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Bridging the Gap

The Tech Challenge 2017 Lesson 4: Engineering

Developed by The Tech Academies of Innovation

I. Lesson Overview

Can your team build the appropriate bridge to fit the needs of various terrains?

Lesson Description: Students will build an assigned bridge in order to increase knowledge of various types of bridges. Students will then engage in a design challenge in which they will build a bridge of their choosing that is designed to meet the criteria and constraints of a specified terrain. Students will be increasing their ability to determine how well a design meets the criteria and constraints of a project.

Grade Levels: 4-8

Education Outcomes:

4-5th Grades

Students will:

- Generate and explain a design to a design problem
- Compare solutions based on the criteria and constraints of a design problem
- Make a recommendation for a proposed solution based on evidence collected from multiple design solutions

6-8th Grades

Students will:

- Generate a data collection tool in order to collect and evaluate data in a systematic way
- Evaluate competing design solutions using the criteria and constraints of a given design problem

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- Make a recommendation for a proposed solution based on evidence collected from competing design solutions

Education Standards

Met: (Note: bolded parts of the standards are fully met by this lesson)

Next Generation Science Standards (NGSS) Performance Expectations (PE):

4th -5th Grades

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.**

NGSS Science and Engineering Practices (SEP):
Planning and carrying out investigations:
Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon **or test a design solution.**

Innovator Mindsets: Collaboration
Exercise flexibility and willingness to be helpful in making necessary compromises to accomplish a common goal (see the Framework for 21st Century Learning, Collaborate with Others)

6-8th Grades:

MS-ETS1-2. **Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.**

NGSS Science and Engineering Practices (SEP):
Planning and carrying out investigations:
Plan an investigation individually and **collaboratively, and in the design: identify** independent and dependent variables and controls, **what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.**

Addressed: (The following standards are practiced in this lesson but are not explicitly taught and assessed)

Next Generation Science Standards (NGSS) Performance Expectations (PE):

MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

NGSS Disciplinary Core Ideas (DCI):

ETS1.B: Developing Possible Solutions
Research on a problem should be carried out before beginning to design a solution. Testing a solution involves investigating how well it performs under a range of likely conditions.
ETS1.C:
Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed.

NGSS Science and Engineering Practices (SEP):
6. Constructing Explanations and Designing Solutions
Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.
Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design problem.

7. Engaging in Argument from Evidence
Make a claim about the merit of a solution to a problem by citing relevant evidence about how it meets the criteria and constraints of the problem.

NGSS Crosscutting Concepts (CCC):
Influence of Science, Engineering, and Technology on Society and the Natural World
The uses of technologies and limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions.
Engineers improve existing technologies or develop new ones to increase their benefits, decrease known risks, and meet societal demands.

Framework for 21st Century Learning: Collaboration
Collaborate with Others #3: Exercise flexibility and willingness to be helpful in making necessary compromises to accomplish a common goal (see the Framework for 21st Century Learning)

II. Advanced Prep & Set-Up for Lesson

Building Bridges Advanced Set-Up

Materials for a class of 32 students:

- 16 - 11x11 in. Cardboard sheets
- 16 - 11x7 in. Cardboard sheets
- 50 - rubber bands (various sizes)
- 48 - 10 in. pieces of cotton string
- Scissors (2 pairs per group)
- 1 single hole puncher
- 680 Craft sticks
- Roll of tape (masking or painter's tape - 1 per group)
- 8 - 4x6 in. pieces of styrofoam (preferably floral or polyethylene foam)
- 48 - soft foam circles (approximately 4 in. diameter and 2 in. thick)
- 16 Packing foam sheets (various sizes)
- 80 -12 in. square dowel rods
- 20 - 12 in. round wooden dowel rods

Data Collection and Notebooks

- We recommend making additional copies of the data collection handouts for any additional prototypes.
- Another strategy includes creating a Science Journal/Notebook that includes a combination of data collection sheets, sketch pages, rubrics, vocabulary, and note taking pages.
- The Science Penguin
- Using Interactive Notebooks for Inquiry-based Science

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- 8 rustic paint sticks
- 40 - 1 in. food bag clamps
- Rulers (1 per group)
- 100 - 2 inch paper clips hacks
- 50 binder clips (various sizes)
- 10 - 1 lb weights (Empty water bottles can be filled with sand to be used as weights. 500mL bottle ¼ full equals ½ lbs, ½ full equals 1 lbs, ¾ full equals 1 ½ lbs and a full bottle equals 2 lbs. A full 2 L bottle equals 8 lbs)
- Glue gun/sticks
- Duct tape
- 8 box cutters (Safety cutters, such as Klever Kutter or Floracraft foam cutter)
- Class set of safety goggles (1 per student)
- Building Bridges Data-Collection Handouts (1 per student; See Appendix D, "Data-Collection Handouts")
- Bridge Informational Cards (1 per group; See Appendix D, "Bridge Informational Cards")

Set-Up

1. Post the Design Challenge for students to see, either on chart paper or a whiteboard. It is helpful to keep the design problem visible for the duration of the challenge.
   - Goal: Build a structure to span an 18 inch gap
   - Design for:
     - Length (at least 18 inches long)
     - Strength (ability to support weight)
2. Materials:
     - Sort different materials into bins and arrange them along an area of the room for easy student access.
     - Instruct students to take only the supplies they need at one time, they can revisit the table if new supplies are needed.

3. Work Areas:
   - Have an area to design and build prototypes for each group of students. Each area should have a set of the basic supplies listed per group of students on the previous page (2 pairs of scissors, 1 roll of tape, 1 ruler 1 pair of safety goggles per student).
   - Students should design in groups of 3-4 students.
   - Consider moving chairs out of the way to encourage students' movement.

4. Testing Area:
   - If possible, have this area off to the side (away from the Design and Materials tables).
   - Place two regular tables or students desks parallel to one another with an 18 inch gap to test students' designs.

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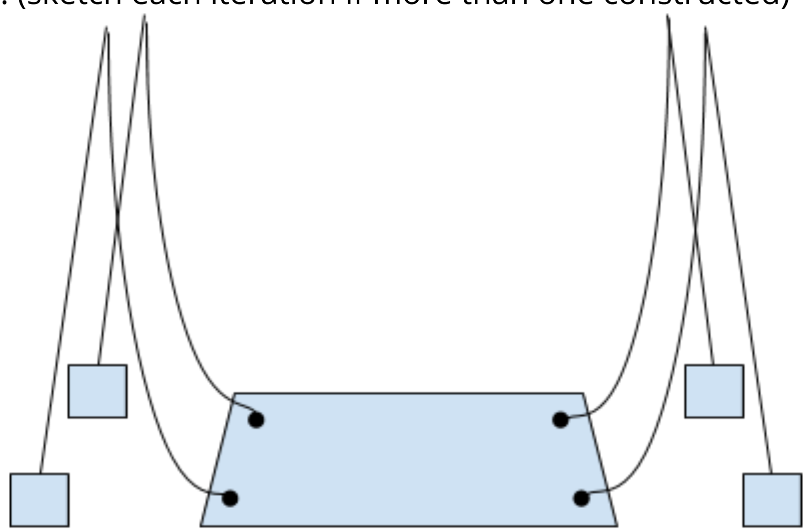
5. *Data Collection*

- Please refer to Data Collection table below in "Bridging the Gap Advanced Set-up."

Sample Data Collection for Grades (4-5)

Type(s) of bridge	Length	Width	Height	List of materials used	Time to construct	Weight held
Suspension	*15 in.*	*6 in.*	*5 in.*	*String, cardboard, wood dowels, tape*	*15 min.*	*5 lbs.*

Sketch of structure: (sketch each iteration if more than one constructed)



This solution meets the following criteria and constraints:

The design held more than 2 lbs of weight.

The design supports itself, and is not taped down to the table.

Criteria and constraints not met by this solution:

The design is short of 18 inches long.

The design was not completed in the 10 minute window.

To improve on this design, in our next design, we plan to...

Make the design longer.

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Bridging the Gap Advanced Set-Up

Materials (per approximately 32 students)

- 16 - 11x11 in. Cardboard sheets
- 16 - 11x7 in. Cardboard sheets
- 50 - rubber bands (various sizes)
- 48 - 10 in. pieces of cotton string
- Scissors (2 pairs per group)
- 1 single hole puncher
- 680 Craft sticks
- Roll of tape (masking or painter's tape - 1 per group)
- 8 - 4x6 in. pieces of styrofoam (preferably floral or polyethylene foam)
- 48 - soft foam circles (approximately 4 in. diameter and 2 in. thick)
- 16 Packing foam sheets (various sizes)
- 80 -12 in. square dowel rods
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- 8 rustic paint sticks
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- Rulers (1 per group)
- 100 - 2 inch paper clips hacks
- 50 binder clips (various sizes)
- 10 - 1 lb weights (Empty water bottles can be filled with sand to be used as weights. 500mL bottle ¼ full equals ½ lbs, ½ full equals 1 lb, ¾ full equals 1 ½ lbs and a full bottle equals 2 lbs. A full 2 L bottle equals 8 lbs)
- 8 box cutters (Safety cutters, such as Klever Kutter or Floracraft foam cutter)
- Class set of safety goggles (1 per student)
- Scenario Cards (1 scenario card per group; See Appendix D, "Scenario Cards")
- Bridging the Gap Data Collection Handout [4-5th] or Bridging the Gap Data Collection Plan [6-8th] (3-4 per group; See Appendix D)
- Bridging the Gap Solution Summary (1 per student; See Appendix D)
- Team Design Solution Evaluations Handouts (1 per student; See Appendix D, "Team Design Solution Evaluations")

Optional Material for Lesson Extension

In preparation for The Tech Challenge, it is helpful for students to experience a Design Challenge on a larger scale. Bridging the Gap can be extended to cover multiple days, in which students would construct bridges out of more durable materials. It is important to stay true to the Engineering Design Process and allow students freedom in building, however, basic safety and usage guidelines should be in place. The following are some websites that may be helpful when planning to use tools with children.

For younger students, a Floracraft foam cutter will ensure safety and prevent injuries.

Helpful readings on tools and safety:

- "10 Tools Every Kid Should Learn to Use"
- "Teaching Kids How To Use Tools"
- "DIY for Kids"

Set-Up

1. Provide each group with a Scenario Card, if needed, make two copies of a scenario card for each group.
    - Goal: Build a structure to span a specified gap
    - Design for:

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- Length (20 or 25 inches long, as specified by the Scenario Card)
- Strength (ability to support weight)

2. Materials:
   - Sort different materials into bins and arrange them along an area of the room for easy student access.
   - Instruct students to take only the supplies they need at one time, they can revisit the table if new supplies are needed.

3. Work Areas:
   - Have an area to design/build prototype for each group of students.
   - Each table should have a set of the basic supplies listed per group of students on the previous page.
   - Students can design in groups of 3-4 students.
   - Consider moving chairs out of their way to encourage students' movement.

4. Testing Area:

   Due to the fact that this design challenge has 5 different challenge measurements. Specific testing areas for all 5 challenges are listed below:

   Using 2 tables or desks, set up an 18 inch gap as a starting point for the scenarios.
   - Testing area for the Desert Design should be the standard 18 inches, but the surface on both sides of the river must represent a sandy surface. This could be done using a container of sand or dirt on each side, or it could be simulated by attaching sponges to the surface on each side of the gap..
   - Testing area for Mountain Design should be the standard 18 inch gap, however one side should be raised approximately 3-5 inches. This can be done by stacking a couple pieces of wood or textbooks on one side.
   - Testing Area for Ice Design should be the standard 18 inches, however a fan should be placed on one side and the structure must remain stable while being blown by "wind".
   - Testing Area for the Jungle should be the standard 18 inches.
   - Testing Area for Vast Bay Design should extend the gap to 25 inches.

Data Collection

1. As Students are generating data collection tools for (section D), take note that they will not all look like the model data collection tool.
2. Try to lead students to create a logical and concise tool for collecting and evaluating data.

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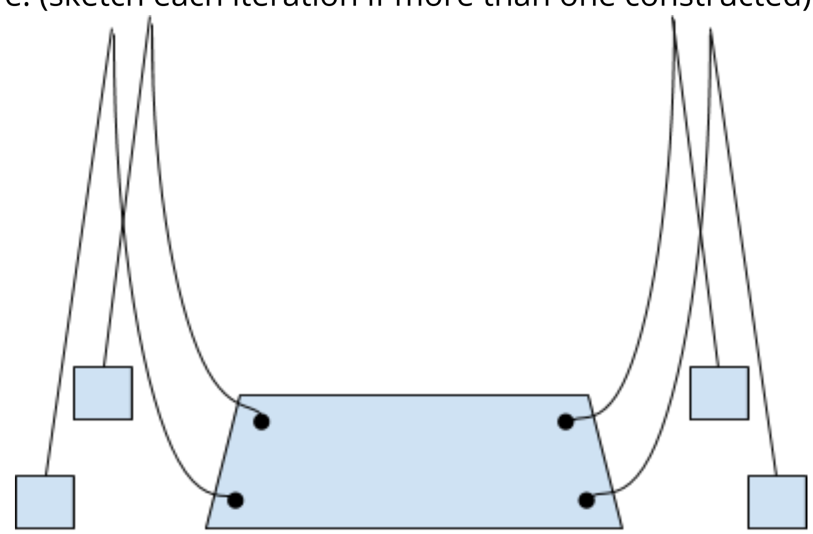
Sample Data Collection Plan for Grades (4-5)

Type(s) of bridge	Length	Width	Height	List of materials used	Time to construct	Weight held
Suspension	15 in.	6 in.	5 in.	String, cardboard, wood dowels, tape	15 min.	5 lbs.

Sketch of structure: (sketch each iteration if more than one constructed)



This solution meets the following criteria and constraints:
The design held more than 2 lbs of weight.

The design supports itself, and is not taped down to the table.

Criteria and constraints not met by this solution:
The design is short of 18 inches long.
The design was not completed in the 10 minute window.

To improve on this design, in our next design, we plan to...

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Data Collection Plan (Grades 6-8)

Scenario:___ICE____________________

How will you determine how well each design meets the criteria and constraints of each solution?

Criterion or Constraint	**Data that will measure each design's success on this criterion or constraint:** Be specific on how measurements should be recorded.
Example: *Must span 2 feet.*	*Measurement of the length of the device in feet to the nearest ½ inch.*
Structure must remain stable with wind.	*We will measure if and how far the design moves (to the nearest ¼ inch) when fan is set to different power settings.*
Must span 18 inch gap.	*We will measure every tested prototype in inches.*
The structure must support itself and 8 pounds.	*We will test each design first to see if it can support its' own weight. Then we will place ½ pound weights on the bridge to measure how much weight can be supported before the design reach its' failure point. We will record the maximum weight supported before failure to the nearest ½ pound.*

What tools will you need to collect the above data?
Science notebook, ruler, fan, writing instrument, observation, 16 ½ pound weights.

How many data will support a claim that your solution is the optimal solution for your given scenario?
We want to find at least 3 data or evidence to support our design works well in the ice environment.

On the back of this sheet, design the data collection table you will need to collect data to assess each of your criteria and constraints.
Example

Prototype # 4	
Bridge span:* *19 inches *(length in feet to nearest ½ inch*	

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Bridging the Gap Solution Summary (Grades 4-8)

Answer the following questions to help guide your evaluation and comparison:

Claim: What claim can you make about your final design?

Our final design can withstand a windy environment and a lot of weight.

Evidence: What evidence do you have about how well this (and other prototypes) met the design criteria and constraints?

1. Our 4th design was able to stay in one place when tested with the fan set at level 3.
2. We positioned the fan in the north, east, west, and south direction and the bridge did not move, or moved just a little from our first design.
3. Our design was able to hold up the weight, up to 10 pounds.

Reasoning: How does your evidence support your claim?

Our bridge was strong, because even at the highest level on the fan, it moved very little or not at all.
Our bridge withstood the fan at its' highest settings in different directions, which shows that the bridge can withstand wind in the real environment, where the wind can come from many directions.
By holding up to 10 pounds of weight, our bridge showed that it was strong enough to hold lots of weight over it's entire span. This is similar to the conditions the bridge must withstand in the real icy environment.

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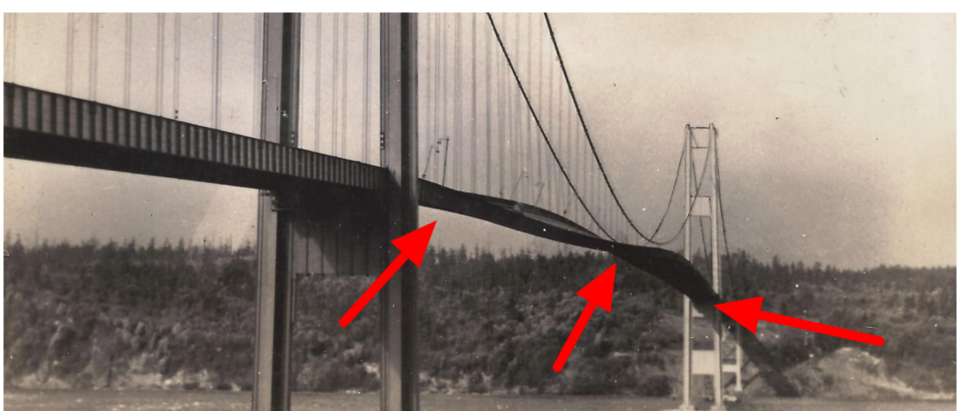
III. Building Bridges Lesson Guide

Guiding Question: Can you build a bridge for the specified scenario that will cross a gap using the materials provided?

A. Introduction (20-30 minutes)

1. Introduce students to the world of bridges as engineering structures that serves societal purposes.
   - *Prompt: We are going to be engineers for this project and learn about bridges.*
   - *Who here has ever been on the Golden Gate or Bay bridge or any bridge?*
   - *Why do we need bridges? / Why is it important for a working society to have bridges?*
   - Possible answers include: Bridges allow people to overcome natural obstacles. They reduce the time it takes to travel and transport people and resources. Some natural obstacles include water, hills, cliffs, animal habitats.
   - What do you think are the challenges of building a bridge? (Accept all answers.)
   - Introduce engineering vocab. **Civil engineering-** is a professional engineering discipline that deals with the design, construction, and maintenance of the physical and naturally built environment, including works like roads, bridges, canals, dams, and buildings.
   - Where have you seen examples of civil engineers' work?
   - Encourage students to identify specific buildings, bridges, roads, etc. in your local community.

2. Show A History of Bridge Disasters. Start discussion on failure points, make connection to engineering criteria and constraints.
   - *Do you think the engineers of the bridges in the video made the best possible design?*
   - *Should they have maybe considered other solutions? Did they think of all the possible scenarios that would impact their bridge design?*
   - Introduce failure point vocabulary. **Failure points** are places in the design where the structure breaks down.
   - *In the video, did you see any examples of **failure points**, and if so, where in the design did you see the bridge fail?*
   - Paused video at 0:14, 1:04, 1:17 to point out failure points of bridges.
   - Use the following pictures to demonstrate failure points:



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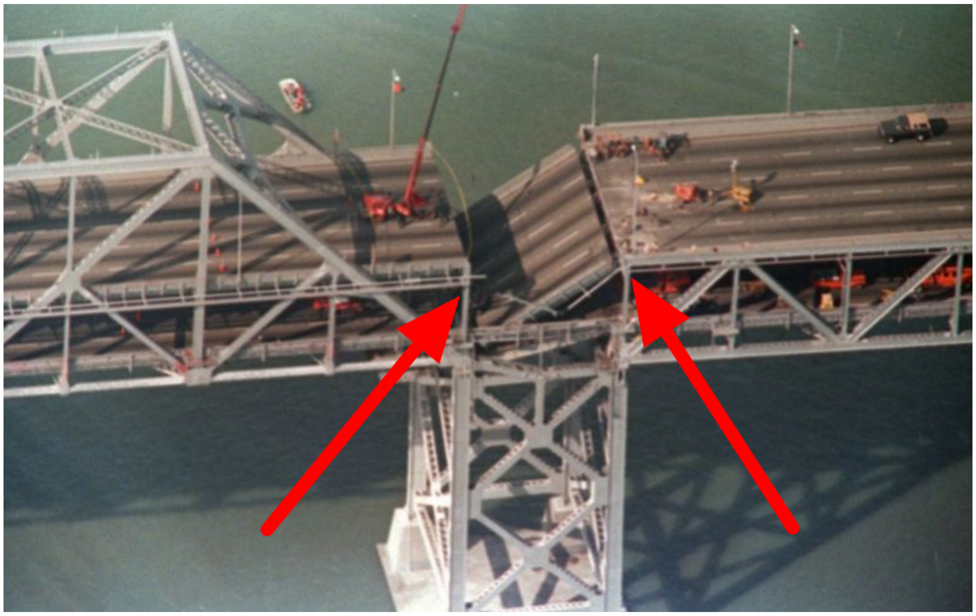

3. Explain to students they are going to be acting as civil engineers for the design challenges. Part of civil engineering is testing and recording data on multiple solutions to a problem, and using that information to make the best possible design. Engineers collaborate together to compare and evaluate multiple design solutions. The goal is to try and meet both criteria and constraints while designing your solution--making improvements with more data collected as you find and improve around failure points. Information you might share with students includes:
   - They will be making their own structures as civil engineering teams. They will be designing and making structures that best fit the given criteria and constraints.
   - They will be split into groups to get some more background knowledge that will help them in designing and comparing multiple design models of their structure.
   - In order to assess the success of each design, it will be critical to test carefully and collect data that demonstrates how well each design meets each **criteria** and **constraint**.

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> **Criteria and Constraints**
>
> Criteria and constraints were originally introduced in Animal Rescue Lesson Plan, please refer to "Animal Rescue" lesson, Section III: Animal Rescue Lesson Guide, page 9.

4. Review with students some possible reasons why civil engineers might have to think about **criteria** and **constraints** when constructing a design, and discuss their importance in assessing the success of a design.
   - **Constraints** are real-life limitations with which engineering designs must comply.
   - **Criteria** are the requirements or desired features of a design problem often describing the purpose and standards that a system or device must meet.
   - *What are some criteria and constraints civil engineers might have in the real-world?* (Criteria might include the length of the span that must be crossed; the amount of weight the bridge is expected to support; ability to withstand local weather conditions, etc. Constraints might include budget, schedule, standard lane sizes, etc.)
   - *What were some criteria and constraints engineers might have forgotten on the bridges that collapsed in the video?*
   - *How might you use these criteria and constraints to decide if your design is successful?*
   - *How will we know if our design meets the weight requirement?* (You could place weights on it until it collapses).
   - Probe for specifics. *Where should we place the weight? How much at a time? Why? How will that test be similar to real-life? How is it different?*
   - *How well each design meets the given criteria and constraints of this challenge will be important in assessing the success of our solutions.*

B. Building Bridges (45-60 minutes)

1. Introduce the Building Bridges design challenge.

Design Problem:
- *Your team is testing various bridge designs as part of your civil engineer training. Your design team is asked to construct and evaluate a bridge assigned to you by your local government in hopes of selecting the best bridge to use at a later time. Your team will share the findings of your bridge design with the other design teams. Can your team build a structure to cross a gap using the given materials?*

Criteria:
- Your structure must span an 18-inch gap
- Your structure must support itself
- Your structure must hold 2 pounds of weight
- You must construct their assigned bridge type

Constraints:
- You have 20 minutes to design and build a bridge
- You must contribute to imagining, building, testing and data collection.
- You may only use the materials provided

Testing:
- You are free to test their design by moving up to the testing area. Using sand filled bottles, you will test how much weight a design can support
- Fill in the data sheets with your observations as your team test, be sure to observe the weight, and failure points.

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2. Divide students into teams of 4, and introduce students to various bridge types.
   - Give each team a Bridge Informational Card (See Appendix D, "Bridge Informational Cards").
   - Give students 3 minutes to read the informational card with their team and discuss the information on the card.
   - Tell the teams that they will be designing and building their own bridge of the type described on their card.

3. Review the importance of iteration in the engineering design process.
   - Emphasize the importance of multiple iterations in order to improve your final design.
     - Fail early and fail often in order to find the **optimal** design.
   - Each new iteration can provide insight towards designing a better solution.
   - Encourage students to test their design(s) multiple times during their build-time.
   - Give each team a Building Bridges Data Collection Handout or Data Collection Plan (See Appendix D, "Building Bridges Data Collection Handout" and "Data Collection Plan").

Additional Engineering Vocabulary

Bridge Information Cards includes the following additional bridge vocabulary:

Tension: The pulling force on a structure or material when weight is applied.

Compression: The pushing effect on a structure or material when weight is applied.

Truss Bridge: A bridge made of connected parts that forms triangular components.

Suspension Bridge: A bridge made of ropes or cables from the vertical suspenders to hold the weight of bridge deck and traffic.

Arch Bridge: A bridge made in a way that load of is carried outward along the curve of the arch to the supports at each end.

Abutment: A mass or structure for resisting the pressure of water on a bridge or pier.

Optimal Design: There is no perfect design in engineering. Instead engineers aim for the optimal design that best meets the criteria and constraints.

4. Review the Building Bridges Data Collection Handout and Data Collection Plan and discuss the importance of data collection with students. Important points to discuss include:
   - *Focused collection of data helps guide the design process.*
   - *Data collection is what allows us to learn from our failures, and allows us to communicate our failures to other engineers.*
   - *Data from failed designs is just as important as data from successful designs.*
   - Go over how teams will collect data throughout the design and building process (drawing designs, measurements, etc.)

5. Designate 1 student from each group as the "Supply Coordinator." Explain that only the Supply Coordinators are allowed to get up and get materials from the material table. Tell students that they will have 20 minutes to build, test, redesign, and rebuild their structure.

6. While students are working on their designs, the teacher should walk around and ask questions. Some suggested questions are:
   - *What materials did you choose? Why?*
   - [6th-8th] *What are the unique properties of the materials you chose? How do those properties affect the structure/stability of your bridge?*
   - *What is it about your type of bridge that makes it difficult to design/build?*
   - *Are there parts of your design that are being compression and tension when there is a load on it?*
   - [4th-5th] *How do the different materials work together? Have you considered how any of the other materials could fulfill the same function?*
   - *Which criteria and constraints are you finding easiest to meet?*
   - *Which criteria and constraints are you finding the most difficult to meet?*

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7. At the end of the time limit, bring the class together to test and share their designs. Have each group explain their design model, and ensure they are using their data tool handout as evidence. Groups should use weights to test and collect using their data tool. Assist groups that may need help testing and collecting data.

C. Content Learning (45-60 minutes)

1. Review the observations and data-collection handouts used on the Building Bridges design challenge (section B.)
   - Have each group present their findings while the audience takes notes on the various advantages and disadvantages as well anything they noticed (qualitatively or quantitatively). Students will fill in the provided data tool set for each different bridge type including their own.
   - Students should:
     - explain how their model fits the criteria and constraints.
     - discuss the materials used and provide reasoning for their selections.
     - share some of the difficulties they had and if they needed to make multiple versions.

2. Questions you might use while reviewing the different bridge types:
   - *Which did you notice to be the "strongest" or hold most weight?*
   - *Which covered the most distance?*
   - *Which used the least material to cover the distance required?*
   - Accept all answers at this point. General differences between bridges will be discussed below.

3. Questions you might use to discuss assessment of designs based on criteria and constraints:
   - *Did your design meet the given criteria? How do you know?*
   - *What are some ways you evaluated how well each design solution met the criteria and constraints?*
   - *How did you modify your design to fit the given constraints?*
   - *How did you use your data collection tool to compare and evaluate your design solution?*
   - Bring attention to the importance of specific and careful measurement of each solution for each criteria and constraint. This is particularly important for grades 6-8 who will be designing their own data collection methods in the next design challenge.
   - *How did you determine if your design solution was successful or not?*
   - *How did the criteria and constraints help you work toward solutions to the design problem?*
   - *Is there a solution you felt best met the challenge? What evidence do you have to support that claim?*
   - Students' answers will vary. Help them to focus on how they assessed their solutions according to each criteria and constraint to determine its success and using these data to back up design claims.

Share-out

Discussions during share-out can naturally lead to opportunities where engineering concepts, practices, and vocabulary can be introduced. Below are some definitions to possibly introduce as discussion evolves:

Trade-off: a situation in which you must choose between or balance two things that are opposite or cannot be had at the same time. e.g. making something really strong might mean increasing the weight of a design—trading off less weight for strength.

Iterative design and **prototyping**: multiple versions of a design will be created and tested along the design process, each version is an incremental step in the final design.

The following resources may be helpful when teaching about prototypes:

"10 Early and Rarely Seen Prototypes of Now Famous Gadgets"

4. Introduce the construction of evidence-based conclusions.
   - By presenting their thoughts on which bridge worked best with the criteria and constraints of the engineering design challenge, students just took part in argumentation and explanation. Explain that a very important part of science and engineering is the ability to explain your idea or your design, and that explaining needs to be backed up by evidence or data.

Claim Evidence Reasoning (CER) Framework

Typically, CER is framed with a guiding question that students must create a claim or answer to. For the purpose of this lesson, claims about bridges are left open ended to allow students to choose between various types of bridges and their different functionality.

Support students to have freedom and imagination in their reasoning, not all students will think alike, and different perspectives over shared evidence has contributed to major scientific discoveries such as evolution, light, and gravity.

Claim Evidence Reasoning is a helpful framework for students to justify their design decisions, and engage in argumentation.

For more information on this framework, see the *Formulating scientific explanations using the Claim, Evidence, and Reasoning framework. – A resource for teachers to understand the CER framework from NTSA*.

- *Now that you have seen all the evidence about the different type of bridges, what is one claim we can make about the suspension bridge, compared to the other bridges?*
- *Possible claim about suspension bridge to other types:*
  - *Strong winds can cause them to sway.*
  - *They cover more distance.*
  - *They weight less.*
  - *They need strong columns/support.*
- *When making a claim, why is important to back it up with evidence? How many pieces of data/evidence do you think we need to support this claim?*
- *Possible answers: More is better than less or nothing when it comes to how many, three is the general rule of thumb for this lesson. It is important to have data or evidence because it can be tested and proven.*
- *What data/evidence do we have from your bridge designs that supports this claim?*
- *Possible evidence for claims that suspension bridges:*
  - *Sway in the wind: Our testing showed that the fan blew the suspension design the furthest, more frequently.*
  - *Cover more distance: Each model measured more than other designs and types of bridges.*
  - *Weight less: The designs weight less compared to others, more often.*
  - *Need strong columns: The designs had to be weighted down at some point to support the test loads.*
- Explain that two people looking at the same data can believe it is evidence for two different things. For example, the thermometer reads 85 degrees and that is evidence backed up math and the properties of mercury when reacting to heat, yet one person might think that 85 degrees is pleasant while another might think that 85 degrees is hot. Evidence must be backed up by reasoning.
  - What are some reasons why one person might find 85 degrees pleasant or hot or even cold?
- *How does our data and evidence support your claim? What are the reasons why your data helps support your claim?*
- *Possible answers/reasoning why and how evidence for suspension bridges support claims with*
  - *Wind: because wind pushed the bridges the furthest in many tests, it shows that wind affects this suspension types more than other types.*
  - *Distances covered: because the data collection showed we made longer bridges using the suspension type more often, it shows that we can create longer bridges with this type.*
  - *Weight less: When weighting our bridges, suspension bridges consistently weight in less than other types.*
  - *Need strong columns: Our prototypes of suspension bridges held more weight when we were able to give it a strong support base with weights or columns that supported it. The heavier the weight, the more the design could hold up in test.*
- *[6-8th] How does the manner in which you collect your data important to the process?*
- *Possible answers include: the more data the better, careful measurement helps with accuracies, placement of test load something that affected testing, but did we collect that data?*
- *[6-8th] What are somethings that can happen if data is not collected in a careful way?*
- *Possible answers include: bad evidence leads to bad reasoning, we can have a total collapse or failure point like in the video, we can build using the wrong material if we think something is light, but is actually heavier.*
- *[6-8th] What are some ways to make sure that data is collected carefully.*

- *Possible answer include: using partners to help measure, measuring more than one time, taking careful notes, testing more than one time.*
- *[6-8th] In the next design challenge, you will be designing your own data collection tests for each criteria and constraint, so thinking about how you do this will be important to support your design claims for your solution.*

5. 4. After reviewing the bridge types as a class, show the following 4.45 minute video, Brief Introduction to Bridges, reviewing various bridge types used and some of their qualities.
   - Following the video be sure to have a discussion about the various types of bridges.

Truss
- *Was it challenging to make the triangles required for the support?*
- *What did you notice about the amount of materials required?*
- *How did the design look aesthetically?*
- Advantages: *Strong, can hold heavy weight, withstand extreme weather.*
- *Disadvantages: heavy, requires a lot of material, but less then arch, expensive*

Suspension
- *What did you notice about the materials used, that was different from other designs?*
- *Did the structure take long to construct?*
- *What challenges did you face with your design model?*
- *Advantages: Covers long distances, weight less than other types, aesthetically pleasing.*
- *Disadvantages: affected by extreme weather, expensive, uses moderate amount of materials.*

Facilitator's Note: Brief Introduction of Bridges

- **Beam bridge** is the only bridge not covered. It is defined as horizontal beam supported at each end by piers or abutments. You can use any example of a plank or board spanning across a gap as a singular piece.
- A strategy to engage students in STEM is to show the historical significance of science and engineering. Highlight that science and engineering is an ever-evolving body of knowledge and a continuous cycle of practice and improvements.
- Reconnect students to question of why bridges are important to society, recommended as a NGSS theme.
- For more information on differences in bridge types, please read:

  PBS's Build a Bridge
  PBS's Building Big

Arch
- *Was making the distance a challenge?*
- *How much weight did your bridge support?*
- *Did you require a lot of materials for your design?*
- *Advantages: Strong, can hold up a lot of weight, aesthetically pleasing, can blend into environment, can use local materials.*
- *Disadvantages: covers short to moderate distances, requires a lot of material for distance covered.*

6. [6-8th] In middle school students are asked to combine successful parts of multiple designs into an improved design as well as to understand the concept of **optimal design**.
   - Ask students:
     - *Who tried 3 or more solutions before they found success?*
     - *Did your final solution combine parts from previous tries? Which parts?*
   - There is no perfect solution to any problem and there are many solutions that work, but engineers often look for the strengths of different prototypes and combine these features into a new solution to find an **optimal solution**—one that best meets the criteria and constraints.

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D. Bridging the Gap (60-80 minutes)

1. Introduce the Bridging the Gap engineering design challenge.
    - Review the important functions of bridges: What are some reasons we might have for building a bridge? Review the different types of bridges that students built in the first design challenge (truss, suspension, and arch). Review the data collection process and worksheet: What data did we collect? Why did we collect these data?
    - Explain to students that they will be split into new groups. Each group will be given a scenario that they will have to solve. For each scenario they will need to build a bridge in order to solve a problem. Some bridges will work better than others for some scenarios. Your group will have to design, build, and collect data in order to solve your particular scenario.
    - Split students into groups. Each group should include at least 1 member from each of the Building Bridges challenge group (ex. Group: 1 truss "expert", 1 suspension "expert", and 1 arch "expert")

    Design Problem:
    - Your group will be given a scenario-card (see Appendix D, "Scenario Cards"). The scenario-card will describe a problem with which your team is faced. You will have to use your knowledge of bridge designs to present a convincing claim on why your design is best suited to your given scenario. Your claim must be supported by data from your data collection sheet, and must explain the reason (or how and why) your data supports your claim. Your team should compare and evaluate the different bridge designs to determine which you will construct. Each scenario will have at least one unique criteria or constraint. Can you build a structure for your team's specific scenario?

    Criteria and Constraints:
    - Each scenario has its own set of criteria and constraints (Refer to Scenario-Card Handouts for each scenario's criteria and constraints)

2. Guide students as they work on the Bridging the Gap engineering design challenge.
    - Give each group:
        - a scenario-card (ideally, you want two groups for each scenario; i.e. 2 Desert groups, 2 Jungle groups, etc.).
        - [4th-5th] a Bridging the Gap Data Collection Handout and (6th-8th) Data Collection Plan (see Appendix D, "Bridging the Gap Data Collection Handout" and "Data Collection Plan")
        - 60 seconds to read their scenario-cards
    - [4th-5th] As a class, discuss the purpose of collecting each piece of data for this design challenge (ex. Why are we measuring height/weight held?).
    - [6th-8th] Give students 3 minutes to discuss with their groups what data should be collected for this design challenge and how they will collect it. Give groups 2 minutes to create a data-collection chart with the data they decided should be collected for this design challenge.
    - Give groups 5 minutes to discuss which bridge design they will try first to solve their problem.
    - Designate 1 student from each group as the "Supply Coordinator." Explain that only the Supply Coordinators are allowed to get up and get materials from the materials table. Tell students that they will have 20 minutes to build,

> **Co-Planning Data Collection**
> Now that students have had some structured data collection experience, work with them to plan their data collection methods for this challenge.
>
> [4th-5th] You can write the students' ideas for relevant data by projecting a blank copy of the data-collection handout and filling it in, or by writing their ideas on a white-board.
>
> [6th-8th] As a whole class discuss one piece of data that is important to collect, how this might be collected (to what level of precision) and recorded. Model this on a chart or whiteboard before having students design their own data collection table.

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test, redesign, and rebuild their structure.

3. While students are working on their designs, the teacher should walk around and ask questions. Some suggested questions are:
   - *What materials did you choose? Why?*
   - *What type of bridge did you choose for your scenario? Why?*
   - *Which criteria and constraints are you finding easiest to meet?*
   - *Which criteria and constraints are you finding the most difficult to meet?*
   - *What are ways we can collect data more carefully?*
   - *What are ways we can identify and address failure points?*

4. When teams are done building their devices, lead the class in final testing and demonstration of their designs
   - Remind groups that their presentation must include:
     - Their scenario and the criteria and constraints
     - An overview of their bridge design
     - Their claim to support why their design best meets their given scenario
     - An evaluation of the three bridge types and why they might or might not work in their scenario given the criteria *and* constraints
     - Data that supports their claim(s)
     - (6th-8th) Reasoning for the data they chose to collect
     - Whether or not their bridge met the criteria and constraints
   - As groups are presenting, lead a discussion with the presenters as well as the rest of the class. Possible questions include:
     - (4th-5th) *How well does each design solution meet the criteria and constraints?*
     - (6th-8th) *Which design best meets each criteria and constraint? How do you know? Given this, how could you combine the best parts of different solutions to optimize our solution?*
     - *Would your bridge meet the criteria and constraints of the groups that presented before you? Be specific, which criteria or constraints would you not meet?*
     - *What could you change about your bridge to make it meet the criteria and constraints of other groups?*
     - *What would you change about your bridge design if you had to do this again?*
     - *What ideas did you have that were unsuccessful? What did you learn from these unsuccessful attempts?*

Teacher's Cheat Sheet

Ideal Bridge Designs for each Scenario (any bridge can work for any scenario, these are just suggestions)

- Desert Scenario - Suspension (ideal), Arch (acceptable), Truss (less desirable)
- Jungle Scenario - Suspension (ideal), Arch (less desirable), Truss (least desirable)
- Mountain Scenario - Truss (ideal), Suspension (less desirable), Truss (least desirable)
- Vast Bay Scenario - Arch (ideal), Truss (ideal), Suspension (acceptable)
- Ice Scenario - Arch (ideal), Truss (ideal), Suspension (least desirable)

E. **Evaluation**

1. Meeting a specified criteria and staying within the confines of certain constraints is a critical skill for engineers. In this lesson it is important to gauge whether students are able to determine if a design has met the specified requirements. This can be done through analysis of other team's designs, as well as support of their own design choices using evidence. Students could evaluate and record data (see Appendix D, "Team Presentation Evaluations") about their peers' designs during a gallery walk or oral presentations.

2. In order to determine a student's ability to use criteria and constraints when making an informed decision, present each student with a hypothetical situation and ask them to write a recommendation (see Appendix D, "Scenario Recommendation") for the type of bridge they would build if they were a civil engineer working on the project. One extension is students writing a hypothetical situation, then switching with a partner to write a recommendation. Additionally, a modification may be presenting students with multiple choices for a given situation and asking them to support the choice they feel is best.

3. Communication is a critical skill for students of the 21st century. At the conclusion of the design challenge teams can present their bridges to the class. Presentations should include an overview of their given scenario, criteria, constraints, and their design process. Teams should clearly explain and support their choice of bridge type and provide reasoning as to why their choice is best when compared to other bridge types. At the conclusion of each presentation the teacher can ask tailored questions to gauge individual students' understanding.

4. The rubric included in this lesson guide is designed to evaluate student mastery of the "met" standards using the categories Below Standard, Approaching Standard, Meeting Standard, and Above Standard. This allows teachers to give individual feedback particularly for the students who are Below Standards or Above Standard in particular areas. In the Below Standards and Above Standards sections of the rubric, the idea is that no student should be receiving these scores without personalized attention from the teacher – either as remediation or an extension to reach students where they are. With that in mind, the descriptions and observations in these two sections are simply examples of what you might see for students performing at that level. The comments and notes in these sections should be tailored to the specific student and should accompany individualized support and conversations.

5. At the end of a project or design sequence, engineers (and indeed all scientists) share their work with an audience, whether that is the client or other stakeholders. For students, this type of presentation is just as important. Connecting students with an authentic audience is key to driving engagement and helping students relate what they are learning to the real world. Our goal here is to ensure that our budding engineers feel the interconnectedness of what they are doing and experience the "why" behind problem solving.
   - Some ways to do this are:
     - A mini conference
     - A panel
     - Teach back to younger students
     - Recommendations/ proposal to important constituents
     - A letter to the editor
     - A multimedia presentation to post on the Internet
   - Think through what you want students to gain from the interaction:
     - If it's technical feedback, think about inviting experts for a pitch session or judging panel
     - If it's response or action, think about having students make presentations to a community group or decision-making body (such as a school board, city council, or neighborhood association)
     - If it's a celebration, think about inviting community members whose talents or contributions are being honored or recognized in student projects
   - Try to connect to who the audience would be for the "real-world" version:
     - If students are producing documentaries, plan a red carpet screening event
     - If students are making sense of history, set up a museum-style exhibition
     - If students are producing literature, plan a book release party, author chat, or poetry slam

6. When students have completed the design challenge and have reflected as a class, remind them that they will be completing self-reflections on how they did throughout the design challenge and the design process. Review the parts of the self-reflection with them, and remind them that reflection is part of the process and is how we improve. Just like during the engineering process, we have to be honest with ourselves and others about what went well and what we still need to improve.

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IV. Appendices

A. Vocabulary

The following is the start of a suggested list of words to discuss as you read and discuss with students.

term	**student-friendly definition**
constraint	the limitations of a design problem which typically include budget and schedule limitations but may also include other limitations such as maximum size restrictions
civil engineering	is a professional engineering discipline that deals with the design, construction, and maintenance of the physical and naturally built environment, including works like roads, bridges, canals, dams, and buildings.
abutment	a mass or structure for resisting the pressure of water on a bridge or pier
arch bridge	Is a bridge with abutments at each end shaped as a curved arch, arch bridges work by transferring the weight of the bridge and its loads practically into a horizontal thrust
compression	the applied inwards (“pushing”) forces to different points on a material or structure
criteria	the requirements or desired features of a design problem often describing the purpose and standards that a system or device must meet
design problem	The identified challenge, goals, or needs that a design addresses. What you are trying to solve.
design process	a series of steps that engineers use to guide them as they solve problems. The process is nonlinear but cyclical, meaning that engineers repeat the steps as many times as needed, making improvements along the way of imagining, creating, reflecting, testing and iterating. These are steps used to come up with solutions: [design process graphic goes here]
engineer	a person who designs and builds innovative solutions (machines, systems, or structures) to solve a problem or meet a need
engineering	the process that engineers go through to create, design, test, and build a solution
failure point	a place where the design or system failed
function	the action or purpose of an object including how it moves or interacts with other objects
iteration	when you try different solutions (create, test, reflect, imagine) over and over
load	another word for force, or what the structure has to hold up to; in a machine doing work, like simple machines, a load is the weight or mass being supported and/or moved
optimal design	the design or device that best meets the criteria and constraints

prototype	the models that you build to test before you get to your final solution
structure	the material or arrangement of parts in an object to make up the whole
suspension bridge	arch bridge having a deck suspended from cables anchored at their extremities and usually raised on towers or columns
tension	the applied outwards (“pulling or stretching”) forces to different points on a material or structure, typically a rope or cable.
trade-off	a situation in which you must choose between or balance two things that are opposite or cannot be had at the same time
truss	A structural frames constructed on the geometric rigidity of the triangle

B. Resources and Background Information

- Building Big: Wonders of the World Databank - Students can use this website to research amazing bridges from around the world. http://www.pbs.org/wgbh/buildingbig/wonder/structure/browse.html#Bridge
- CER Framework – Learn the basic of this framework to introduce writing, presenting, and argumentation of science explanation.
- Building A Bridge- A comprehensive primer on bridge types, with visuals, and interactive games that cross cuts with concepts and principles taught in this lesson. http://www.pbs.org/wgbh/nova/tech/build-bridge-p1.html

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D. Lesson Handouts

Handout	**Page(s)**
Bridge Informational Cards 3 handouts with information on Arch, Suspension, and Truss bridges	25
Scenario Cards 5 handouts with scenarios, criteria, and constraints: Ice, Jungle, Desert, Mountain, Vast Bay	28
Building Bridges Data Collection Handout (4^{th}-8^{th}) Handout includes data collection table, sketch area, and guiding questions.	33
Bridging the Gap Data Collection Handout (4^{th}-5^{th}) Handout includes data collection table, sketch area, and guiding questions.	35
Bridging the Gap Data Collection Plan (6^{th}-8^{th}) Includes the handout mentioned above with the addition of CER page.	35
Bridging the Gap Data Solution Summary (4^{th}-8^{th}) A guide for making a claim about student solutions backed up by evidence and reasoning.	36
Team Presentation Evaluations A reflective tool as students present and share-out.	37
Sample Completed Team Presentation Evaluation An example of completed Team Presentation Evaluation data	38
Bridging the Gap 4^{th}-5^{th} Grade Rubric Guideline of standards assessment with metrics for measuring below, approaching, meeting, and above standards.	39
Bridging the Gap 6^{th}-8^{th} Grade Rubric Guideline of standards assessment with metrics for measuring below, approaching, meeting, and above standards.	40

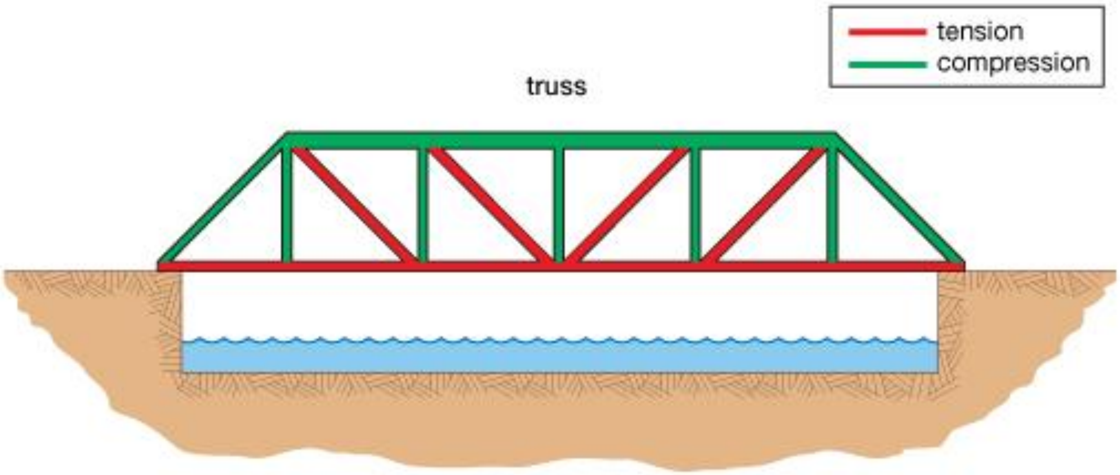
Name: ______________________________

Date: _______________ Class:__________

Bridge Information Cards

Truss bridge

A **truss bridge** is a **bridge** whose load-bearing superstructure is composed of a **truss**, a structure of connected elements forming triangular units.



Name: ______________________________

Date: _______________ Class:__________

Suspension Bridge

Bridges that use ropes or cables from the vertical suspender to hold the weight of bridge deck and traffic.

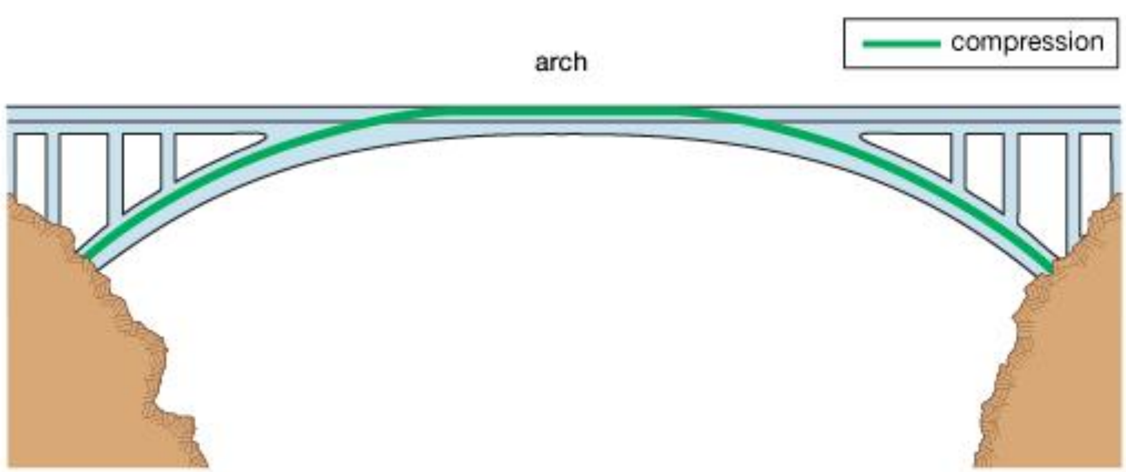
- 

Name: ______________________________

Date: _______________ Class:__________

Arch bridge

Instead of pushing straight down, the load of an arch bridge is carried outward along the curve of the arch to the supports at each end. The weight is transferred to the supports at either end. These supports, called the abutments, carry the load to the ends of the bridge.



Name: ______________________________

Date: _______________ Class:__________

Scenario Cards

Vast Bay

Location: United States, San Francisco Bay

Criteria: The structure must span a 25 inch gap

The structure must support itself

The structure must support 8 pounds of weight

Constraints: Teams have 20 minutes to construct their structure

Team must only use the materials provided

Scenario: People are frustrated by the high amount of traffic on all roads across the San Francisco Bay. Governor Brown has hired your team to build a new bridge across the bay. Design and build a bridge that will allow people to travel from one side of the bay to the other.

Name: ______________________________

Date: _______________ Class:__________

Mountains

Location: Chile, Andes Mountain Range

Criteria: The surface on the far end of the gap must be 5 inches above the team's starting position.

The structure must span an 18 inch gap

The structure must support itself

Constraints: Teams have 20 minutes to construct their structure

Teams must only use materials provided

Scenario: Your team is attempting to reach the summit of Mount El Muerto. In order to reach the summit you must cross a deep ravine. The cliff on the other side of the ravine is higher than the cliff you are currently on. Find a way across the ravine so you can continue your journey to the summit.

Name: ______________________________

Date: _______________ Class:__________

Jungle

Location: Brazil, Amazon Jungle

Criteria: The structure must span an 18 inch gap

The structure must support itself

Structure must support 2 pounds of weight

Constraints: Team must only use rubber bands, string, rope, cardboard, and wood materials that are provided

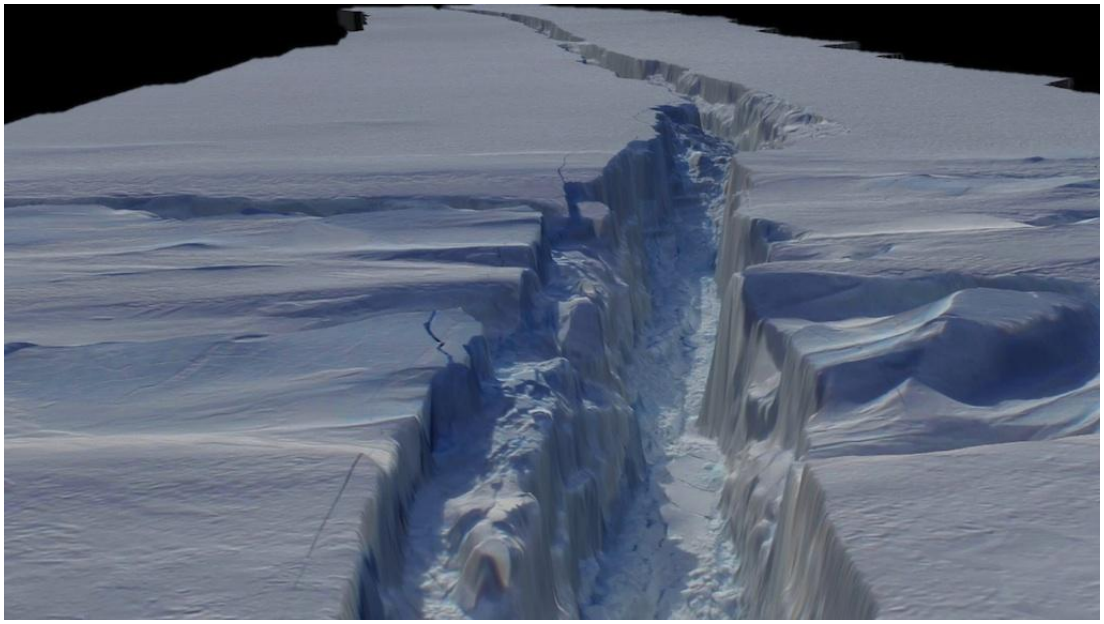
Teams have 20 minutes to construct their structure

Scenario: Your team is stranded in the Amazon Jungle with nothing but food, water, and an axe. You need to cross the Amazon River to reach a nearby village. You cannot swim or take a boat across the river because it is filled with crocodiles. Find a way to cross over the river to the other side so you can call for help in the village.

Name: ______________________________

Date: _______________ Class:__________

Ice



Location: Antarctica

Criteria: Structure must remain stable while being blown by wind (wind is generated by a fan or a piece of cardboard)

Structure cannot use the bottom of the ice chasm

The structure must span an 18 inch gap

The structure must support itself

The structure must support 8 pounds of weight

Constraints: Teams have 20 minutes to construct their structure

Team must only use the materials provided

Scenario: An ice chasm separates your team from camp. Your snowmobiles do not have enough gas to go around the chasm and you cannot leave the vehicles behind. A strong wind is blowing across the icy tundra. Find a way to cross the chasm and bring your snowmobiles with you before you freeze to death.

Name: ______________________________

Date: _______________ Class:_________

Desert

Location: Egypt, Nile River

Criteria: Surface on both sides of the river must be made of sand, dirt, or a spongy material

The structure must span an 18 inch gap

The structure must support itself

The structure must support 8 pound of weight

Constraints: Teams have 20 minutes to construct their structure

Team must only use the materials provided

Scenario: The Nile River has flooded and destroyed the only bridge that connects your small village to the big city on the other side. Without a bridge, you cannot get to the hospital on the other side. The water is too fast to swim or take a boat across. Find a way to get your people access to the medicine they need in the big city.

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Name: ______________________________

Date: _______________ Class:__________

Building Bridges Data Collection Handout (Grades 4-5)

Bridge:____________________

Prototype#__

Type(s) of bridge	Length	Width	Height	List of materials used	Time to construct	Weight held
Sketch of structure:						
This solution meets the following criteria and constraints: Criteria and constraints not met by this solution: To improve on this design, in our next design, we plan to….						

Guiding Questions:

- What kind of structure did you have in mind when constructing?
- Why did you select that bridge type for this particular scenario?
- How might you further improve on your design?

Name: ______________________________

Date: _______________ Class:__________

Bridging the Gap Data Collection (Grades 4-5)

Scenario:____________________

Prototype#__

Type(s) of bridge	Length	Width	Height	List of materials used	Time to construct	Weight held

Sketch of structure:
This solution meets the following criteria and constraints: Criteria and constraints not met by this solution: To improve on this design, in our next design, we plan to….

Guiding Questions:

- What kind of structure did you have in mind when constructing?
- Why did you select that bridge type for this particular scenario?
- How might you further improve on your design?

Name: ______________________________

Date: _______________ Class:__________

Bridging the Gap Data Collection Plan (Grades 6-8)

Scenario:_____________________

How will you determine how well each design meets the criteria and constraints of each solution?

Criterion or Constraint	**Data that will measure each design's success on this criterion or constraint:** Be specific on how measurements should be recorded.
Example: *Must span 2 feet.*	*Measurement of the length of the device in feet to the nearest ½ inch.*

What tools will you need to collect the above data?

How many data will support a claim that your solution is the optimal solution for your given scenario?

On the back of this sheet, design the data collection table you will need to collect data to assess each of your criteria and constraints.

Example

Prototype #	
Bridge span: *(length in feet to nearest ½ inch*	

Name: ______________________________

Date: _______________ Class:__________

Bridging the Gap Solution Summary (Grades 4-8)

Answer the following questions to help guide your evaluation and comparison:

Claim: What claim can you make about your final design?

Evidence: What evidence do you have about how well this (and other prototypes) met the design criteria and constraints?

Reasoning: How does your evidence support your claim?

Name: ______________________________

Date: _______________ Class:__________

Team Presentation Evaluations

Using the criteria and constraints outlined for each scenario, evaluate the design solutions of the other teams in the class.

Scenario	Met Criteria Y/N	Evidence	Followed Constraints Y/N	Evidence	Suggestions for Future Iterations
Jungle					
Vast Bay					
Mountain					
Desert					
Ice					

1. Evaluate your design, in which scenarios would your bridge work or not work? Explain your answer using evidence from the design challenge.

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Name: ______________________________

Date: _______________ Class:__________

Sample Completed Team Presentation Evaluation

Using the criteria and constraints outlined for each scenario, evaluate the design solutions of the other teams in the class.

Scenario	Met Criteria Y/N	Evidence	Followed Constraints Y/N	Evidence	Suggestions for Future Iterations
Jungle	Y	• Structure was able to support 2 lbs • Spanned 18 inches	N	• Used tape, which is a restricted material	• Teams should use another material to hold the bridge together
Vast Bay	N	• Structure was unable to span 25 inches	N	• Team did not finish in the 20 minute time limit	• Teams could explore other materials
Mountain	Y	• Supported minimum weight requirement • Spanned the gap	Y	• Finished before time limit • Only used supplied materials	• Add reinforcements to try to increase the amount of supported weight
Desert	N	• The bridge could not attach to the spongy sides	N	• Team did not finish in the 20 minute time limit	• Try to focus on making small modifications to each iteration
Ice	Y	• Spanned 18 inch gap • Supported minimum weight • Withstood “wind”	Y	• Finished in 20 minute time limit • Used given materials	• Aim for a method to use less materials

1. Evaluate your design, in which scenarios would your bridge work or not work? Explain your answer using evidence from the design challenge.
2. Answers will vary depending on the given scenarios and structures built by the student teams..

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Name: ______________________________

Date: _______________ Class:__________

Bridging the Gap 4th-5th Grade Rubric

Standards	Below Standard	Approaching Standard	Meeting Standard	Above Standard
NGSS PE (Engineering Comparing Solutions PE 3-5-ETS1-2) ***Generate and compare multiple possible solutions to a problem based on how well each meets the criteria and constraints of the problem****.* **NGSS SEP** (3 Planning and carrying out investigations): *Grades 3 through 5:* ***Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation*** *of a phenomenon or* ***test a design solution.***	*Areas that individual students may need one-on-one support with*: • Perseverance. Not giving up/ quitting too soon. • Identifying failure points as a decision point for what to try next (rather than starting all over from scratch).	• 1 or 2 solutions evaluated and documented (Cross team evaluations). • Final claim about the final solution is supported by 1-2 logical pieces of data comparing solutions to how well the criteria and constraints and by reasoning that may not be logical or clear. • Areas to strengthen might include: o Thoroughness of analysis of each design against the criteria and constraints o Logic or accuracy of data used to support this analysis	• 3 or more solutions were evaluated and documented (Cross team evaluations). • Explanations of how each solution meets the criteria and constraints are documented completely and are supported with observed and measured data. • Final claim about the final solution is logical and well supported by evidence including comparisons of solutions to how well the criteria and constraints were met and by logical reasoning.	*Areas where students may exceed:* • Thoroughness and detail of documentation • Use of multiple forms of data to support analysis • More than 5 solutions tried/ documented *Ideas for next steps for growth:* • Identify aspects of each design that best met each criteria/constraint • Propose a new solution that combines best features of these different designs • Graphically represent data
Innovator Mindsets: Collaboration *Exercise flexibility and willingness to be helpful in making necessary compromises to accomplish a common goal (see the Framework for 21st Century Learning, Collaborate with Others)*	*Areas that students may need educator support with:* • What flexibility and compromise look/sound like and what it doesn't look/sound like. • Language/ helpful phrases for communicating in a flexible way/engaging in respectful debate • Strategies for working through conflict/disagreement	• 1 or very few instances documented of how student was flexible. • Areas to strengthen might include: o Examples given don't really show flexibility or compromise o Examples given don't align with teacher observations or other team member reports of team dynamic	• Documented numerous instances of how individual student was flexible and helpful in making compromises with other team members.	*Areas where students may exceed:* • Self- reflection that shows students notice where they were not flexible/ had trouble being flexible and how they corrected that or plan to. • Demonstrated ability to help others try something different who might be struggling. *Ideas for next steps for growth:* • Make students aware of their strengths in this area and how this will benefit them in 21st Century careers. (Constant change of business requires flexibility) • Encourage them to identify other aspects of collaboration that they struggle with and how they can work on these. (e.g. listening, helping valuing everyone's contributions, etc.)

The Tech Museum of Innovation Bridging The Gap

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Bridging The Gap 6th-8th Grade Rubric

	Below Standard	Approaching Standard	Meeting Standard	Above Standard
NGSS SEP (3 Planning and carrying out investigations): *Grades 6 through 8:* ***Plan an investigation*** *individually and* ***collaboratively, and in the design: identify*** *independent and dependent variables and controls,* ***what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.***	*Areas that individual students may need one-on-one support with*: • Identification of appropriate data to measure a particular criterion/constraint • Clarity and specificity on how measurements will be made • Specificity of how measurements will be recorded (e.g. to the nearest centimeter) • Building an appropriate data collection table.	• Data Collection Plan includes explanations on how data for at least 4 criteria and constraints will be measured and recorded; however, these explanations may not always be clear or specific on how data will be measured and recorded). • The data collection methods and tools in the Data Collection Plan for 2 of the criteria and constraints will deliver data that will measure success. • The number of data indicated to support a claim is too low for the given problem. • Table for collecting data fits at least 3 measurements listed in the plan.	• Data Collection Plan includes clear, specific explanations on how data for at least 4 criteria and constraints will be measured and recorded. • The data collection methods and tools in the Data Collection Plan will deliver data that will measure success of at least 3 criteria or constraints. • The number of data indicated to support a claim is at least 3 and is reasonable for the given problem. • Table for collecting data fits most measurements listed in the plan.	*Areas where students may exceed:* • Clear, specific and detailed data collection methods *Ideas for next steps for growth:* • Guide students to identify the dependent and independent variables of a fair test for one of the tests of their criteria or constraint). • Challenge students to assess the validity of one of their data collection methods.
NGSS--Engineering Evaluate Competing Designs *(PE MS-ETS1-2)* ***Evaluate competing design solutions using a systematic process to determine how well they Meet the criteria and constraints of the problem***	*Areas that individual students may need one-on-one support with*: • Being systematic in measurement and recording of data. • Identifying the cause of a design's failure/ difficulty. • Making design improvement decisions based on the failure point. • Identifying which criteria and constraints a design is not meeting based on failure points.	• Data is collected for at least 1 design on all of the measurements planned in the Data Collection Plan. • Data collection is complete but may lack detail or specificity in many cases. • Explanation of solution does not include all criteria and/or constraints or is not supported by data. • Final claim about the final solution is supported by 1-2 logical pieces of data comparing solutions to how well the criteria and constraints and by reasoning that may not be logical or clear. • Areas to strengthen might Include: ○ Thoroughness of analysis of each design against the criteria and constraints. ○ Logic or accuracy of data used to support this analysis	• Data is collected for at least 2 designs on all of the measurements planned in the Data Collection Plan for at least 2 designs. • Data collection is detailed and specific. • Explanations of how each solution meets the criteria and constraints are documented completely and are supported with data. • Final claim about the final solution is logical and well supported by evidence including comparisons of solutions to how well the criteria and constraints were met and by logical reasoning.	*Where students may exceed:* • Careful, methodic collection and recording of data. • Clear and detailed explanation of failure points and causes • Focused improvements on failure points and ability to persevere until optimal designs are reached *Ideas for next steps for growth:* • Allow students to propose an engineering problem they are interested in exploring and solving on their own • Allow students to delineate all criteria and constraints for a given design problem • Ask students to assess design decisions and specifically identify trade-offs they made

Name: ______________________________

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Innovator Mindsets: Collaboration *Exercise flexibility and willingness to be helpful in making necessary compromises to accomplish a common goal (see the Framework for 21st Century Learning, Collaborate with Others)*	*Areas that students may need educator support with:* • What flexibility and compromise look/sound like and what it doesn't look/sound like. • Language/ helpful phrases for communicating in a flexible way/engaging in respectful debate • Strategies for working through conflict/disagreement	• 1 or very few instances documented of how student was flexible. • Areas to strengthen might include: o Examples given don't really show flexibility or compromise o Examples given don't align with teacher observations or other team member reports of team dynamic	• Documented numerous instances of how individual student was flexible and helpful in making compromises with other team members.	*Areas where students may exceed:* • Self- reflection that shows students notice where they were not flexible/ had trouble being flexible and how they corrected that or plan to improve in future. • Demonstrated ability to help others try something different who might be struggling. *Ideas for next steps for growth:* • Make students aware of their strengths in this area and how this will benefit them in 21st Century careers. (Constant change of business requires flexibility) • Encourage them to identify other aspects of collaboration that they struggle with and how they can work on these. (e.g. listening, helping valuing everyone's contributions, etc.)