t make any changes yet.

Improve ”Adjust the design and make it better”

The Improve step is where your team can adjust and make the model better. Consider what went wrong during the testing in the Create step. Discuss with your team about what changes can be made to solve for those problems.

Consider the original plan and each step the team identified in the Plan step. Discuss where one or two steps identified in the Plan step could have been done differently to avoid some of the problems found during the Create step.

Q: Does the team know more or less about the problem or challenge after completing the first model?
A: Everyone should have a better understanding.

Consider what has been learned during the previous Plan and Create steps. Discuss what additional information is available to help improve the model / solution

Iterate

continuous improvement

This is the opportunity to improve on the team's concept. You get to repeat the Plan-Create-Improve steps of the Engineering Design Process. Create a new model or improve on the original model to create a better solution to the problem.

Q: What is the advantage of repeating these steps?
A: Build on the learning experience. Consider ideas that the team decided not to explore. Seek out more information needed to better address the problem.

Adult leaders ensure full team member involvement. Notice any tendency for just one or two people on the team to take over most of the work. Support engagement of the outspoken individuals and encourage quieter members to participate more fully.

Consider your cell phone, first developed in 1973. The original cell phones were just phones, with no cameras or touch screens, and weighed around 2.5 pounds. In the 1990s cell phones were much smaller and became popular. Over time the cell phone companies iterated on the design, adding basic cameras, screens and speakers were added. Now, your cell phone is a full computer that has 1 million times more memory and 100 hundred thousand times the processing power of the computer used for the first moon landing in 1968.

Next phase may be to introduce an engineering challenge that will be solved walking through the steps of the Engineering Design Process.

WiggleBot – Slide Deck titled 'Engr Design Build WiggleBot'

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