BE AN ENGINEER!
DESIGNING TO SOLVE PROBLEMS

The Be an Engineer! Designing to Solve Problems series gives readers an in-depth look at how engineers tackle real-world problems.

Each book includes a hands-on project that provides readers with an opportunity to design, build, and/or test the title-specific structure. In addition, a code printed in the back of each book provides access to supplemental online content. This guide reinforces the big ideas and main concepts that are common across the series, and connects the Engineering Design Process with its real-world uses.

Use this guide to engage readers as they learn how engineers use the design process to solve problems. Readers will also learn about the criteria engineers consider when designing safe and stable structures to meet the needs of specific environments.

Participation in these lessons will help students understand the steps in the Engineering Design Process. They will acquire the skills needed to take on challenges, carefully consider options, and test ideas to determine the best solution for a specific problem.

The lesson plans in this guide are tailored for grades K-3 with varying levels of support, and cover science and engineering standards. They are aligned to Next Generation Science Standards and provincial curriculum expectations—all noted on each lesson plan. Each lesson plan is designed to stand alone. As such, they do not need to be presented in sequential order. Helpful reproducible worksheets appear at the end of this guide. The following titles are referenced throughout this guide:

A TUNNEL RUNS THROUGH
A SKYSCRAPER REACHES UP
A DAM HOLDS BACK
A BRIDGE GOES OVER

As students investigate the topics addressed in the guide and become more knowledgeable about the Engineering Design Process, they will sharpen their problem solving and critical thinking skills.
In addition to this guide, the following learning materials are available:

- **Investigations and Projects**: Each title in the Be An Engineer! series includes a hands-on activity that provides readers with an opportunity to design, build, and/or test the title-specific structure.

- **Digital Materials:** A code printed in the back of each book provides access to Crabtree Plus—a safe, online learning environment with supplemental digital content, including simulations and interactive activities that reinforce and extend key series concepts.

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The Engineering Design Process

Curriculum Correlations:

Correlation to Next Generation Science Standards

4-3-5 Engineering Design. Students who demonstrate understanding can:

3-5-ETS1-1	Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
3-5-ETS1-2	Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
3-5-ETS1-3	Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

Correlation to Ontario Science Standards

Understanding Structures and Mechanisms. By the end of Grade 3, students will:

1.	Assess the importance of form, function, strength, and stability in structures through time;
2.	Investigate strong and stable structures to determine how their design and materials enable them to perform their load-bearing function;
3.	Demonstrate an understanding of the concepts of *structure*, *strength*, and *stability* and the factors that affect them.

Learning Objectives:

This lesson is designed to reinforce and extend students' understanding of the Engineering Design Process and how it applies to real-world problems.

Prerequisites:

Students should read the books from the series *Be an Engineer! Designing to Solve Problems* to familiarize themselves with the different steps in the Engineering Design Process.

Multiple Intelligences:

The following intelligences will be activated throughout the lesson:

- Bodily-Kinesthetic
- Logical-Mathematical
- Visual-Spatial
- Interpersonal

Materials:

- One Engineering Design Process tracking sheet (appendix i) per group
- Cardboard
- Straws
- Glue
- Scissors
- String
- Paper clips
- Popsicle sticks
- Tape
- Rubber bands
- Cups
- Pipe Cleaners
- Craft Foam
- Optional: Engineering Design Process image (appendix ii)

Creative Inquiry

Setting the Stage

Pose a question to the class that outlines a problem observed in the classroom. For example, perhaps there is one area of the room that requires better organization. Teachers could also provide a real-world scenario or have the class come up with their own problem to solve. Lead the class in a brainstorming activity to come up with different problems to be solved. (*Tip: It would be helpful to set criteria for the problem, such as: the solution must benefit everyone in the class.*) Once the problem has been determined, write it on a chart paper or in a largely visible area so the students will be able to reference the problem throughout the process.

Activity

Next, explore the steps to the Engineering Design Process. You can make anchor charts for each step and/or print out the provided Engineering Design Process image to hand out to students (appendix ii). Explain that the Engineering Design Process is used by engineers and other thinkers to solve problems and meet needs.

Discuss each step:
1. Ask: Ask questions to gather information about the problem you are trying to solve.
2. Brainstorm: Work with a group to come up with different ideas to solve the problem. Choose the best solution.
3. Plan and make a model: Create a plan to carry out your solution. Draw a diagram and gather materials. Make a model of your solution.
4. Test and Improve: Test your model and record results. Using the results, improve, or make your design better. Retest your improved design.
5. Communicate: Share your design with others.

Have these steps in highly visible areas for the students to refer to as they work through the problem. They can also refer to page 9 in one of the books from the *Be an Engineer! Designing to Solve Problems* series.

Place the students in groups and tell them they must use the Engineering Design Process to come up with a solution to the problem. They can record their ideas on the Engineering Design Process tracking sheet (appendix i). They will be able to work through steps 1, 2, and part of 3 before they need to start gathering supplies. Once the groups are ready to gather supplies, they will need to make a list of what is available in the classroom, and a list of what they will need to bring in. Make sure the items they are planning to bring in from home or to retrieve from elsewhere are safe materials to be used in class. Help the students to think of alternative supplies if something on their list is not safe. This process would work well over a couple of days to allow the students time to gather and bring in other materials. Teachers may wish to put limits on the size and types of materials that can be brought in. After time has been given to collect materials, the groups can continue with where they left off in step 3 and move on to steps 4 and 5.

Share, Discuss, and Reflect

Have each group present their ideas and solution to the problem. Engage in class discussion following every presentation or all of the presentations. Questions prompts include: *What works well about this solution? What could be changed? How could this solution be improved?*

The class should decide on the best solution to implement, and examine whether it solved the problem. They should write down their observations about the solution on their Engineering Design Process tracking sheets. In class discussion, talk about how the solution worked or did not work.

Accomodations and Extensions

Students should be visually supported with Engineering Design Process anchor charts or print-outs.
Place students strategically in groups based on strengths and weaknesses.
Extend this challenge by having the groups combine the best of every idea and continue the engineering design process for one overall solution.

Assessment

Use teacher observation and anecdotal notes to track student participation in groups and class discussion. Have students hand in their Engineering Design Process tracking sheets. Check sheets for comprehension.

EXPLORING BRIDGES

Curriculum Correlations:

Correlation to Next Generation Science Standards

4-3-5 Engineering Design. Students who demonstrate understanding can:

3-5-ETS1-1	Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
3-5-ETS1-2	Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
3-5-ETS1-3	Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

Correlation to Ontario Science Standards

Understanding Structures and Mechanisms: Strong and Stable Structures. By the end of Grade 3, students will:

1.	Assess the importance of form, function, strength, and stability in structures through time;
2.	Investigate strong and stable structures to determine how their design and materials enable them to perform their load-bearing function;
3.	Demonstrate an understanding of the concepts of *structure*, *strength*, and *stability* and the factors that affect them.

Learning Objectives:

This lesson is designed to reinforce and extend students' understanding of bridges, and their structure and function. Students will also strengthen their problem solving skills using the Engineering Design Process.

Prerequisites:

Students should read the book *A Bridge Goes Over* to familiarize themselves with the different types of bridges and designing to solve problems.

Multiple Intelligences:

The following intelligences will be activated throughout the lesson:

- Bodily-Kinesthetic
- Logical-Mathematical
- Visual-Spatial
- Interpersonal
- Existential

Materials:

- One copy of the Engineering Design Process tracking sheet (appendix i) per group
- Cardboard Pieces
- Straws
- Glue
- Scissors
- Newspaper
- Playdoh
- String or Yarn
- Paper clips
- Aquarium Gravel
- Popsicle sticks
- Masking Tape
- Rubber bands
- Cups
- Pipe Cleaners
- Craft Foam
- Paper Towel Tubes
- Clay
- Plastic Spoons
- Weighted test materials, such as books

Creative Inquiry

Setting the Stage

Begin with a narrative hook to establish attention and interest. For example, pose questions about the materials used to make some familiar items, such as:

- Why are bicycles made from metal or steel and not glass? (*Metal/steel is strong and sturdy to hold rider, and glass is too fragile.)*
- Why are pencils made from wood and not steel? (*Wood can be easily shaped by hands or machines; it is also lightweight so people can easily move it when they write)*

These promps should guide readers to consider the big ideas of form and function and choosing materials that are appropriate for the purpose.

Connect this idea with the work done by engineers. Engineers must carefully select the right materials to meet the needs of a design.

Activity

Present the challenge: Explain to students that they will take on the role of an engineer and design a bridge to meet specific conditions. They will work in small groups and follow the steps of the engineering design process to design a bridge that meets set criteria.

Introduce criteria with students. They can choose to build one of the four types of bridges described in the book—arch, cantilever, suspension, or beam.

The bridge must:

- Be at least 12 inches (approximately 30 cm) long
- Support a weight of at least one pound (0.45 kg) while a low-speed fan creates wind directed at the center of the bridge

Hand out the Engineering Design Process tracking sheet (appendix i). Review the instructions, stressing to students that they will document the steps in writing as well as be prepared to present their ideas to the class. Tell the groups that they will have two class periods (2 X 50 minutes, or other period of time specified by teacher) to complete the bridge. Students can use any of the materials you have provided. Remind them that using the right materials for the job is important. They do not need to use everything provided. It is for them to determine which materials fit their design.

Share

When class time is up, each group will present their bridge and give a brief explanation outlining the details recorded on the Engineering Design Process tracking sheet. Students can then repeat the test in front of the class. Repeat this for each group's bridge structure. Once every group's structure has been tested, have the groups reflect on their tracking sheet about the results of the final test on their bridge structure.

Discussion and Reflection

Have a whole class discussion about the things students noticed worked well or did not work within their own groups. Question prompts may include: *What would they change about their design after seeing another group's design? What was good about their design, and what could be improved on? How did they choose which materials they used in their design? Would they change their material choices? Is there a material with a property, such as strength, that they wish they could have used? If so, what is the material and property, and why do they feel it would have improved their design?*

Accomodations and Extensions

Support students by walking them through an example of the "Ask," "Brainstorm," and "Plan and Make a Model" stages. Ensure steps are visually displayed in classroom or handed out. Place students strategically in groups based on strengths and weaknesses.

Extend this challenge by giving each material a cost and provide each group with a budget.

Assessment

Use teacher observation and anecdotal notes to track student participation in groups. Have students hand in their design process tracking sheets. Check sheets for comprehension.

EXPLORING SKYSCRAPERS

Curriculum Correlations:

Correlation to Next Generation Science Standards

4-3-5 Engineering Design. Students who demonstrate understanding can:

3-5-ETS1-1	Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
3-5-ETS1-2	Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
3-5-ETS1-3	Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

Correlation to Ontario Science Standards

Understanding Structures and Mechanisms: Strong and Stable Structures. By the end of Grade 3, students will:

1.	Assess the importance of form, function, strength, and stability in structures through time;
2.	Investigate strong and stable structures to determine how their design and materials enable them to perform their load-bearing function;
3.	Demonstrate an understanding of the concepts of *structure*, *strength*, and *stability* and the factors that affect them.

Learning Objectives:

This lesson is designed to reinforce and extend students' understanding of skyscrapers, and their structure and function. Students will also strengthen their problem-solving skills using the Engineering Design Process.

Prerequisites:

Students should read the book *A Skyscraper Reaches Up* to familiarize themselves with the different types of skyscrapers and designing to solve problems.

Multiple Intelligences:

The following intelligences will be activated throughout the lesson:

Bodily-Kinesthetic Logical-Mathematical Visual-Spatial	Interpersonal Existential

Materials:

- One copy of the Engineering Design Process tracking sheet per group
- Cardboard pieces
- Straws
- Glue
- Scissors
- Newspaper
- Playdoh
- String or Yarn
- Paper clips
- Aquarium Gravel or small pebbles
- Popsicle sticks
- Masking Tape
- Rubber bands
- Paper Cups
- Pipe Cleaners
- Craft Foam
- Paper Towel Tubes
- Clay
- Plastic Spoons
- Weighted test materials, such as books

Creative Inquiry:

Setting the Stage

Skyscrapers are able to meet the needs of many people. In cities or areas that don't have a lot of space, they allow a lot of people to live and work.
Over time there have also been many people who wanted to design and build the tallest building. When one is built and given the title of tallest building, then others try to beat the record.

Brainstorm with the class and create a mindmap of all the tall structures they can think of in their own community and around the world. Identify where they are located and any specific features the students may know about any of the buildings or structures. Focus on the features of each building that help it stand, such as the shapes of the bases or the towers. Refer to the book *A Skyscraper Reaches Up* for information on other skyscraper supports, such as X-bracing, and identify where students see these on real structures.

Here are some to explore:

- Burj Khalifa, in Dubai, the world's tallest building
- Great Pyramid of Giza, oldest Egyptian pyramid, one of the Seven Wonders
- Eiffel Tower, Paris, France, made of wrought iron, lattice design
- Chrysler Building, New York
- Empire State Building, New York
- Lincoln Cathedral, England
- CN Tower, Toronto, Canada, concrete tower, was tallest freestanding structure and world's tallest tower until 2010 when Burj Khalifa was completed

Activity

Present challenge: Explain to students that they will take on the role of engineers. They will work in small groups and follow the steps of the Engineering Design Process to design a skyscraper that meets set criteria.

Introduce and review the criteria with students. Skyscraper must be:

- At least 15 inches (38 centimeters) tall.
- Must have supports, such as X-braces. Students can refer to the *A Skyscraper Reaches Up* book for support ideas.
- Mostly made up of newspaper and masking tape.
- Support the weight of a common pre-selected textbook resting on top.

Hand out the Engineering Design Process tracking sheet (appendix i). Review the instructions, stressing that they will document the steps in writing as well as be prepared to present their ideas to the class.
Tell the groups that they will have two class periods (2 X 50 minutes, or other period of time specified by teacher) to complete the skyscraper.
Students can use any of the materials you have provided. Remind them that using the right materials for the job is important. They do not need to use everything provided. It is for them to determine which materials fit their design.

Share

After the time is up, each group will have to stop building. Each group gives a short explanation about their skyscraper and share their notes on the Engineering Design Process tracking sheet. Teacher may encourage sharing by asking: *What changes did they make to their structure, and why? What was the biggest challenge or most surprising discovery you made during the design process?*

Then, test their finished structure and the group can respond verbally to the result of the test. Repeat this for each group's structure. Once every group's structure has been tested, have the groups reflect on their tracking sheet about the results of the final test on their structure.

Discussion and Reflection

Have a whole class discussion about the things the students noticed that worked well or did not work within their groups. Question prompts may include: *What would they change about their design after seeing another group's design? What was good about their design, and what could be improved on? How did they choose which materials they used in their design? Would they change material choices?*

Accomodations and Extensions

Support students by walking them through an example of the "Ask," "Brainstorm," and "Plan and Make a Model" stages. Fill out these steps together. Tracking sheet could be recreated on whiteboard or smartboard.
Place students strategically in groups based on strengths and weaknesses.
Extend this challenge by giving each material a cost and provide each group with a budget.

Assessment

Use teacher observation and anecdotal notes to track student participation in groups. Have students hand in their Engineering Design Process tracking sheets. Check sheets for comprehension.

EXPLORING DAMS

Curriculum Correlations:

Correlation to Next Generation Science Standards

4-3-5 Engineering Design. Students who demonstrate understanding can:

3-5-ETS1-1	Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
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Correlation to Ontario Science Standards

Understanding Structures and Mechanisms: Strong and Stable Structures. By the end of Grade 3, students will:

1.	Assess the importance of form, function, strength, and stability in structures through time;
2.	Investigate strong and stable structures to determine how their design and materials enable them to perform their load-bearing function;
3.	Demonstrate an understanding of the concepts of *structure*, *strength*, and *stability* and the factors that affect them.

Learning Objectives:

This lesson is designed to reinforce and extend students' understanding of dams, and their structure and function. Students will also strengthen their problem-solving skills using the Engineering Design Process.

Prerequisites:

Students should read the book *A Dam Holds Back* to familiarize themselves with the different types of dams and designing to solve problems.

Multiple Intelligences:

The following intelligences will be activated throughout the lesson:

- Bodily-Kinesthetic
- Logical-Mathematical
- Visual-Spatial
- Interpersonal
- Existential

Materials:

- One copy of the Engineering Design Process tracking sheet (appendix i) per group
- Large, flat container for dam construction (*Required)
- Measuring cups for water criteria (*Required)
- Water (*Required)
- Cardboard pieces
- Straws
- Glue
- Scissors
- Newspaper
- Playdoh
- String or Yarn
- Paper clips
- Aquarium Gravel
- Popsicle sticks
- Masking Tape
- Rubber bands
- Paper Cups
- Pipe Cleaners
- Craft Foam
- Paper Towel Tubes
- Clay
- Plastic Spoons
- Weighted test materials, such as books

Creative Inquiry:

Setting the Stage

Begin with a narrative hook to establish attention and interest. For example, tell a story about a town that was built alongside a river. People loved living beside the river, watching the canoes and kayaks paddling up and down the river, waking along the river edge, and, at night, seeing the moon reflecting on the water. It was beautiful. Sometimes when it rained, the river would get very full and the water level would rise almost to the edge of the path. The people who lived beside the river became worried when it rained and feared the water would overflow and flood their land.

Continue the story to say that once, it rained for three days straight and the town flooded. Explain that a dam is a structure that holds back and collects water. It can solve the problem of flooding.

Activity

Present the challenge. Explain to students that they will take on the role of engineers and design a dam to solve the town's problem. They will work in small groups and follow the steps of the engineering design process to design a dam that meets set criteria.

Introduce and review the criteria with students. The dam must be:

- At least 4 inches (10 centimeters) wide
- Able to hold back at least 17 ounces (500 mL) of water

Hand out the Engineering Design Process Tracking Sheet (appendix i). Review the instructions, stressing that students will document the steps in writing as well as be prepared to present their ideas to the class. Tell the groups they will have two class periods (2 X 50 minutes, or other amount of time specified by teacher) to complete the dam structure, and that they can use any of the materials you have provided for them. Remind them that using the right materials for the job is important. They do not need to use everything provided. It is for them to determine which materials fit their design.

Share

After the time is up, each group will have to stop building and be ready to do a short explanation about their dam structure and what steps they went through to design. Question prompts might include: *What improvements did they make? Or what changes did they make to their structure?* Then you can test the structure and the group can respond verbally to the result of the test. Repeat this for each group's dam structure. Once every group's structure has been tested, have the groups reflect on their design process tracking sheet about the results of the test on their dam structure.

Discussion and Reflection

After all design process tracking sheets have been submitted, have a whole class discussion about the things the students noticed that worked well or did not work in their design. Question prompts may include: *What would they change about their design after seeing another group's design? What was good about their design, and what could be improved on? How did they choose which materials they used in their design? Would they change material choices?*

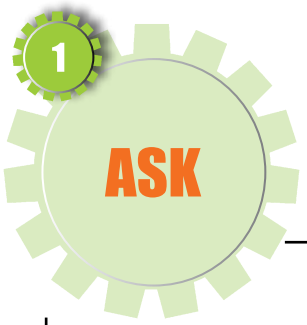
Accomodations and Extensions

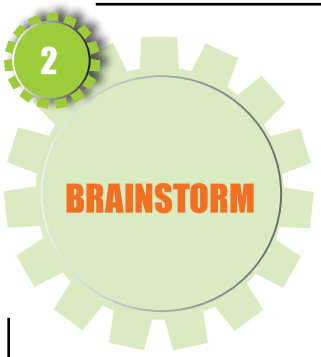
Support students by walking them through an example of the "Ask," "Brainstorm," and "Plan and Make a Model" stages. Fill out these steps together. Tracking sheet could be recreated on white board or smartboard.
Place students strategically in groups based on strengths and weaknesses.
Extend this challenge by giving each material a cost and provide each group with a budget.

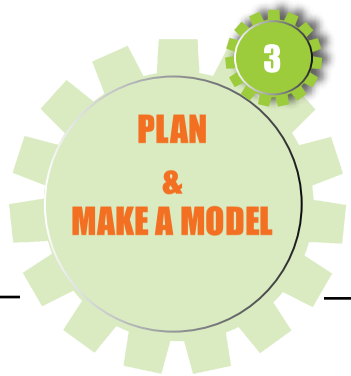
Assessment

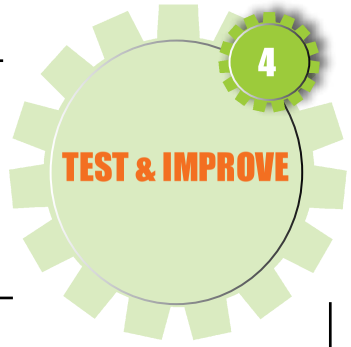
Use teacher observation and anecdotal notes to track student participation in groups. Have students hand in their Engineering Design Process tracking sheets. Check sheets for comprehension.

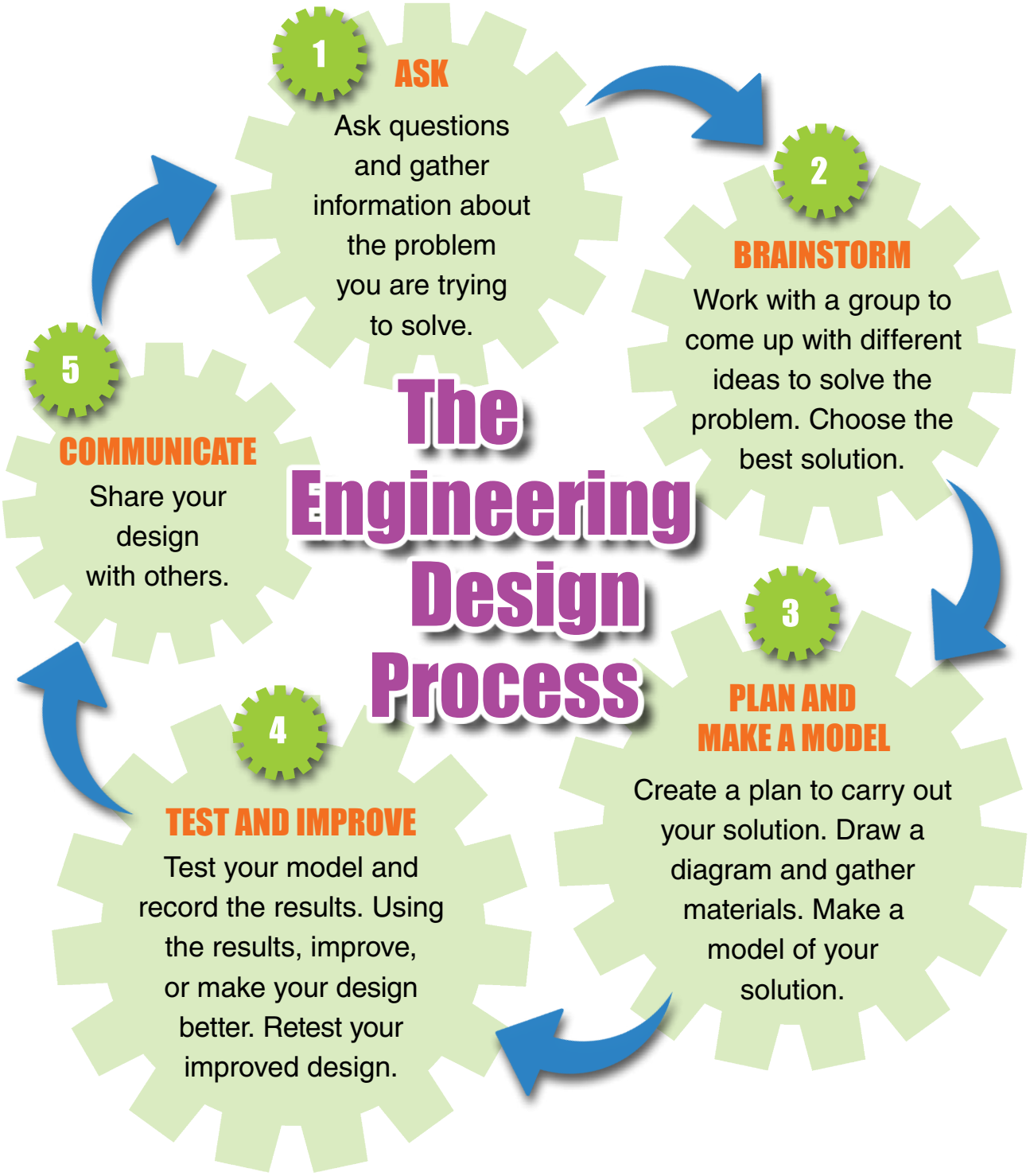
Engineering Design Process Tracking Sheet










The Engineering Design Process
1
ASK
Ask questions and gather information about the problem you are trying to solve.
2
BRAINSTORM
Work with a group to come up with different ideas to solve the problem. Choose the best solution.
3
PLAN AND MAKE A MODEL
Create a plan to carry out your solution. Draw a diagram and gather materials. Make a model of your solution.
4
TEST AND IMPROVE
Test your model and record the results. Using the results, improve, or make your design better. Retest your improved design.
5
COMMUNICATE
Share your design with others.