INTRODUCTION TO THE ENGINEERING DESIGN PROCESS

ELEMENTARY UNIT 1

FIVE 45-60 MINUTE SESSIONS

Catapult Learning™

Catapult Learning, LLC
Two Aquarium Drive, Suite 100
Camden, NJ 08103
1-800-841-8730

www.catapultlearning.com

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UNIT 1: INTRODUCTION TO THE ENGINEERING DESIGN PROCESS

Essential Questions

- What is the engineering design process?
- How can I use the engineering design process to solve problems?

LESSON 1: WHAT IS THE ENGINEERING DESIGN PROCESS?

SESSION 1: THE ENGINEERING DESIGN PROCESS

Lesson Objectives

Students will be able to:

- Describe the steps of the Engineering Design Process (EDP) and explain the importance of each step.
- Give examples of how these steps are used in an engineering project.

SESSION 2: USING THE EDP TO DESIGN AND BUILD A VEHICLE

Lesson Objectives

Students will be able to:

- Use the EDP to design and build a car that solves the problem and meets the requirements.

LESSON 2: ENGINEERING DESIGN CHALLENGE: BUILD A STRUCTURE

SESSION 1: DEFINE THE PROBLEM AND RESEARCH

Lesson Objectives

Students will be able to:

- Define the problem.
- Conduct research for a design challenge.

SESSION 2: BRAINSTORM AND CHOOSE A SOLUTION

Lesson Objectives

Students will be able to:

- Brainstorm a solution that meets the requirements of a design challenge based on research.
- Evaluate solutions and come to an agreement with peers about the best solution.

SESSION 3: BUILD A PROTOTYPE AND TEST

Lesson Objectives

Students will be able to:

- Build a prototype from a design sketch.
- Test and refine a design to meet the challenge requirements.

ASSESSMENTS

	Daily Log sheet	Formative Assessment	Summative Assessment
LESSON 1			
Session 1		Question students as they perform activities	Listen to group presentations
Session 2	X	Question students as they perform activities	Watch and listen as groups present their vehicles
LESSON 2			
Session 1	X	Question students as they perform activities	Listen to group presentations
Session 2	X	Question students as they perform activities	Listen to group presentations
Session 3	X	Question students as they perform activities	Watch and listen as groups present their prototypes Review students' Post-Build Checklists

BACKGROUND INFORMATION

The Engineering Design Process (EDP) is a series of steps that engineers use to guide them in solving problems. The process reflects the way that engineers approach problem-solving—brainstorming for ideas, trying them out, learning from their mistakes, and then trying new ideas.

The steps are taught in sequence in this program, but as students internalize the process, they will find that the system is flexible. In fact, students may find that this process is a good way to tackle many tasks. With its emphasis on creative and critical thinking, students learn that there are many ways to approach a problem and that mistakes provide opportunities to learn.

This program uses the following Engineering Design Process steps:

1. Define the Problem
2. Research
3. Brainstorm
4. Choose a Solution
5. Build a Prototype
6. Test

Many consider Filippo Brunelleschi to be one of the first architectural engineers, and perhaps even a founder of the Engineering Design Process. In 1419, he won a competition to build the dome of the cathedral in Florence, Italy. The dome Brunelleschi was to build was enormous—over 150 feet wide. No one had ever built a freestanding dome of that size, and most people believed it couldn't be done. Brunelleschi developed plans and sketched them, though none remain, and he invented ingenious contraptions to aid the building process. This developing of ideas and planning was a new concept. The magnificent Florence Cathedral dome remains a masterpiece of engineering, and a testament to advances that can be made with creative problem-solving.

GROUP ROUTINES

Students will have the opportunity to work in whole groups, with small groups, with partners, and independently. For most building and problem-solving activities, students will work with a partner. You may choose to combine sets of partners to make small groups.

TIMING

[add note that teachers can extend timing as needed]

EXPECT THE FOLLOWING KITS

- **A teacher kit of basic supplies for your class.** The kit will contain items such as markers, graph paper, chart paper, tape, and pencils. A packing slip detailing the materials supplied is in the kit. Plan to keep these materials on hand for use in every class.
- **Building supplies.** <More information to come>
- **A course kit of materials for this unit.** These items apply directly to the course of study. Plan to keep them on hand for use in every class. They include the following:
  - Engineering Design Process poster
  - Daily Log sheet (1 copy per student per lesson or session)
  - Design Notebook (1 per student)

Name: _____ **Date:** _____

Project Name: _____

Daily Log

Tasks Completed:
Resources Used:
Problems Encountered and Solutions:
My Contributions:
What I Learned Today:

Notes:

		L1: S1	L1: S2	L2: S1	L2: S2	L2: S3
NGSS Next Generation Science Standards						
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.		X	X		
3-5-ETS1-2	Generate and compare multiple possible solutions to a problem based on how well each is likely to meet criteria and constraints of the problem.		X		X	
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.		X			X
Twenty-first Century Skills (4Cs: Critical Thinking, Communication, Collaboration, Creativity)						
Creativity and Innovation	Think Creatively	X	X	X	X	X
	Work Creatively with Others	X	X	X	X	X
	Implement Innovations		X			X
Critical Thinking and Problem Solving	Reason Effectively	X	X	X	X	X
	Use Systems Thinking		X		X	X
	Make Judgments and Decisions	X	X	X	X	X
	Solve Problems		X	X	X	X
Communication and Collaboration	Communicate Clearly	X	X	X	X	X
	Collaborate with Others	X	X	X	X	X
Habits of Mind						
Persisting		X	X	X	X	X
Managing Impulsivity		X	X	X	X	X
Listening with Understanding and Empathy		X	X	X	X	X
Thinking Flexibly		X	X	X	X	X
Thinking about Thinking (Metacognition)		X	X	X	X	X
Striving for Accuracy		X	X	X	X	X
Questioning and Posing Problems		X	X	X	X	X
Applying Past Knowledge to New Situations		X	X	X	X	X
Thinking and Communicating with Clarity and Precision		X	X	X	X	X
Creating, Imagining, Innovating		X	X	X	X	X
Responding with Wonderment and Awe		X	X	X	X	X
Taking Responsibility for Risks			X	X	X	X
Finding Humor		X	X	X	X	X
Thinking Independently		X	X	X	X	X
Remaining Open to Continuous Learning		X	X	X	X	X

Common Core State Standards						
CCSS.ELA-LITERACY.RI.3.1	Ask and answer questions to demonstrate understanding of a text, referring explicitly to the text as the basis for the answers.		X	X	X	
CCSS.ELA-LITERACY.RI.5.3	Explain the relationships or interactions between two or more individuals, events, ideas, or concepts in a historical, scientific, or technical text based on specific information in the text.		X			
IT MIG National Core Art Standards						
VA:CR1.13a	Elaborate on an imaginative idea.		X		X	X
VA:Cr1.14a	Brainstorm multiple approaches to a creative art or design problem.		X		X	

45–60 mins

SESSION 1: THE ENGINEERING DESIGN PROCESS

Objectives

- ✓ **I can** describe the steps of the Engineering Design Process (EDP) and explain the importance of each step.
- ✓ **I can** give examples of how these steps are used in an engineering project.

Materials

Projectable 1

Resource 1

Engineering Design Process poster

Paper bag

Tape

Copy paper

Preparation

1. Make a copy of Resource 1. Cut out the cards and put them in a bag.
2. Hang the EDP poster in the classroom where it can easily be seen.
3. Write the following three questions on chart paper. Allow space below each question for answers.
   - ***What is an engineer?***
   - ***How do engineers work?***
   - ***What have engineers done to improve people's lives?***

Differentiation Opportunities

INTRODUCTION

To provide support, help students understand the difference between the first questions you've asked them to answer. For "What is an engineer?" students should look for statements that help define an engineer. For "How do engineers work?" students should look for answers that tell what engineers do.

To provide support, add to the list you are creating so that students can see the breadth of work that engineers do. For example, engineers develop artificial retinas to help people see; create satellites that can detect drought.

To challenge students, discuss types of engineering and the work the engineers do. For example: civil engineers (buildings, bridges); mechanical engineers (machines, refrigerators); chemical engineers (food, chemical products); electrical engineers (systems for computers, buildings); computer engineers (hardware, software).

INSTRUCTION/SMALL GROUP ACTIVITY: THE EDP STEPS

To provide support, you may give students stems to help them answer the questions posed. For example:

- Define the Problem. ***The parts of the problem are _____, _____, and _____.***
- Research. ***We know _____ and _____ about this problem/about [this structure].***

To challenge students, ask them to think of other questions and answers for the step they were assigned.

EVIDENCE OF LEARNING

To provide support as students give their presentations, ask guiding questions. For example:

- ***What is your part of the EDP and why is this part important?***
- ***What is one thing you would do to accomplish your part of the EDP?***

You may have students draw diagrams or maps to illustrate their part of the EDP.

INTRODUCTION 10 MINUTES

SAY: ***When we're faced with a problem, what do we do?*** (Try to solve it.) ***There are people whose job is to solve problems. We call them engineers. Their work is mainly about how and why things work. Today we're going to learn more about engineers and what they do.***

Point to the chart paper and read aloud the first two questions.

Display the paper bag with the cards in it. Tell students that some answers to these questions are in the bag. You may choose to warn students that some of the cards have statements that do ***not*** answer the questions.

Have a student choose a card from the bag and read what is on the card. Guide students to identify which question the information on their card answers. Then have the student tape the card to the chart under the appropriate question. Continue this process until all the cards have been pulled out of the bag. Discuss the non-answers with students. Introduce the concept of a preconceived idea, or idea that we have before learning about something directly.

The questions and answers are listed below.

What is an engineer?

- An engineer finds creative and practical solutions to problems.
- An engineer designs and builds products, machines, structures, and systems that help solve a specific problem.
- An engineer is concerned with how and why things work.
- An engineer designs things but doesn't build them. (This is a non-answer; put to the side or throw away.)
- An engineer is an inventor.
- An engineer uses math and science, but not real-world knowledge to solve problems. (This is a non-answer; put to the side or throw away.)

How do engineers work?

- Engineers think creatively.
- Engineers work in teams.
- Engineers never make mistakes. (This is a non-answer; put to the side or throw away.)
- Engineers ask questions.
- Engineers make connections and look for patterns.
- Engineers solve problems on the first try. (This is a non-answer; put to the side or throw away.)

Read aloud the last question on the chart paper. Explain to students that there are many different kinds of engineers. Ask students to think about the structures, machines, and systems they see in the world around them. Ask them to name some things they think engineers have designed and built. Make a list of students' ideas. Encourage students to explain, or comment on, how these things have improved people's lives. The list may include some of the following:

- fuel-efficient cars
- mountain bikes
- superglue
- laptops
- clothing that repels mosquitoes
- video games
- solar-heated buildings
- bridges

SAY: ***You are all going to be engineers in this course. You will ask questions and solve problems, design and build structures, learn from what you've made, and start over again. These are the things that engineers around the world do.***

Leave the chart paper up to remind students what engineers do and how they work.

INSTRUCTION 20–35 MINUTES

Whole-Class Activity: Introduce the Engineering Design Process 10 min

SAY: *We encounter problems every day. It might rain when we planned a picnic. Or, like the other day, I ran out of butter when I wanted to make cookies. Sometimes you have to figure out how to share games or toys. What steps do you take when you have a problem you need to solve?*

Lead a discussion with students, prompting them to think about and share the ways they approach problems in their own lives. For example, maybe they think about possible solutions, or different ways to approach the problem.

SAY: *When engineers need to solve a problem, they follow a process called the Engineering Design Process, or EDP for short.*

Point to the EDP poster. Invite a student to read each step. After a step is read, have students discuss what it means. Students may not be familiar with the word ***prototype***. Tell them that a prototype is a first model of something.

Small-Group Activity: The EDP Steps 10–25 min

Create six groups of students. Before you begin, ask students to suggest rules for group work so they can work well together, and everyone has a chance to participate. Write these rules on a piece of chart paper. For example:

- *Treat each other with respect.*
- *One student speaks at a time.*
- *Each student participates.*
- *When a question comes up, try to answer it within the group before asking the teacher.*
- *There are no bad ideas.*

Give each group one step in the EDP and an engineering project. Explain to students that they will work together to come up with examples of what their step might look like within the scope of the project they've been assigned. Alternatively, you may have students choose a project from the list they created earlier and that you recorded on chart paper.

Pass out copy paper and pencils to each group. Encourage students to take notes or draw diagrams or sketches as they work. Display Projectable 1. If students need support, read the questions aloud, or have fellow students read them to help them as they work. Observe students and prompt and guide them with additional questions as needed.

Other possible engineering projects include:

- Design and build a waterproof cell phone
- Design and build a solar-powered pizza oven
- Create a self-cleaning litter box
- Create an amusement park ride that is fast and fun, and also safe
- Create a door for a home that can be opened only by the people who live there
- Design and build an automatic dog walker

EVIDENCE OF LEARNING 15 MINUTES

Beginning with the "Define the Problem" group, have each group give a presentation to the rest of the class explaining what they would do to accomplish their part of the EDP. Encourage the students who are listening to ask questions and make connections to the other steps in the process.

ASK:

- *What was the best part of the process you went through as you discussed your step? Why?*
- *What was the hardest problem to overcome?*

Examining the Engineering Design Process

1. Define the Problem

- What are the essential parts in this problem?
- Who will be helped by solving this problem?
- Why do you need to solve this problem?
- What is your specific goal?

2. Research

- What is required to solve the problem?
- Who will use your design/product?
- What do you already know about existing designs/products?
- How do your ideas relate to the problem?
- What materials could you use to solve the problem?
- What questions do you have?

3. Brainstorm

- How could you sketch your ideas?
- What else can you do to encourage new ideas?
- What are some new and different ways to solve the problem?
- What are some "off-the-wall" ideas?

4. Choose a Solution

- What are the good points about each idea?
- Which ideas are possible given your time, tools, and materials?
- What are the ideas that don't work so well?

5. Build a Prototype

- What does it mean to build a prototype?
- How could you go about that process?
- What materials will you need?
- What happens if you need to make revisions to your design as you create a prototype?

6. Test

- What is the point of testing your prototype?
- What can you learn?
- What might be the next steps after testing?

An engineer finds creative and practical solutions to problems.	An engineer designs and builds products, machines, structures, and systems that help solve a specific problem.
An engineer is concerned with how and why things work.	An engineer designs things, but doesn't build them.
An engineer is an inventor.	An engineer uses math and science, but not real-world knowledge to solve problems.
Engineers work in teams.	Engineers never make mistakes.
Engineers ask questions.	Engineers make connections and look for patterns.
Engineers solve problems on the first try.	Engineers think creatively.

45–60 mins

SESSION 2: USE THE EDP TO DESIGN AND BUILD A VEHICLE

Objectives

✓ **I can** use the EDP to design and build a car that solves the problem and meets the requirements.

Materials

Projectable 2

Projectable 3

Worksheet 1 (1 per student)

Daily Log sheet (1 per student)

3-ring binder, for Design Log (1 per student)

K'NEX kits (1 per pair)

Preparation

1. Make copies of Worksheet 1 and the Daily Log sheet.
2. Write the following on chart paper or on the board: ***Design Challenge: Build a vehicle that moves straight across a hard surface as far as possible using minimal effort.***
3. Use a separate sheet of chart paper to list each of the following EDP steps:
   - ***Define the Problem:***
   - ***Research:***
     - » ***What is a vehicle?***
     - » ***What allows vehicles to move?***
     - » ***What parts must a vehicle have?***
     - » ***What is the problem we need to solve?***
     - » ***What are the key parts, or requirements, of the problem?***
     - » ***What questions do we still have?***
   - ***Brainstorm:***
     - » ***3-wheels***
     - » ***4-wheels***
     - » ***lightweight base***
     - » ***the back could be tilted***

     (**Note:** If possible, include sketches along with your brainstorming ideas)
   - ***Choose a Solution:***
     (Create a T-chart with the headings: ***Pros*** and ***Cons***)

Differentiation Opportunities

INSTRUCTION/WHOLE-GROUP ACTIVITY

STEP 3: Brainstorm

To provide support, tell students that their sketches do not have to be exact models. Any sketch is fine as long as it makes sense to them and is labeled so they won't forget what it means.

To challenge students, encourage them to come up with the most far out idea they can think of.

STEP 5: Build a Prototype

To provide support, suggest that students think of how to build the prototype before starting on it. They might be able to have one student work on one part while another student works on another part.

Encourage students to think about the part that interests them. Have them work on that part of the prototype.

EVIDENCE OF LEARNING

To provide support, ask questions as they give their presentations. For example:

- How did you divide up the work to finish your vehicle?
- If you had more time is there any way you would modify your vehicle?
- Are their any ideas from some of your classmates that you would like to try?

INTRODUCTION 5 MINUTES

SAY: *Today you are going take on your first engineering design challenge. Here's your challenge: To build a vehicle that moves straight across a hard surface as far as possible with minimal effort.*

Point to the design challenge that you wrote on the chart. Then refer to the EDP poster.

SAY: *For this first challenge, we'll go through the process of building the vehicle using each step in the EDP.*

Display a K'NEX kit. If students have used a K'NEX kit, Legos, Lincoln Logs, or other building kits, have them briefly share their experiences. Guide students to make connections among the different kits they have played with.

Explain that students will be using the K'NEX kits to build the vehicle.

INSTRUCTION 30–45 MINUTES

Whole-Group Activity:
Use the EDP to Design and Build a Vehicle

STEP 1: DEFINE THE PROBLEM

Think aloud to model for students how you define the problem in the challenge.

SAY: *So, the first step is defining the problem. The challenge is to build a vehicle, that's one part of the problem.*

On the chart paper titled ***Define the Problem,*** write ***build a vehicle.***

SAY: *But it's not just any vehicle. The challenge says it must move across a hard surface with minimal effort. Hmm. What does "minimal effort" mean?*

Solicit ideas from students and write their ideas on the chart paper. Add any clarifications that may be needed.

STEP 2: RESEARCH

SAY: *To research vehicles, we're going to think about what we already know about them. I know a vehicle is something that moves things around.*

Question students about what they know about vehicles. Create a mind map to keep track of their ideas. Encourage students to build on each other's ideas and prompt them to think more deeply as necessary.

ASK:

- *What is a vehicle?*
- *What allows vehicles to move?*
- *What parts must a vehicle have?*
- *What is the problem we need to solve?*
- *What are the key parts, or requirements, of the problem?*
- *What questions do we still have?*

[DESIGN: Insert mind map model that shows possible answers to these questions and others: TK]

STEP 3: BRAINSTORM

SAY: *Next, we need to brainstorm our solutions to the problem. What kind of vehicle can we build that will solve the problem? When I started brainstorming, I remembered that there are no bad ideas, so I wrote down whatever came into my head. I wanted to get down as many ideas as possible.*

Display the chart paper titled ***Brainstorm***.

SAY: *One of the most important parts of the Brainstorm step is to make sketches of our ideas. The sketches helped me keep track of my thinking. Sometimes, later in the engineering design process, we may want to go back to this step and find ideas that we want to explore again or in a different way. Sketching and taking notes is part of the record-keeping process that engineers always use.*

[DESIGN: Insert Brainstorming Chart with the following information and sketch(es): TK]

Have students contribute their own brainstorming ideas about the vehicle you will build. Add their ideas to the chart paper. Remind them to withhold any discouraging remarks or criticism of others' ideas. Encourage students to build on each other's ideas. Remind them to stay focused on the problem they want to solve. If there is time, students may add sketches, too.

STEP 4: CHOOSE A SOLUTION

Display the piece of chart paper labeled ***Choose a Solution***.

SAY: *For this step we will evaluate the vehicle ideas and designs that we have brainstormed. Let's look at the pros and cons of each idea—or the things that will help us solve the problem and the things that don't really help solve the problem at all.*

Record students' pros and cons on the T-chart. Encourage students to respond to each design idea.

SAY: *These pros and cons can help us decide which design option we want to try. Sometimes we take characteristics of a design we aren't going to use and put them into the design we are going to build.*

Guide students to choose the solution they think will work best. Encourage them to work together to come to a decision.

ASK:

- *What are our requirements to solve the problem?* (build a vehicle; must move as far as possible on a hard surface)
- *Does this solution meet our requirements?*
- *Are there any ideas that we might combine to create a better solution?*

STEP 5: BUILD A PROTOTYPE

Explain that students will now use the K'NEX to build a prototype of the vehicle. Pass out a Daily Log sheet (one per student) and the sets of K'NEX to pairs of students.

SAY: *Take a few moments to play with the K'NEX pieces. Explore how they fit together and how you can build things with the pieces. Then you can start building the vehicle. As you build, you may discover that your design will change as you build and learn. In the end, we may all end up with vehicles that look quite different from our original design, but they may all solve the problem. As you build your prototype, take notes about the process you use to build. Record any problems you run into. On your log sheet, write about ways you overcame or addressed those problems to come up with a solution. Remember one of the most important things about being an engineer is keeping a record of the projects you work on.*

Display Projectable 2. Encourage students to refer to the checklist as they work on their prototypes. Read the questions aloud if students need guidance and support.

STEP 6: TEST

SAY: *For this step we will test the vehicles to see if they meet the design challenge and solve the problem. If we have time, we can make any changes needed, or we can take notes about the changes we'd like to make in the future.*

Explain that students may find that a vehicle doesn't work as well as they thought it would. Reinforce the idea that mistakes are a natural, fun, and valuable part of the learning process, and they can get us closer to a solution that works. Explain that engineers create things all the time that don't work as well as they would like them to or don't work at all.

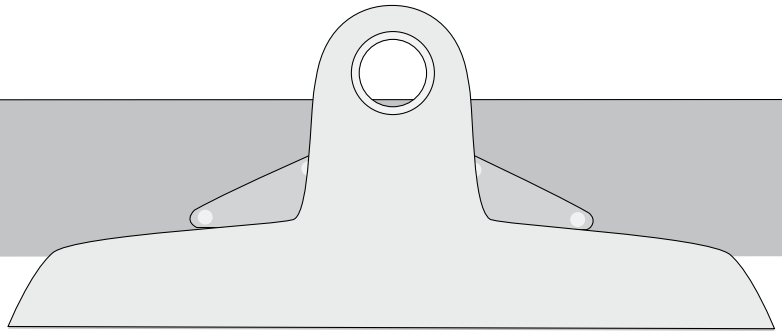
SAY: *As engineers, we don't make mistakes. When things don't work, it gives us information to help us figure out what might work.*

Display Projectable 3. Encourage students to refer to the checklist as they test their designs. Read the questions aloud if students need support. Remind them to take notes on their log sheets to keep track of the testing and any changes they would make in future versions of the vehicle.

EVIDENCE OF LEARNING 10 MINUTES

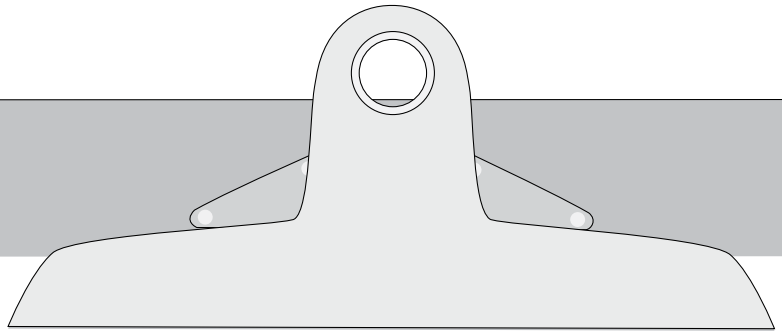
Have each pair of students share the vehicle they have built. Ask students to share specific examples of problems they encountered during the building or testing process, and how they overcame those problems.

Distribute a 3-ring binder and Worksheet 1 to each student. Have students write their name on the cover sheet. Then have them insert the Daily Log sheet into their Design Notebook.



Build a Prototype Checklist

- ✓ Have you followed the ideas presented as the best choice?
- ✓ Have you run into any problems? How have you solved them?
- ✓ Partway through the process: STOP. Assess your prototype. Are you on the right track?
- ✓ Are you taking notes and making sketches to keep track of the process of building a prototype?
- ✓ Have you made changes to the original design? Take notes about your changes!



Test Your Design Checklist

- ✓ Revisit the design challenge:

  Build a vehicle that moves straight across a hard surface as far as possible with minimal effort.

- ✓ Does the vehicle meet the challenge? If not, what isn't working?

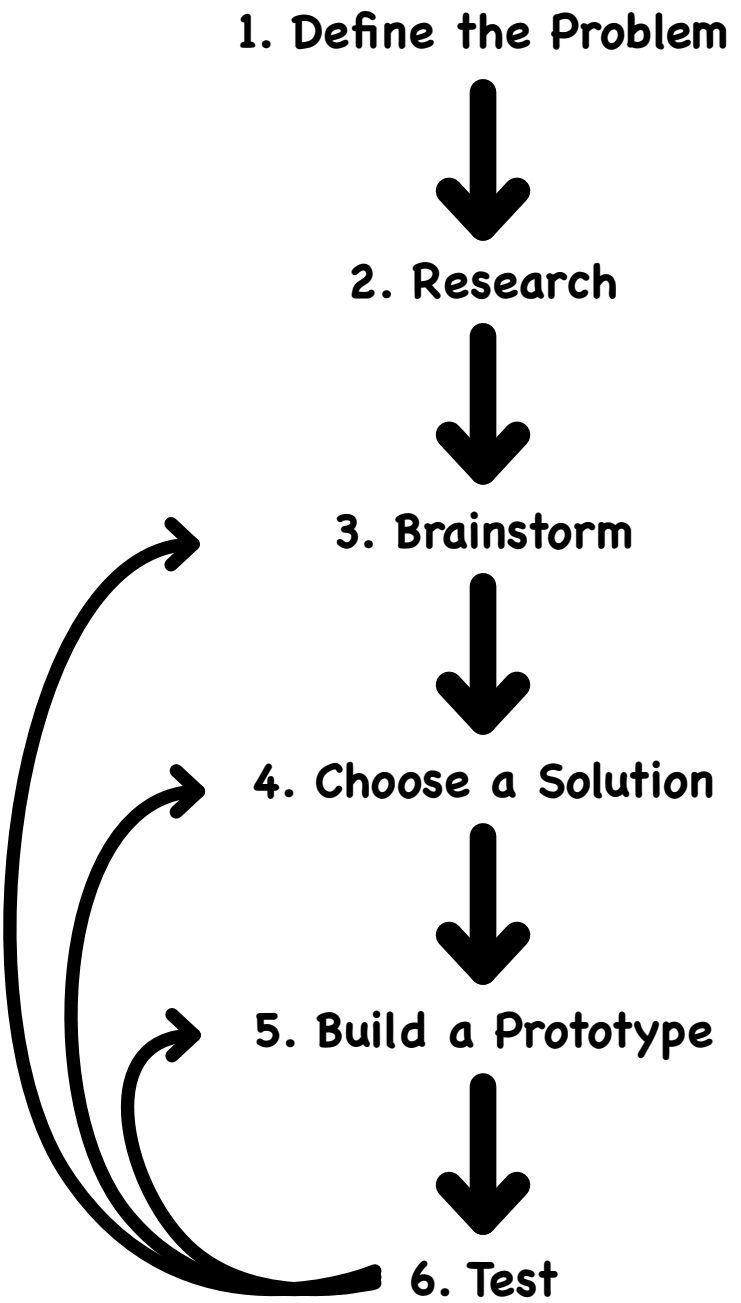
- ✓ Why do you think it's not working as you'd like it to?

- ✓ How can you refine the design to meet the challenge?

- ✓ Are you taking notes as you test?

Name: _____

Design Log



45–60 mins

SESSION 1: DEFINE THE PROBLEM AND RESEARCH

Objectives

✓ **I can** define the problem and conduct research for a design challenge.

Materials

Projectable 4

Resource 2 (1 per student; 1 for teacher)

Daily Log sheet (1 per student)

Engineering Design Process poster

Design Notebooks

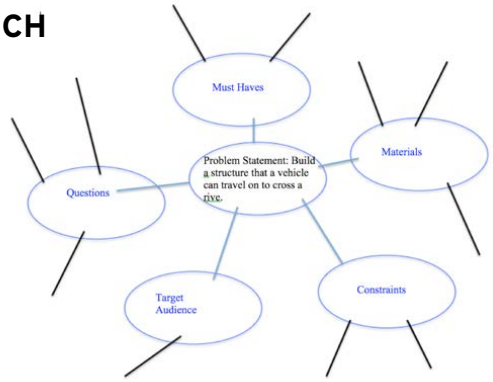
Preparation

1. Make copies of Resource 2 and the Daily Log sheet.
2. On a sheet of chart paper, write the title, ***Design Challenge***. Then write: ***Build a structure that a vehicle can travel on to cross a river.*** Save this to use in Session 2.
3. Design and build a structure so you have a model and also become familiar with the process students will undertake.

Differentiation Opportunities

INSTRUCTION/SMALL-GROUP ACTIVITY: RESEARCH

To challenge students, have them create an idea web with circles. The central circle should contain the problem statement. Examples of circles around the problem statement would be Must Haves, Materials, Questions, Target Audience, and Constraints. Student might think of more categories. Students can then either write things in the circles or have lines going from the circles to key comments for that category as shown below in black.



EVIDENCE OF LEARNING

To provide support, ask students questions as they summarize the day's lesson. For example:

- ***What is your problem statement?***
- ***What did you discover in your research?***

INTRODUCTION 10 MINUTES

Distribute Resource 2, the story ***Trekking Trouble***, and read it aloud or have students read it to themselves. Ask students to retell the story in their own words.

ASK:

- ***What problems or difficulties do the characters encounter?*** (the weather, the rain, the swollen creek)
- ***How do the characters respond to the problems they encounter?***
- ***What is the major problem in the story?***
- ***What do the characters need? What are the constraints, or limitations, they face in this situation?***

Explain to students that they have just completed the first and second steps in the Engineering Design Process—Define the Problem and Research. Ask them to go a little deeper for the research step.

ASK:

- ***What do we already know about ways that people get across a river or other obstacle?***
- ***What materials do the characters in the story have?***

Have students put Resource 2 in their Design Notebooks to use in the next lesson.

SAY: ***Now, we'll follow the EDP to build our own structures, just as we followed the EDP to build vehicles. Today we will work with the first two steps: Define the Problem and Research.***

INSTRUCTION 25–40 MINUTES

Small-Group Activity: Define the Problem 10 min

Have students work with partners. Give each student a blank Daily Log sheet and their Design Notebooks.

ASK: ***What are your ideas about how we should define the problem for this design challenge?***

Guide students to recognize that it would help to break the problem down into parts. Also, they should state the problem, so they understand exactly what it is they need to solve.

Give partners several minutes to define the problem. Ask them to write a problem statement on their Daily Log sheets.

ASK:

- ***What is the first part of our challenge?*** (to build a structure)
- ***What does this structure have to be able to do?*** (span a river)
- ***What other features does this structure need?*** (vehicle needs to fit on it; structure needs to be able to hold the weight of the vehicle)

Invite volunteers to share their problem statements.

Small-Group Activity: Research 15–30 min

Tell students that now they'll do the research step. Have partners begin by thinking about all the things they know about structures that carry vehicles. Remind students of the mind map you created in the last lesson. Encourage students to record their ideas on their Daily Log sheets using a mind map, an idea web, or by taking notes. Tell students that they may also add additional questions they have to their research notes.

Give partners about ten minutes to work on their own. Then have partners get together with another set of partners. Display Projectable 4. Have students share their research and then refer to the questions on the projectable as they continue to research their structures.

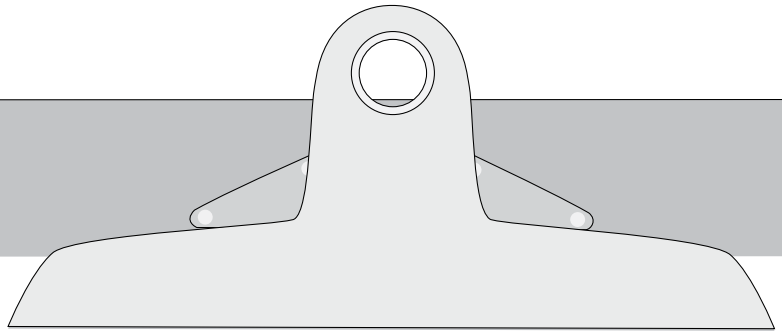
Bring students together and ask volunteers to share their findings with the class. Focus on any outstanding questions students have. Allow listening students to answer these questions if possible.

EVIDENCE OF LEARNING 10 MINUTES

Ask students to summarize what they did in the lesson today.

ASK:

- *How was your experience engaging in the Define the Problem and Research steps different today?*
- *In what other classes, or in what other parts of your life, could you use these two steps?*
- *Why would you use these steps when you face problems?*



Research Questions

- What is the function of the structure?
- Who or what needs to use the structure?
- What are examples of structures that go across rivers?
- What are the important features of these structures?
- What improvements might you make to these structures?
- What materials are these structures made of?
- Do these structures have any safety issues? If so, what are they?

Trekking Trouble!

By Sydnie Meltzer Kleinhenz

I sit on the couch and gaze out the window at the heavy, gray skies. Mom and I had planned to go on a hike today, but the weather doesn't look promising.

"Are you ready, Jess? Let's go!" Mom says.

I jump up with a grin. I should have known better. When Mom says we're going hiking—we're going hiking!

At the trailhead, we put on our backpacks and walk into the misty day. "It is a little damp," I say.

Mom looks around. "You don't need sun to see the beauty in nature. Look at the pattern of rings on this tree stump." She tries to wrap her arms around the stump, but they only go halfway.

"That must have been a huge tree," I say.

We hop on rocks to cross a burbling creek and crouch to make our way under low-hanging vines. Mom points out a hollow log decorated with frilly fungus. I pick up two branches for us to use as walking sticks.

We hear a rumble in the distance. The wind picks up. Suddenly, we are caught in pouring rain.

Mom and I dash into an opening under a cliff. "This seems like a good time for lunch," she says.

I look nervously at the water pooling outside our shelter. "I wonder how long the storm will last."

"Oh, I wouldn't worry about it," Mom says.

We eat. We thumb wrestle. We play Twenty Questions. Finally, the downpour turns into drips.

Mom scans the trail ahead. "It doesn't look so good for hiking," she says.

We tramp back toward the car. Our walking sticks steady us as we slip on the slick mud. But then we reach the creek and stop like we've hit a brick wall.

include simple illustration of flooded stream

"Where are the rocks we hopped on?" Mom asks.

"Exactly!" I answer, studying the scene. The creek has risen. Now all we can see is rushing water.

Mom walks toward a long log. "Maybe we can shove this into the water and walk across it." We push and pull and tug and grunt, but we can't move it.

"Maybe we can use this hollow log," I say.

As I lift, the log breaks into chunks of spongey wood. I lift again, closer to the middle. It's surprisingly light.

Mom and I push the log into the water. Then we watch as it breaks apart and slips away downstream.

"We can toss big rocks into the water. They'll pile up, like islands," I say.

Holding a rock with both hands, I heave it out toward the center of the creek. It lands with a plop at my feet.

Mom and I stare at the creek. "This is a real problem," I say. "What can we build to get across?" I look and see materials all around us—logs, rocks, branches, and vines.

"I have an idea for a project," I say.

And then Mom and I get to work.

45–60 mins

SESSION 2: BRAINSTORM AND CHOOSE A SOLUTION

Objectives

- ✓ **I can** brainstorm a solution that meets the requirements of a design challenge based on research.
- ✓ **I can** evaluate solutions and come to an agreement with my peers about the best solution.

Materials

Resource 2 (from previous lesson)

Daily Log sheet (1 per student)

Engineering Design Process poster

Design Notebooks

Copy paper

Preparation

1. Make copies of the Daily Log sheet.
2. Post the chart paper with the design challenge written on it.

Differentiation Opportunities

INSTRUCTION/SMALL-GROUP ACTIVITY: BRAINSTORM

To challenge students, encourage them to think out of the box on some of the solutions.

EVIDENCE OF LEARNING

To provide support, ask questions to students who are stuck as they give their summary of what they did today. For example:

- *What were some of the pros and cons in your solutions?*
- *Which solution did you choose and why?*
- *What did you learn about the process?*
- *What did you like?*
- *What would you do differently?*

INTRODUCTION 5 MINUTES

Have students locate Resource 2, the story ***Trekking Trouble***, in their Design Notebooks and read it aloud again. Review the problem the characters face. Ask students what they remember about brainstorming solutions for building a vehicle.

ASK: ***What is important to do during brainstorming?*** (get a lot of ideas down; take notes; make sketches)

Give students a few minutes to brainstorm solutions to the problem in the story. Ask volunteers to share their ideas.

Review the design challenge and the EDP. Explain to students that today they will brainstorm and choose the best solution for their structures.

ASK:

- ***What do we need to remember when we're brainstorming?*** (to avoid discouraging remarks or criticism of ideas; to get down as many ideas as possible)
- ***Why is it important to stay focused on the problem we want to solve?*** (Even though all our ideas might not work, we want them to deal with the problem at hand.)
- ***Why is it important to make sketches and keep notes?*** (We may want to combine different parts of different ideas. We may want to come back to our ideas after we test the prototype.)

INSTRUCTION 30–45 MINUTES

Small-Group Activity: Brainstorm 15–25 min

SAY: ***Remember, for the brainstorming step, you want an open atmosphere where everyone feels free to contribute in a creative way. This is very important to finding creative solutions.***

Have students work with the same partners they worked with in the last session. Have each set of partners work with another set of partners.

Give each student a copy of a Daily Log sheet, their Design Notebooks, and a piece of copy paper. Tell students to begin brainstorming. Remind them to focus on quantity, not quality.

Observe students working together and facilitate as needed. For example, if you see that a student has not contributed, you may specifically ask what his or her ideas are. Remind students to take notes and make sketches and label their ideas.

Remind students of the questions they asked and answered about brainstorming on Projectable 1 in Session 1:

- ***How could you sketch your ideas?***
- ***What else can you do to encourage new ideas?***
- ***What are some new and different ways to solve the problem?***
- ***What are some "off-the-wall" ideas?***

When groups have finished brainstorming solutions, look over their notes. Make sure they are clear and that they are labeled.

Small-Group Activity: Choose a Solution 15–20 min

Have students create a T-chart on the back of their Daily Log sheets with the headings, ***Pros*** and ***Cons***. Tell students to review the problem they are trying to solve. Then have small groups discuss the pros and cons of their different ideas from the brainstorming session.

Ask questions to guide students as they work toward choosing the best solution.

ASK:

- ***What was the problem you needed to solve?***
- ***What are the good things and the not-so-good things about each idea?***
- ***How does each solution meet our requirements? How does each solution come up short?***
- ***What do you need more information about? Where can you find that information?***

SAY: ***At the end of this step you should have chosen a design. Remember, you can always pick up details from a design that you didn't choose.***

Some groups may finish early. When a group finishes early, look over their work to make sure they have completed the task. Then ask the students in the group if they would like to be consultants to give help to any group that asks for it. Write volunteers' names on the board under the label ***Consultant***.

SAY: ***Engineers are like all of us. They get stuck sometimes and need help. One way they get that help is by calling in outside consultants. The outside consultant talks to the group and tries to offer some suggestions for solving their problem.***

Explain to students that on the board you've listed the names of students who have finished their work and would like to act as consultants. Students may ask any of these students for help if they are stuck. Tell the consultants to cross their name off the list if a group asks them for help. Then students will know that consultant is no longer available.

SAY: ***A consultant can offer your group suggestions, but it is up to the group to decide to follow the suggestions.***

EVIDENCE OF LEARNING 10 MINUTES

Have each group share the structure design they chose to build. Encourage them to talk about the process they went through in making this decision and give the main reasons they selected the chosen design. Ask them to share any problems they had and how they solved those problems. For example, perhaps they got some feedback that they can integrate into their designs.

Have students complete their Daily Log sheet. Then they can put the sheet and any other papers from the day into their Design Notebooks.

45–60 mins

SESSION 3: BUILD A PROTOTYPE AND TEST

Objectives

- ✓ **I can** build a prototype from a design sketch.
- ✓ **I can** test and refine my design to meet the challenge requirements.

Materials

Resource 3 (1 per student)

Worksheet 2 (1 per student)

Daily Log sheet (1 per student)

Engineering Design Process poster

Design Notebooks

K'NEX kits (1 per pair of students)

Cardstock (2–3 strips per pair)

Tap

Student vehicles from Lesson 1: Session 2

Preparation

1. Make copies of the Daily Log sheet and Worksheet 2.
2. Cut the cardstock into strips about 3 inches wide.
3. Post the design challenge.

Differentiation Opportunities

INSTRUCTION/SMALL-GROUP ACTIVITY: BUILD A PROTOTYPE

Some students may get lost in the process of building a prototype. To provide support for those students, encourage them to go back to their sketches. Encourage them to look at what they've built so far and determine what they have yet to build.

EVIDENCE OF LEARNING

Share the rubric on Resource 3 to support students as they prepare their presentations.

To provide support and help motivate students, suggest that they give their presentation as though they were on television. You might even have students take turns being the interviewer.

INTRODUCTION 5 MINUTES

Review the design challenge with students. Tell students that today, they will be working on the last two steps of the EDP.

ASK:

- ***What do we need to remember when we build a prototype?*** (follow the ideas we noted when we chose the best solution; make sure the prototype meets the requirements of the challenge)
- ***Why is it important to take notes and make sketches as you build your prototype?*** (We should keep track of the process and note if any changes are made.)
- ***What do we need to remember when we test our prototypes?*** (to look at the challenge again to make sure we're testing if the design solves the problem; test for what works and what doesn't work; take notes about what could change to refine the design or to make it better)

INSTRUCTION 30–45 MINUTES

Small-Group Activity: Build a Prototype 15–25 min

Have students work with their partners. Give each student a copy of the Daily Log sheet, their Design Notebooks, and graph paper. Give each set of partners the K'NEX kit.

SAY: ***You've defined the problem, researched, brainstormed solutions, and chosen the best solution. Now you get to build a prototype.***

Before students get started, ask them how they will decide where to start. Suggest that partners plan how they will proceed. Remind them to take notes and record their steps on their log sheets. Tell them they may use the graph paper to make sketches of the process they use to build their prototypes.

Once students have worked on their prototypes for ten minutes or so, have them pause. Distribute copies of Worksheet 2. Have students go through the checklist to make sure they've done everything.

ASK:

- ***What have you learned?***
- ***What has surprised you so far?***

Have students continue the activity and finish making their prototypes.

Small-Group Activity: Test 15–20 min

SAY: ***For this step you will test the structure you built to see if it meets the design requirements. Then, you can make refinements to meet the requirements. First, the vehicle needs to fit on the structure.***

Give partners the vehicles they built in Lesson 1, Session 2. Have them work together to test their structures three or more times. Ask volunteers if they can think of ways they could make their structures stronger or more reliable.

ASK:

- ***How could you refine the design to better meet the requirements?***
- ***What have you tried to change?***
- ***How did it work?***
- ***If it didn't work, why do you think so? Why do you think this is happening?***
- ***Is there another way to look at this?***

If time allows, have students rework their prototypes and then retest them.

EVIDENCE OF LEARNING 10 MINUTES

Invite partners to share the structure prototype they built and explain how they used the EDP to build it. They should show how their structure meets the design challenge requirements. Ask students questions about the process. For example,

ASK:

- ***What do you think is the best feature of your design?***
- ***What was the hardest problem to solve?***
- ***What would you do differently to make your structure more successful in meeting the design challenge?***
- ***What did you learn?***
- ***What did the results of your test show? What revisions did you make after testing?***
- ***What did you see in other groups' structures that could have improved yours?***
- ***How did you work with your team?***
- ***What challenges did you experience working with others? How did you overcome them?***
- ***What might you do differently next time?***

Encourage listening students to ask questions, too.

Have students add any additional details to their Log sheets. Then, have them insert the sheet and other papers into their Design Notebook.

Name: _____

Presentation Rubric

	Excellent	Good Work	Needs Some Work
Organization	Ideas presented in an order that makes sense	Ideas mostly presented in an order that makes sense	Ideas presented in an order that does not make sense
	Ideas and facts support the main idea	Most information supports the main idea, but some don't	Includes information that does not support the main idea
Explanation of Ideas	Explanation of how EDP used is clear	Explanation of how EDP used is somewhat clear	Explanation of how EDP used is unclear
	Very clear how the structure/design meets the design challenge	Not entirely clear how the structure/design meets the design challenge	Not clear how structure/ design meets design challenge
Eyes and Body and Voice	Keeps eye contact with the audience most of the time; speaks clearly	Makes some eye contact with the audience; speaks clearly most of the time	Does not look at the audience or speak clearly
	Stands with good posture	Fidgets or slouches a little	Fidgets or slouches
Questioning	Asks questions to fill in the gaps between what he/she knows and doesn't know	Sometimes asks questions to find out what he/she doesn't know	Doesn't ask questions to find out what he/she doesn't know.
	Has a questioning attitude; creates strategies to find answers	Sometimes has a questioning attitude	Does not have a questioning attitude.
Thinking Flexibly	Able to change mind when presented with new information	Sometimes considers other points of view	Difficulty considering other points of view
	Finds alternatives by looking at ideas in another way	Tries to think about different options and ideas	Difficulty thinking about different options and/or ideas
Creating, Imagining, and Innovating	Thinks of original and creative solutions	Tries to think of creative solutions	Difficulty seeing more than one solution to a problem.
	Looks at possibilities from many angles	Sometimes looks at different possibilities from different angles	Difficulty considering different possibilities
Persisting and Growth Mindset	Works through challenges and failures	Works through some challenges and failures	Does not work through challenges and failures
	Stays focused on task and project goals	Able to focus some of the time	Difficulty focusing
Working as a Group	Able to work productively in a group	Worked together most of the time with others in a group	Not able to work well with others in a group
	Able to both contribute ideas and listen to others' ideas in the group	Able to contribute ideas to the group some of the time	Difficulty sharing ideas with others in a group

Name: _____

Post-Build Checklist

- ✓ Does your structure solve the problem you needed to solve?
  If not, review your problem statement.
- ✓ Did you follow the design ideas you highlighted when you chose the best solution?
  If not, go back to that step and review the choices you made.
- ✓ Did you take notes and make sketches?
  These will help you when you test your prototype!
- ✓ Have you encountered any problems?
  Ask: ***Why do you think this [problem] happened?***
- ✓ Did you look back at the Brainstorming step for ways to improve the structure?
  You may find an idea that you can use!

Rate your work on the Engineering Design Process

	Great!	Okay	Not-So-Great	Ideas for Improvement
Define the Problem				
Research				
Brainstorm				
Choose a Solution				
Build a Prototype				
Test Your Prototype				

Group Work

- ✓ Did both partners participate?
  If not, what can you change next time?
- ✓ Did you have any problems working together?
  If so, what might you do differently?