BRIDGE UP!

ENGINEERING

VERSION 2.0

November 2016

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Minnesota Department of Transportation

Wisconsin Department of Transportation

Center for Global Environmental Education,
Hamline University School of Education

Stillwater Area Public Schools

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About STILLWATER AREA PUBLIC SCHOOLS

Stillwater Area Public Schools (SAPS) are well known for providing a solid and rigorous curriculum that focuses on the expanded basics of reading, writing, math, logic and speaking. SAPS K-12 STEM program was designed to engage students, improve academic achievement, and enhance the quality of education by providing 21st century learning skills for every student with direct, meaningful and hands-on experiences in the areas of science, technology, engineering, and mathematics.

About HAMLINE UNIVERSITY'S CENTER FOR GLOBAL ENVIRONMENTAL EDUCATION

The Center for Global Environmental Education (CGEE) is an integral program in the School of Education at Minnesota's oldest university—Hamline University, which celebrated its 150th anniversary in 2004. Since CGEE's inception in 1990, teachers, students, community leaders, and concerned citizens have come to CGEE for inspired instruction and outstanding educational resources. The Center's pioneering work in environmental education is grounded in the tradition of progressive learning that has been a hallmark of Hamline's School of Education. CGEE's commitment to the strategic use of technology combined with hands-on learning creates and supports global communities of learners committed to the stewardship of local environments.

CGEE Mission

To foster environmental literacy and stewardship in citizens of all ages.

CGEE achieves its mission through complementary programs that impact four audiences:

- Distinctive professional development and graduate degree programs for educators
- Project-based, K-12 initiatives that have enriched learning for hundreds of thousands of students worldwide
- Multimedia programs that have impacted millions of citizens through multiple channels of dissemination
- Community outreach initiatives that engage citizens in local stewardship

Inspiring Students in Engineering

The St. Croix Crossing is a bridge that will connect St. Joseph, Wisconsin, and Oak Park Heights, Minnesota, and replace the Stillwater Lift Bridge. The modern engineering concepts used to build it provide an exciting opportunity to teach the community about how bridges are built and maintained.

Experts predict significant growth in the demand for qualified employees in engineering fields. The St. Croix Crossing project gives teachers and students a unique opportunity to watch civil engineering at work. The Minnesota and Wisconsin Departments of Transportation hope the Bridge Up! curriculum will get students excited about real-work transportation planning, design and construction and to inspire them to pursue engineering as a career.

The Bridge Up! curriculum provides classroom resources for teachers using bridge design and construction principles as the foundation for learning. Classroom activities are designed to help bring students closer to the everyday work of engineers and construction workers.

With the St. Croix Crossing as the catalyst for the Bridge Up! curriculum, the Minnesota and Wisconsin Departments of Transportation are excited for the opportunity to use bridge design and construction as a gateway to science, technology, engineering, and mathematics (STEM) instruction in Minnesota and Wisconsin schools.

Table of Contents

Introduction

"We build too many walls and not enough bridges."

Sir Isaac Newton

Discovering and studying bridges is a great way to learn about people, the times and places they have lived, and the astounding creations of which humans are capable. Throughout human history, people in different times, cultural traditions, and physical locations have found an amazing variety of creative solutions to the practical problems of crossing rivers, valleys, roads, inlets, and bays. Some bridges are built as enduring monuments of a city or a civilization, drawing attention to themselves as symbolic, signature statements. Others are nearly invisible as they humbly do their work of helping us get from A to B. But even the simplest bridges employ engineering and science principles that are fundamentally important and fascinating in their own right. The design, siting, financing, and construction of bridges involves applied geometry, mathematics, physics, environmental and material sciences, and multiple specializations within engineering—not to mention economics, politics, architecture, and the ability to organize and lead teams of workers.

Welcome to Bridge Up!—Engineering

Capturing some of the wonder of bridges in the interest of inspiring a new generation of transportation engineers is the driving goal of this program. It offers Minnesota and Wisconsin schools a rich collection of K-12 learning resources that are integrated with engineering and science standards. The genesis of the project is linked to the creation of a new bridge over the St. Croix River—St. Croix Crossing. While this striking new bridge is highlighted in places throughout the Bridge Up!—Engineering materials, the project and its materials also incorporate images and information about other regional and international bridges and is intended to be equally useful and interesting for students wherever they live.

Program Resources

The Bridge Up!—Engineering program consists of the following three learning resources:

- Multimedia iBook for grades K-3
- Multimedia interactive web modules for grades 4-12
- Activity Guide (this document)

The program's content was developed in a close-working collaboration between the Stillwater Area Public Schools, Hamline University's Center for Global Environmental Education and the Minnesota Department of Transportation. MnDOT engineers—in particular Kevin Western and Arielle Ehrlich—helped shaped the project's vision and content from the beginning. A team of Stillwater teachers developed lesson plans and helped make all content relevant and useful for busy educators. The multimedia production team from Hamline University worked to create engaging visualizations and interactive learning experiences. Staff at Himle Rapp & Company provided oversight and editing for this activity guide. Tracy Zdroik assisted with design and layout for this activity guide.

We hope that you and your students find Bridge Up!—Engineering to be a useful, enjoyable addition to your classroom and curricula.

How to Use the Program in Your Classroom

Here are some ways teachers can use Bridge Up! in the classroom:

- **Teacher Presentation Tool:** Use the program as a presentation tool, projecting the program's content to the class using a computer projector, screen, and audio speakers.
- **Student Computer Lab Resource:** All students in the class can use the program at once in a computer lab.
- **Student Class Project Resource:** Use the program as a resource for individual students to use as part of class projects or when other classroom work is completed.
- **Student Exploration and Presentation:** Have groups of students thoroughly explore different sections of the program and then present those sections to the rest of the class using Bridge Up! as a presentation tool.
- **Student Use at Home:** Have students access the program individually at home via the Web.

Bridge Up! Learning Resources Matrix

MINNESOTA STANDARDS AND BENCHMARKS	MULTIMEDIA	LESSON PLAN
K.1.1.2.1	Web Module: Geometry in Engineering	Engineering Bridges
	Web Module: Fundamental Forces	
K.1.2.1.1	Bridge Up! iBook	Grade K-2: Engineering Bridges
	Web Module: Geometry in Engineering	
	Web Module: Mastering Materials	
K.2.1.1.1	Web Module: Geometry in Engineering	Grade K-2: Engineering Bridges
	Web Module: Fundamental Forces	
	Web Module: Mastering Materials	
1.1.1.1.1	Web Module: Fundamental Forces	Grade K-2: Engineering Bridges
1.1.1.1.2	Web Module: Geometry in Engineering	Grade K-2: Engineering Bridges
1.1.3.1.1	Bridge Up! iBook	
1.1.3.2.1	Web Module: Mastering Materials	
2.1.1.2.1	Web Module: Fundamental Forces	
2.1.2.2.1	Web Module: Mastering Materials	Grade K-2: Engineering Bridges
2.1.2.2.2	Web Module: Mastering Materials	
2.1.2.2.3	Bridge Up! iBook	Grade K-2: Engineering Bridges
	Web Module: Mastering Materials	
2.2.1.1.1	Web Module: Geometry in Engineering	
	Web Module: Fundamental Forces	
	Web Module: Mastering Materials	
2.2.2.1.1	Web Module: Fundamental Forces	
2.2.2.1.2	Web Module: Fundamental Forces	
2.2.2.2.1	Web Module: Fundamental Forces	
2.2.2.2.2	Web Module: Fundamental Forces	
3.1.1.2.2	Web Module: Mastering Materials	
3.1.1.2.3	Web Module: Mastering Materials	
3.1.1.2.4	Web Module: Mastering Materials	
3.1.3.2.2	Web Module: Mastering Materials	Grade 3: Engineering
3.1.3.4.1	Web Module: Geometry in Engineering	
	Web Module: Fundamental Forces	
	Web Module: Mastering Materials	
4.1.2.1.1	Web Module: Fundamental Forces	
4.1.2.2.1	Web Module: Geometry in Engineering	Grade 4: Geometry in Bridge Design
4.1.2.2.2	Web Module: Mastering Materials	Grade 4: Materials

MINNESOTA STANDARDS AND BENCHMARKS	MULTIMEDIA	LESSON PLAN
4.1.2.2.3	Web Module: Mastering Materials	Grade 4: Materials
4.1.3.3.1	Web Module: Fundamental Forces	
	Web Module: Mastering Materials	
4.2.1.1.1	Web Module: Mastering Materials	
5.1.1.1.1	Web Module: Fundamental Forces	
	Web Module: Mastering Materials	
5.1.1.1.2	Web Module: Mastering Materials	
5.2.2.1.2	Web Module: Fundamental Forces	
5.2.2.1.3	Web Module: Fundamental Forces	
6.1.2.1.2	Bridge Up! iBook	
	Web Module: Fundamental Forces	
	Web Module: Mastering Materials	
6.1.2.1.4	Web Module: Fundamental Forces	Grade 6: Tension and Compression Forces
6.1.3.1.1	Web Module: Fundamental Forces	
6.2.2.2.1	Web Module: Fundamental Forces	
6.2.2.2.2	Web Module: Fundamental Forces	
6.2.2.2.3	Web Module: Fundamental Forces	
7.1.1.2.4	Web Module: Fundamental Forces	
	Web Module: Mastering Materials	
8.1.1.2.1	Web Module: Mastering Materials	Grade 7: Bridge Building
8.1.3.3.1	Web Module: Fundamental Forces	
8.1.3.3.2	Web Module: Geometry in Engineering	
	Web Module: Fundamental Forces	
	Web Module: Mastering Materials	
9.1.1.1.7	Web Module: Mastering Materials	
9.1.2.2.1	Web Module: Geometry in Engineering	Grade 9-12: Geometry in Engineering
9.1.3.2.1	Web Module: Mastering Materials	
9.2.2.2.1	Web Module: Fundamental Forces	
9.2.2.2.2	Web Module: Fundamental Forces	
9.2.2.2.3	Web Module: Fundamental Forces	Grade 9-12: Fundamental Forces, Grade 9-12: Mastering Materials
9.2.2.2.4	Web Module: Fundamental Forces	
9.2.3.2.1	Web Module: Fundamental Forces	
9P.2.2.2.1	Web Module: Fundamental Forces	

WISCONSIN STANDARDS	MULTIMEDIA	LESSON PLAN
B.8.2	Web Module: Mastering Materials	
B.12.1	Web Module: Mastering Materials	
C.4.4	Bridge Up! iBook	
	Web Module: Geometry in Engineering	
	Web Module: Fundamental Forces	
	Web Module: Mastering Materials	
D.4.2	Web Module: Geometry in Engineering	Grade 4: Materials
D.4.3	Web Module: Mastering Materials	
D.4.4	Web Module: Fundamental Forces	
D.4.5	Web Module: Mastering Materials	
D.4.6	Web Module: Fundamental Forces	
D.4.7	Web Module: Fundamental Forces	
D.8.5	Web Module: Fundamental Forces	
D.8.6	Web Module: Fundamental Forces	
D.12.11	Web Module: Fundamental Forces	
E.4.8	Web Module: Mastering Materials	
G.4.1	Bridge Up! iBook	Grade 3: Engineering
G.4.3	Web Module: Mastering Materials	Grade 3: Engineering
G.8.3	Web Module: Mastering Materials	
G.12.5	Web Module: Mastering Materials	
H.4.1	Bridge Up! iBook	
	Web Module: Fundamental Forces	

Technology Requirements

Bridge Up!—Engineering includes two kinds of multimedia learning resources: an iBook for grades K-3 and a series of web-based modules for grades 4-12. The technical requirements for these digital learning materials are straightforward and shouldn't pose special challenges for schools with relatively modern hardware and network resources.

Bridge Up!—Engineering iBook. This e-book, which can be downloaded at **http://www.dot.state.mn.us/stem/curriculum/bridgeup/BridgeUp-iBook.ibooks** includes multimedia and interactive elements, and was authored in iBooks Author for playback on Apple iPads and on Mac computers running the Mavericks (10.9) or newer operating systems.

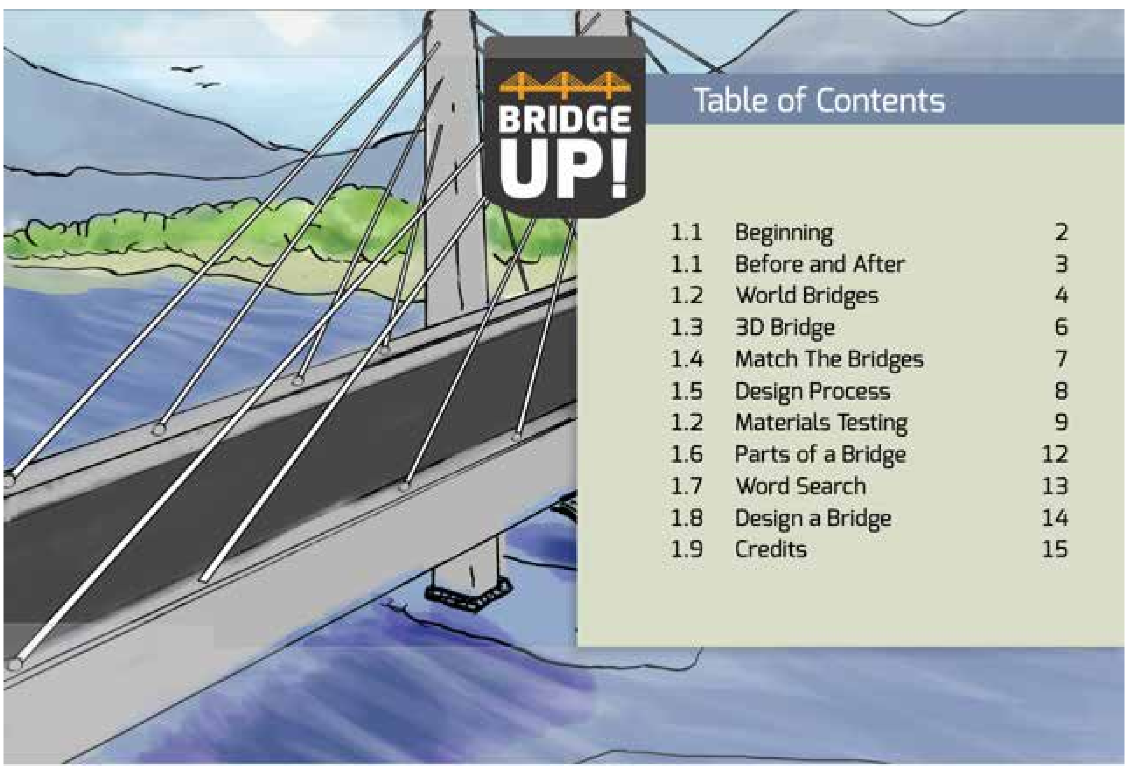
Bridge Up!—Engineering web modules. This series of web modules is found at **http://www.dot.state.mn.us/stem/curriculum/bridgeup/index.html**. As of this writing, fundraising efforts are still underway for development of a final Bridge Up! Design Challenge module that will integrate content from the other modules in a bridge design challenge activity. All of this content is authored in HTML for playback through web browsers (recent versions of Internet Explorer, Firefox, Chrome, and Safari) on Mac and Windows computers as well as on Android and iOS tablets (iPads). Note that the modules include numerous videos, and simultaneous playback from multiple tablets and computers in a school setting which may result in poor performance due to limited bandwidth of school networks.

Multimedia Resources Overview

Bridge Up! iBook for grades K-3

The Bridge Up! iBook tells the story of a young man inspired to become an engineer by his engineer mother. Its vocabulary is suited to grades 4-5. The story can be read aloud by a narrator if the audio icon is clicked on each page. The following image of the Table of Contents indicates the interactive elements—"widgets" in iBook-speak—found in the story. Touching the listed items on the Table of Contents jumps to the relevant page in the story. "Pinching" on any page opens up the Table of Contents.

Table of Contents

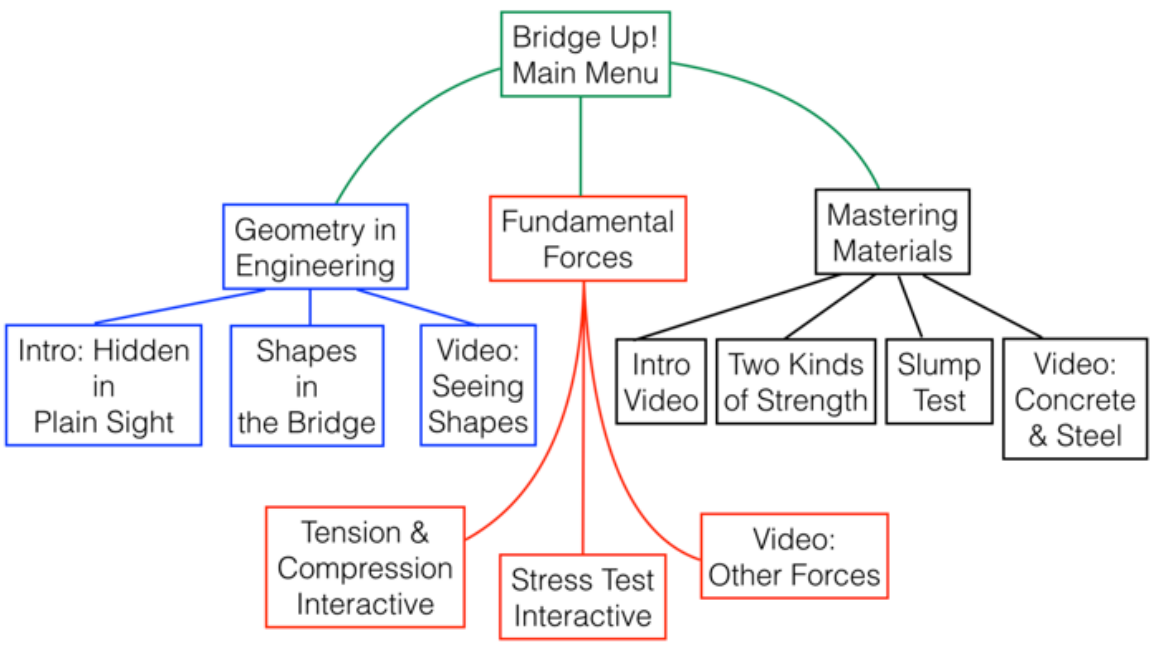


Bridge Up! Web Modules for grades 4-12

The Bridge Up! program's three Web modules can be explored in any order, though we recommend completing the elements within each module in the presented sequence. The modules consist of one or more activities and a video that provides background and context. Modules introduce topics for grades 4-12, with vocabulary geared for grades 4-8. To accommodate deeper learning, an Additional Resources link on the main menu screen offers resources organized by grade ranges that build on the content found in the modules.

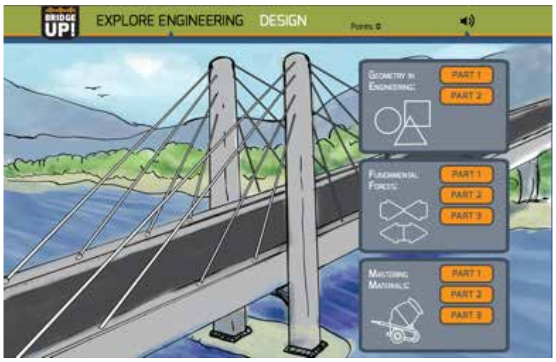
The following flow chart provides an at-a-glance overview of the web-based program's navigational flow.

Navigational Flowchart



Web Modules: Descriptions and Resources

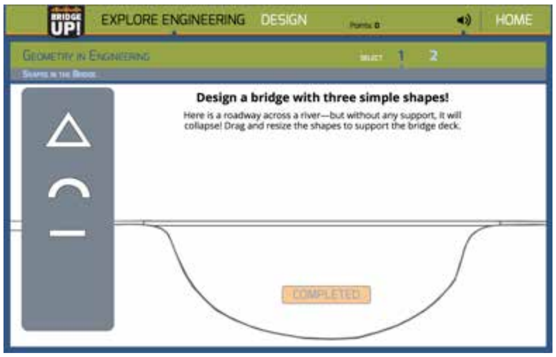
Web Module: Main Menu Screen



- **Geometry in Engineering module** introduces how fundamental geometric shapes—rectangles, triangles, and arches—are used in bridges and other built structures.
- **Fundamental Forces module** introduces forces bridges must withstand: tension, compression, shear, and torsion.
- **Mastering Materials module** introduces the most prominent materials used in bridge building.

Web Module: Geometry in Engineering

The module has two elements, which can be accessed by the numbers on the green menu bar at the top of the screen:



Part 1 Interactive—Big Idea: Triangles, arches, and rectangles are fundamental to simple and complex bridges.

- **Action:** users drag icons for basic geometric shapes to build different bridges.
- **Discussion—Extension:**
    - Can students find the same shapes in structures around their room or school?
    - What other geometric shapes do students see around them?

Part 2 Video. Big Idea: This three-minute video shows how different geometric shapes offer alternative bridge designs that handle weight loads differently.

- **Key Vocabulary:**

Load—a weight that adds stress to a bridge.

Beam bridge—Beam bridges are made of a flat piece, or beam, laid across two or more supports.

Pier—A vertical support member for a bridge.

Deck—Flat bridge surface that vehicles drive on top of.

Arch bridge—Arch bridges are made from one or more arches and abutments.

Stress—Pressure resulting from a load.

Truss bridge—This bridge type has a superstructure composed of elements connected to form triangles.

Video Viewing Guide: “Geometry in Engineering”

As you watch the video, write your answers to these questions—you can pause the video or replay it using the on-screen video controller.

1. What three basic geometric shapes are shown in the opening images of the video?

2. What is the focus of the study of geometry?

3. What are two kinds of stress that bridges must be able to handle?

4. What geometric shapes are found in beam bridges?

5. What was the breaking force of the first balsa wood beam bridge?

6. Did the longer beam bridge handle a greater load than the shorter one?

7. In an arch bridge, where does the stress go?

8. What shapes do you find in truss bridges?

9. Which parts of the truss bridge broke apart first?

Video Viewing Guide: "Geometry in Engineering" "—with answers

As you watch the video, write your answers to these questions—you can pause the video or replay it using the on-screen video controller.

1. What three basic geometric shapes are shown in the opening images of the video?
   Rectangles, circles (and arches), and triangles.

2. What is the focus of the study of geometry?
   The study of shapes and figures.

3. What are two kinds of stress that bridges must be able to handle?
   The weight of vehicles and the weight of the bridge.

4. What geometric shapes are found in beam bridges?
   Rectangles.

5. What was the breaking force of the first balsa wood beam bridge?
   115 pounds.

6. Did the longer beam bridge handle a greater load than the shorter one?
   No.

7. In an arch bridge, where does the stress go?
   To the ground.

8. What shapes do you find in truss bridges?
   Triangles.

9. Which parts of the truss bridge broke apart first?
   The outer diagonal members of the truss.

Web Module: Fundamental Forces

The module has three elements, which can be accessed by the numbers on the green menu bar at the top of the screen:

Part 1 Interactive—Big Idea: Bridges are designed to withstand powerful forces of tension and compression.

- **Action:** Students stack circus trucks on a beam bridge to see how the increasing weight produces tension and compression in different parts of the bridge.

Part 2 Interactive—Big Idea: Tension and compression occur in different places in different bridge designs.

- **Action:** Students choose a bridge type and are challenged to correctly identify tension and compression points.
- **Discussion—Extension:**
    - Which of the bridge types were easiest to predict where forces occur—why?
    - Which were more difficult—why?

Part 3 Video. Big Idea: This six-minute video looks at how engineers have learned from historic collapses how to manage primary forces impacting bridges.

- **Key Vocabulary:**

Tension—a force that pulls a structure apart.

Compression—a force that crushes a structure.

Shear—a force that exerts opposing pressures on a structure.

Torsion—a force that produces stress on a structure through a twisting movement.

Video Viewing Guide: “Fundamental Forces—Mystery of Galloping Gertie”

As you watch the video, write your answers to these questions—you can pause the video or replay it using the on-screen video controller.

1. How old was Galloping Gertie when the bridge fell apart?

2. What force caused the Dee River Bridge disaster?

3. What material was unable to withstand this force in the Dee River Bridge collapse?

4. What changes in engineering eventually resulted from the Dee River Bridge collapse?

5. What force often occurs on bridges and other structures during earthquakes?

6. What features did the new Bay Bridge have to handle shear forces?

7. What force caused the Tacoma Narrows Bridge collapse? What was the source of this force?

8. What feature of Galloping Gertie’s design led to its collapse?

9. What alternative design was used when the bridge was rebuilt?

Video Viewing Guide: “Fundamental Forces—Mystery of Galloping Gertie” ” —with answers

As you watch the video, write your answers to these questions—you can pause the video or replay it using the on-screen video controller.

1. How old was Galloping Gertie when the bridge fell apart?

   Four months old.

2. What force caused the Dee River Bridge disaster?

   Tension.

3. What material was unable to withstand this force in the Dee River Bridge collapse?

   Iron.

4. What changes in engineering eventually resulted from the Dee River Bridge collapse?

   Materials strong in tension and compression: steel and steel reinforced concrete.

5. What force often occurs on bridges and other structures during earthquakes?

   Shear.

6. What features did the new Bay Bridge have to handle shear forces?

   Parts of the bridge were allowed to move independently.

7. What force caused the Tacoma Narrows Bridge collapse? What was the source of this force?

   Torsion.

8. What feature of Galloping Gertie’s design led to its collapse?

   Girders below the bridge deck.

9. What alternative design was used when the bridge was rebuilt?

   Open truss design.

Web Module: Mastering Materials

The module has three elements, which can be accessed by the numbers on the green menu bar at the top of the screen:

Part 1 Interactive—Big Idea: This three-minute video explores key milestones in the evolution of today's main construction materials: steel and concrete.

- **Key Vocabulary:**

  Steel—a metal alloy made of carbon and iron.

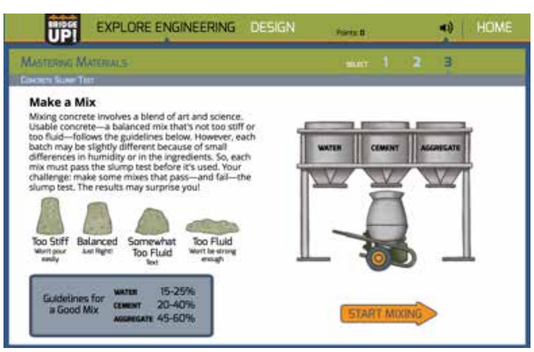
  Concrete—a material made by mixing cement, water, aggregate and other additives.

  Aggregate—sand or pieces of broken or crushed stone or gravel used to make concrete.

  Alloy—a metal made from combining two or more metallic elements.

Part 2 Interactive—Big Idea: Common building materials—wood, concrete, steel and reinforced concrete—have varying strengths regarding forces of tension and compression.

- **Action:** Students explore tension and compression of these materials by positioning representative icons in the correct quadrant of a tension and compression chart.



Part 3 Interactive—Big Idea: Engineers carefully mix concrete's primary ingredients—water, cement, and aggregate—to achieve mixes resulting in optimal strength and fluidity.

- **Action:** : Students control amounts of these ingredients to produce mixes with varied degrees of fluidity.
- **Discussion—Extension:**
  - Have students note percentages in concrete mixtures and develop a chart showing how percentages correlate with different fluid states.

Video Viewing Guide: "Mastering Materials"

As you watch the video, write your answers to these questions—you can pause the video or replay it using the on-screen video controller.

1. What continents did the Roman Empire partially include?

2. What four kinds of structures did Romans make with concrete?

3. What material did the Romans use from volcanoes near Naples?

4. How did Samurai sword makers make sharp edges for their blades?

5. How did Samurai sword makers make their blades flexible?

6. How much stronger were Samurai blades than others?

7. What material is used to reinforce concrete?

8. What are three benefits of reinforced concrete?

9. Worldwide, what percentage of structures are made with concrete?

Video Viewing Guide: “Mastering Materials” ”—with answers

As you watch the video, write your answers to these questions—you can pause the video or replay it using the on-screen video controller.

1. What continents did the Roman Empire partially include?

   Europe, Africa, Asia.

2. What four kinds of structures did Romans make with concrete?

   Roads, buildings, bridges, aqueducts.

3. What material did the Romans use from volcanoes near Naples?

   Ash from silicate rock.

4. How did Samurai sword makers make sharp edges for their blades?

   By adding more carbon.

5. How did Samurai sword makers make their blades flexible?

   By adding less carbon.

6. How much stronger were Samurai blades than others?

   Ten times stronger.

7. What material is used to reinforce concrete?

   Steel.

8. What are three benefits of reinforced concrete?

   Insect proof, water proof, rock hard, fire proof, storm proof.

9. Worldwide, what percentage of structures are made with concrete?

   Fifty percent.

Lesson Plan Elements

Each lesson plan in this activity guide includes the following elements:

Big Idea The central concepts being explored.

Essential Questions The big question explored through the lesson. These could be used as writing prompts.

Background Information Key ideas that the teacher needs to know to adequately teach the lesson.

Standards Minnesota and Wisconsin standard numbers, objectives and benchmarks.

Connections with Multimedia Connect with Bridge Up! interactive iBook and web-based modules.

Activity Description Quick summary of lesson.

Vocabulary Words students need to know in order to understand the lesson and concepts. Include the definitions.

Materials Things required for completion of the activity.

Procedure Steps for delivering lessons to students.

Assessment Procedure for assessing students' understanding of lesson.

Extensions Additional activity suggestions to expand on concepts.

Other Resources Links, books, etc.

BRIDGE UP!
ENGINEERING

LESSON 1 – GRADES K-2

LESSON 1 – GRADES K-2: Engineering Bridges

Big Idea

There are differences between human-made and natural components in our world. An engineer uses human-made materials for constructing a bridge and needs to consider the natural surroundings.

Essential Questions

What are natural things we find in our world?

What materials do engineers use to make bridges?

What are human-made things we find in our world?

How are they different? How are they alike?

Background Information

Our world is a mixture of natural and human-made objects. Natural objects are found in nature and have always been around. Human-made objects are created by humans. Humans sometimes make human-made items from things they find in nature.

Standards & Benchmarks

Minnesota Science Standards

K.1.1.2. Inquiry

Scientific inquiry is a set of interrelated processes used to pose questions about the natural world and investigate phenomena.

Benchmark: K.1.1.2.1 Descriptions of Observations

Use observations to develop an accurate description of a natural phenomenon and compare one's observations and descriptions with those of others.

K.1.2.1 Practice of Engineering

Some objects occur in nature; others have been designed and processed by people.

Benchmark: K.1.2.1.1 Comparing Natural & Human Made

Sort objects into two groups: those that are found in nature and those that are human made.

Wisconsin Science Standards

ENG1.a.1.e Design is a creative process.

ENG1.a.2.e Everyone can design solutions to a problem.

Connections with Multimedia Program

Bridge Up! iBook

Activity Description

Students will identify natural and human-made items using photos.

Vocabulary

World – The Earth and all the people and things upon it.

Natural – Not made or changed by humans.

Human-made – Made by people rather than nature.

Materials

- Several natural objects: rocks, water, plants, dirt, bugs, etc.
- Several human-made objects: pencil, paper, book, cup, etc.

Procedure

- Ask the students if they know what we mean when we say "our world." Lead the discussion so that the students understand that we mean where we live and all the things that surround us.
- Project or draw two columns and label one natural and the other human-made.
- Randomly hold up natural and human-made items one at a time and ask the students whether they thing it is human-made or natural. Ask them to tell you why they think it's natural or human-made. Write (or place if possible) the item in the category the students choose.
- After all items are sorted, ask the students if they can tell you how the natural items are alike (made by nature, free)
- Ask how all the human-made items are alike (not made by nature, you buy them, made by people or robots)

Assessment

Teacher observation

Extensions

Divide the students into groups (3-4). Give each group or member of the group a picture of a bridge over a river. Ask them to work together to decide which things in the picture are natural and which are human-made. Provide time for them to share with the class.

Other Resources

Minnesota STEM Teacher Center. K.1.2.1 Practice of Engineering
http://scimathmn.org/stemtc/frameworks/k121-practice-engineering

Wisconsin Standards for Technology and Engineering
http://cte.dpi.wi.gov/sites/default/files/imce/cte/pdf/te_standards.pdf

Name:

Directions: Circle natural objects. Put an X over human-made objects.

Arch bridge in Eden Township (Pipestone County, MN) Photo credit: Minnesota Department of Transportation

Name:

Directions: Circle natural objects. Put an X over human-made objects.

Truss bridge in Maine Township (Otter Tail County, MN) Photo credit: Minnesota Department of Transportation

LESSON 1 – GRADES K-2 : Engineering Bridges

Big Idea

Communication is important when working with others. You must be able to listen and to ask questions.

Essential Questions

Why do we ask questions?

Why do we need evidence when answering questions?

Standards & Benchmarks

Minnesota Science Standards
1.1.1.1 Scientists
Scientists work as individuals and in groups to investigate the natural world, emphasizing evidence and communicating with others.

Benchmark: 1.1.1.1.1 Observations for Questions
When asked "How do you know?," students support their answer with observations.

Benchmark: 1.1.1.1.2 Descriptions & Comparisons
Recognize that describing things as accurately as possible is important in science because it enables people to compare their observations with those of others.

Wisconsin Science Standards
ENG1.a.1.e Design is a creative process.
ENG1.a.2.e Everyone can design solutions to a problem.
ENG1.a.3.e Discuss the design process is a purposeful method of planning practical solutions to problems.

ENG1.a.4.e Requirements for a design include such factors as the desired elements and features of a product or system or the limits that are placed on the design.

Connections with Multimedia Program

Bridge Up! iBook

Activity Description

Are you my match? – Students will practice asking questions and listening to descriptions given by their peers to locate the person with a matching bridge.

Vocabulary

Description – An account that presents a picture to a person who reads or hears it.

Question – Something asked or an instance of asking.

Bridge – A structure carrying a road, path, railroad, or canal across a river, ravine, road, railroad, or other obstacle.

Shapes – Outward appearances.

Materials

- Pictures of various bridges on card stock (2 to 3 copies of each bridge to form pairs). Pictures of Minnesota bridges can be found at: **http://www.dot.state.mn.us/historicbridges/**
- Hole punch
- String/yarn

Procedure

- Prior to class, make copies of pictures so that there are pairs of pictures enough for your class. If you have an odd number of students in class, one set could have 3.
- Explain to the students that engineers work with many people when building bridges. It is important that they are able to describe what the bridge will look like and how it will be built so that others know what to do.
- Tell the students that today they will practice describing what they see so they can find the classmate with the same picture they have. (You may want to show one picture of a bridge to practice describing as a whole group before playing the game. Have them look for shapes, wires, etc.)
- Hang one bridge picture on the back of each child. Tell them that they may not look at their picture, but may ask their classmates to look and tell them something about their bridge. It's important that they listen to what others tell them so that they can find the person with a matching bridge.
- Allow the students to circulate and describe each other's bridge.
- Alternative Method: Post several pictures of bridges on the wall, keeping the matching pictures in a stack. Divide the class into two teams. Show one picture from the stack to team one and have them give verbal clues to the team two until they can pick the matching bridge from the pictures on the board. Repeat with teams reversing roles.

Assessment

Teacher observation

Extensions

Students can work together in pairs or small groups to draw or build bridges with blocks or Legos and then they can tell the class about their bridge.

Other Resources

Minnesota STEM Teacher Center. *1.1.1.1 Scientists*

http://www.scimathmn.org/stemtc/frameworks/1111-scientists

LESSON 1 – GRADES K-2 : Engineering Bridges

Big Idea
Engineers identify problems and look for ways to solve those problems.

Essential Questions
What is the Engineering Design Process?

Why are certain materials used for various products?

How can you design a successful bridge?

Background Information
The Stillwater Lift Bridge between Minnesota and Wisconsin slowed traffic and caused long back-ups of vehicles in downtown Stillwater when the bridge went up to let vessels through. Traffic congestion can result in pedestrian and traffic safety problems. People in the community and engineers from Minnesota and Wisconsin worked together to determine what the new bridge needed to help solve this problem. They designed and built a four-lane bridge that better met the needs of the traveling public to connect Minnesota and Wisconsin.

Standards & Benchmarks

Minnesota Science Standards

2.1.2.2 Practice of Engineering
Engineering design is the process of identifying a problem and devising a product or process to solve the problem.

Benchmark: 2.1.2.2.1 Objects to Meet Needs
Identify a need or problem and construct an object that helps to meet the need or solve the problem.

Benchmark: 2.1.2.2.3 Benefits of Engineered Items
Explain how engineered or designed items from everyday life benefit people.

Wisconsin Science Standards

ENG2.a.1.e Discuss the engineering design process includes identifying a problem, looking for ideas, developing solutions and sharing solutions with others.

ENG2.a.2.e Explore when designing an object, it is important to be creative and consider all ideas.

ENG2.b.1.e Expressing ideas to others, verbally and through sketches and models, is an important part of the design process.

ENG2.b.2.e Discuss how models are used to communicate and test design ideas and processes.

Connections with Multimedia Program
Bridge Up! iBook

Activity Description

Students will work together in pairs or small groups to create a two-foot bridge that will allow a small car to cross without crumbling.

Vocabulary

Abutment – The part of a bridge that stands at either end and transfers the loads of the bridge back to the ground.

Arch bridge – A bridge made from one or more arches and abutments.

Beam bridge – Beam bridges are made of a flat piece, or beam, laid across two or more supports.

Civil engineering – The field of engineering concerned with the design and construction of public structures, such as buildings, bridges, roads, and water systems.

Engineer – A person who uses his or her creativity and understanding of mathematics and science to design things that solve problems.

Engineering design process – The steps that engineers use to design something to solve a problem.

Load – A heavy or bulky thing that is being carried or is about to be carried.

Materials – The matter from which a thing is or can be made of.

Prototype – A model of a design that is made to help engineers understand and test the design.

Suspension bridge – A bridge made of a platform that is held up by wires or ropes strung from the tops of piers.

System – A set of things working together as parts of a mechanism or an interconnecting network.

Technology – A thing, system, or process that people create and use to solve a problem.

Materials

- Toilet paper or paper towel tubes
- Cardboard boxes/shoeboxes
- Legos
- Masking tape
- Blocks
- String
- Small car (If possible, have multiple so groups can use them to test their bridge)
- Roll of pennies
- Worksheets

Procedure

- Divide students into pairs or small groups.
- Introduce or review the engineering process and tell the students they are to use these steps in solving the problem you will give them.
- The problem is that they need to design and create a bridge that will support a car. Allow them to hold the car so they know how heavy it is.
- Show them how long their bridge needs to be to span a 10-inch space by separating two tables or by putting tape on the floor.
- Distribute the worksheets and answer any questions.
- Allow them to work in their groups to create their bridges from materials provided by you.

Assessment

- Teacher observation
- Worksheets
- Completed bridge

Extensions

Allow students to add pennies to increase load.

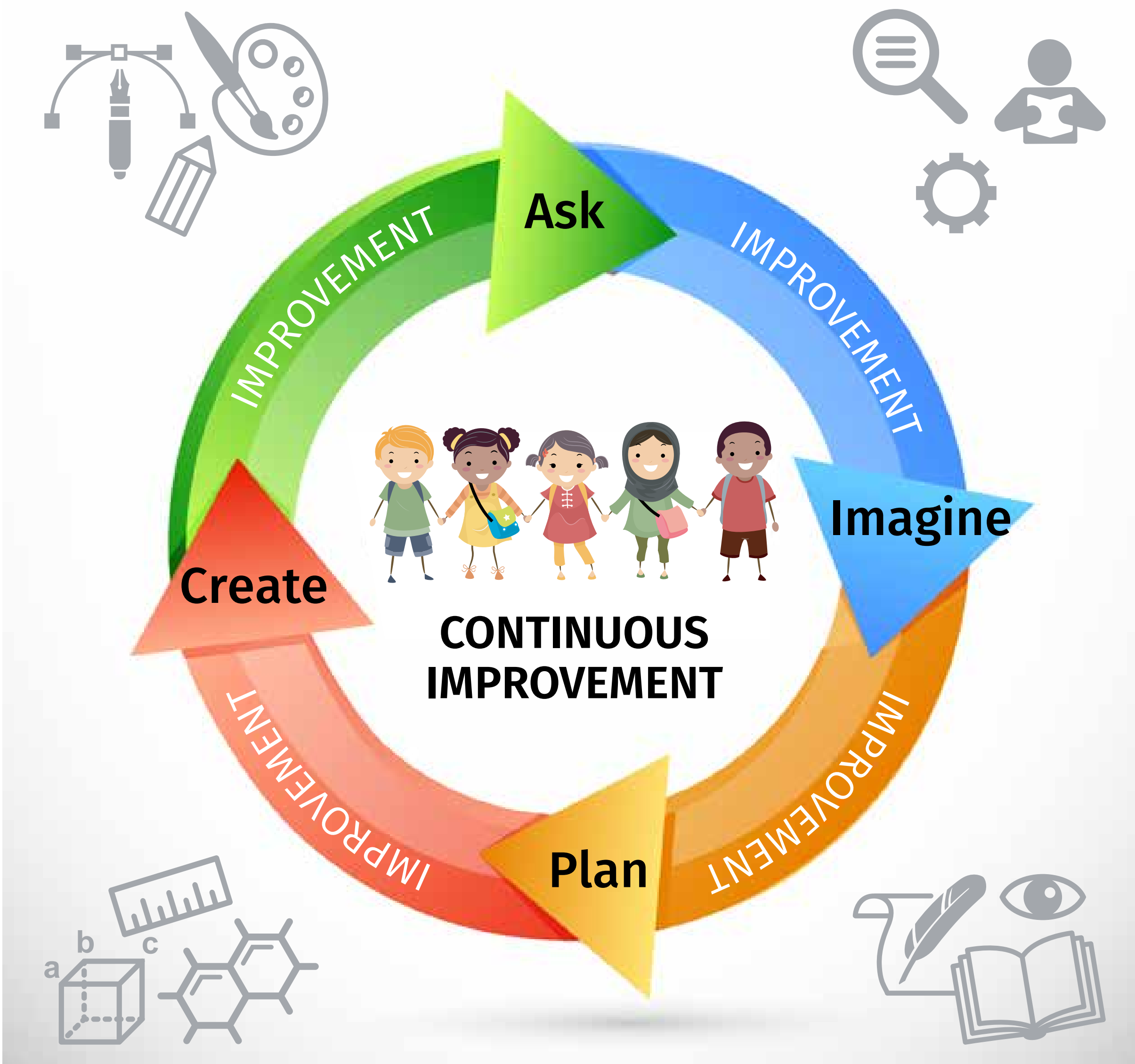
Other Resources

Minnesota STEM Teacher Center. 2.1.2.2 Practice of Engineering

http://www.scimathmn.org/stemtc/frameworks/2122-practice-engineering

Name: ______________________________

Engineering Design Process



Name: ______________________________

Test/Analyze two objects you can use to make bridges.
Compare strengths and weaknesses of materials.
(ex. toilet paper tubes, paper towel tubes, blocks, string, etc.)

Material	Description	Rate the Strength	Would you use this in your design?

Problem: ______________________________

Engineer's Name: ______________________________

Engineering Design Challenge #1: Recording Sheet for Second Grade

Design a bridge that would hold a "load."

____

ASK: What is my problem?

____

IMAGINE: I'm thinking

____

PLAN: My project needs

____

CREATE: It looks like

____

IMPROVE: It could work better if

____

Name: ______________________________

Design Challenge #2 for Second Grade:

Draw and color your bridge. Check and make sure the toy truck can cross safely. If successful, add your Dixie cup, filled with sets of 10 pennies, up to 100, as the "load." How much can your bridge handle?

Did the truck make it? (Yes/No)	How much "load" this trip? (10 pennies, 50 pennies, etc.)

Name: ______________________________

Material	Good or Bad for Bridge Building? Why?

BRIDGE UP! ENGINEERING

LESSON 2 – GRADE 3

LESSON 2 – GRADE 3: Engineering

Big Idea

Students will recognize that the practice of science and/or engineering involves many different kinds of work and engages men and women of all ages and backgrounds.

Essential Questions

What jobs are associated with science and engineering?

Background Information

It requires a great number of people to build a bridge. In the planning stage, civil engineers, landscape and bridge architects, surveyors, and other specialists and technicians are involved. During the construction of the bridge, additional people come on board, such as equipment operators, iron workers, welders, carpenters, electricians, and heavy and tractor-trailer truck drivers. After a bridge is completed, there are people who conduct inspections of bridges and others who maintain them.

Standards & Benchmarks

Minnesota Science Standards

3.1.3.2 Cultures

Men and women throughout the history of all cultures, including Minnesota American Indian tribes and communities, have been involved in engineering design and scientific inquiry.

Benchmark: 3.1.3.2.2 Involvement of Various people

Recognize that the practice of science and/or engineering involves many different kinds of work and engages men and women of all ages and backgrounds.

Wisconsin Science Standards

G.4.1 Identify the technology used by someone employed in a job or position in Wisconsin and explain how the technology helps.

G.4.2 Discover what changes in technology have occurred in a career chosen by a parent, grandparent, or an adult friend over a long period of time.

G.4.3 Determine what science discoveries have led to changes in technologies that are being used in the workplace by someone employed locally.

G.4.4 Identify the combinations of simple machines in a device used in the home, the workplace, or elsewhere in the community, to make or repair things, or to move goods or people.

G.4.5 Ask questions to find answers about how devices and machines were invented and produced.

Connections with multimedia program

Bridge Up! iBook

Activity Description

In this activity, the students will recognize the various jobs surrounding the building of bridges with the use of Eve Bunting's story, *Pop's Bridge*.

Vocabulary

Crew – A group of people doing work.

Tide – The rise and fall of the sea.

Cling – To stick to or hang on tightly to something.

Balancing – Keeping steady.

Foggy – A thick mist or low clouds.

Disappears – Something passes from sight.

Stretch – To extend or spread out.

Excitement – Feeling of great happiness.

Painter – A person that paints structures.

Sky walker – A person works on high wire structures.

Materials

- *Pop's Bridge* by Eve Bunting
- Graphic organizer

Procedure

- Read *Pop's Bridge* as a group or aloud to the students. Point out the features of the book, the different workers, including the cover, pictures, and vocabulary.
- As you read, ask students to summarize and retell the main events of the story every few pages. Also, make sure to point out the various jobs associated with the bridge.
- When you finish reading *Pop's Bridge*, ask students about the main characters' jobs. Invite them to describe interesting things about other characters' jobs.
- Use the students descriptions of jobs associated with *Pop's Bridge* to brainstorm other jobs associated with bridges and construction.
- Have students work with partners to compare and contrast the jobs and responsibilities of the main characters in the graphic organizer.

Assessment

Venn diagram

http://www.eduplace.com/graphicorganizer/pdf/venn.pdf

Extensions

Nonfiction vs. Fiction

http://www.scholastic.com/teachers/sites/default/files/asset/file/nonfiction-vs-fiction-graphic-organizer.pdf

Other Resources

Golden Gate Bridge: Bridge Design and Construction Statistics
http://goldengatebridge.org/research/factsGGBDesign.php

Golden Gate Videos
http://www.travelchannel.com/video/tour-the-golden-gate-bridge-11321

BRIDGE UP! ENGINEERING

LESSON 3 – GRADE 4

LESSON 3 – GRADE 4: Materials

Big Idea

Earth materials are present during engineering. Recognition that rocks may be uniform or made of mixtures of different materials. Minerals can be described and classified based on their physical properties.

Essential Questions

What is our Earth made of?

What properties of rocks and minerals are present in our environment?

Background Information

When constructing bridges, engineers use different types of footings based on soil and rock conditions present. Bridges need to be built on the right type of foundation to make sure the ground can support the bridge. Engineers take soil samples to determine what will need to be constructed to secure the bridge to the Earth's surface. A soil sample tells the engineer what is below the surface of the earth. They can determine the types of rocks: metamorphic, igneous and/or sedimentary. Rocks and minerals have different strengths and qualities, and the supports the bridge will require, is determined by what the engineers find.

Standards & Benchmarks

Minnesota Science Standards

4.1.2.2 Practice of Engineering

Engineering design is the process of identifying problems, developing multiple solutions, selecting the best possible solution, and building the product.

Benchmark 4.1.2.2.2 Ideas & Constraints

Generate ideas and possible constraints for solving a problem through engineering design.

Benchmark 4.1.2.2.3 Evaluating Solutions

Test and evaluate solutions, including advantages and disadvantages of the engineering solution, and communicate the results effectively.

4.4.1 Data Analysis

Collect, organize, display and interpret data, including data collected over a period of time and data represented by fractions and decimals.

Benchmark 4.4.1.1 Collect & Interpret Data

Use tables, bar graphs, timelines, and Venn diagrams to display data sets. The data may include fractions and decimals. Understand that spreadsheet tables and graphs can be used to display data.

Wisconsin Science Standards

C.4.5 Use data they have collected to develop explanations and answer questions generated by investigations.

C.4.6 Communicate the results of their investigations in ways their audiences will understand by using charts, graphs, drawings, written descriptions, and various other means, to display their answers.

D.4.1 Understand that objects are made of more than one substance, by observing, describing and measuring the properties of earth materials, including properties of size, weight, shape, color, temperature, and the ability to react with other substances.

D.4.2 Group and/or classify objects and substances based on the properties of earth materials.

Connections with Multimedia Program

Not applicable.

Activity Description

In this activity, the students will recognize, describe, and classify the different types of rocks in different core samples. After completing the first part of the activity, students will complete pie graphs to represent the specific rock part to the whole core.

FOSS Earth Materials:

This activity could be used after the students have completed the Earth Materials unit or once they have learned about the properties of rocks and minerals, especially with the activities that use limestone and sandstone.

Vocabulary

Crystal – The solid form of a material that can be identified by its natural shape or pattern.

Earth material – The various solids, liquids, and gases that make up the earth.

Erosion – The wearing away of Earth materials by water, wind, or ice.

Geology – The scientific study of Earth's history and structure.

Hardness – A property of minerals that refers to the resistance of a mineral to being scratched.

Igneous – A rock that forms from molten or melted rock.

Metamorphic – A rock that forms into another kind of rock by heat, pressure, or both.

Mineral – A basic Earth material; a rock ingredient that cannot be physically broken down any further.

Rock – An Earth material made up of different ingredients called minerals.

Sediment – Solid matter such as sand or gravel deposited by wind, water, and ice.

Sedimentary rock – A layered rock formed by deposits of sediment.

Credit: Minnesota STEM Teacher Center. SciMathMN and the Minnesota Department of Education.

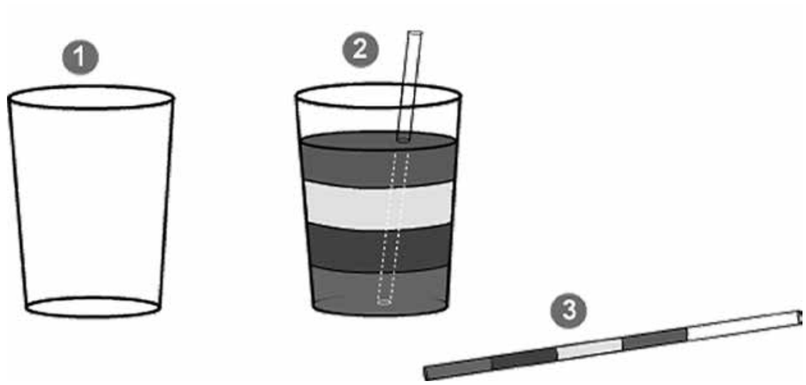
Materials

- Core samples pictures
- Pie graph templates
- Rulers
- Calculator
- Examples of rocks represented in core sample layers

Procedure

Part 1

- Each group will need: Toothpick, plastic knife, clear straw, clear cup, various colors of Play-Doh, sand and glitter to mix into individual layers.
- Prior to analyzing images of core samples of the earth materials below the river bottom, students will need to understand what a core sample is and interact with a basic idea of how a sample could be obtained. Introduce students to what a core sample is and why it is necessary.
- Using Play-Doh of varying colors each group will create a layered “foundation”.



- Students will be given “tools” (toothpick, plastic knife or clear straw) to get their own “core sample” without digging up the entire foundation. Students will eventually see that the best core sample will be obtained using the straw.
- Students should draw a picture of their core sample and discuss the layers.

Part 2

- Present the different core samples (or pictures of core samples) available and describe the areas where the core samples were gathered. (If time is available, you may use a map to identify the locations of where the samples were taken).
- Group students and give each a core sample (or picture of core sample). Also provide examples of different materials present in the core samples.
- While looking at the core samples, students should work with partners to label and describe the different layers that are present in their core samples.
- After labeling the materials, measure the size of each of the different layers (to the nearest inch) and put in a table.
- Measure the overall length of the core sample and record in table.
- Compute the percentage of the whole for the present core sample materials.
- Use the pie graph graphic organizer to present the finding from the core sample.
- Display the students’ findings to the class.

Assessment

Core Sample Table
https://docs.google.com/document/d/1I_pfREXRZhLC-LAmgjAC51REpudJxDzHUje5d325gnM/edit?pli=1

Name: ______________________________

Class: ______________________________

Date: ______________________________

Core Sample Table

Core Sample # ____________________

Core Sample Location ____________________

Total Core Sample Length ____________________

MATERIAL / COLOR	MATERIAL LENGTH	FRACTION LENGTH OF TOTAL (Material Length/ Total Core Length)	% OF TOTAL	DESCRIPTION OF CORE SAMPLE
Exp. Granite/ Brown	5 inches	5/40	12.5	Grainy/Brown

(% of Total = Material Length / Total Core Length* 100)

* Use the pie graphic organizer to present the findings from the core sample
Create a pie chart: **https://www.meta-chart.com/pie**

Extensions

Have students take core samples from school yard.

Invite in a geologist from local college or university to explain the importance of soil samples.

Other Resources

Under Michigan: The Story of Michigan's Rocks and Fossils by Charles Ferguson Barker.

Soil Core Sample Activity
https://www.teachengineering.org/view_activity.php?url=collection/cub_/activities/cub_rock/cub_rock_lesson05_activity1.xml

Soil Core Sample Document
https://www.teachengineering.org/collection/cub_/activities/cub_rock/cub_rock_lesson05_activity1_soilcoreworksheet.pdf

Collecting Soil Samples

Photo Credit: U.S. Department of Agriculture
Agricultural Research Service

Testing Soil

Photo Credit: U.S. Department of Agriculture
Agricultural Research Service

BRIDGE UP!
ENGINEERING

LESSON 4 – GRADE 4

LESSON 4 – GRADE 4: Geometry in Bridge Design

Big Idea

Students will identify bridge designs and the shapes most often found in these designs. They will use this knowledge to create a structure that will sustain weight bearing to explore the reasoning behind the use of these shapes.

Essential Questions

What are the key shapes found in bridges around the state?

Why do these specific shapes get used so often in bridge construction?

Background Information

Around 20,000 bridges span various locations in Minnesota. Of these bridges, about 200 are considered historic bridges (**http://www.dot.state.mn.us/bridge/) (http://www.dot.state.mn.us/historicbridges/**).

Standards & Benchmarks

Minnesota Math Standards: Geometry and Measurement

4.3.1 Shapes

Name, describe, classify and sketch polygons.

Benchmark: 4.3.1.1 Triangles

Describe, classify and sketch triangles, including equilateral, right, obtuse and acute triangles. Recognize triangles in various contexts.

Benchmark: 4.3.1.2 Quadrilaterals

Describe, classify and draw quadrilaterals, including squares, rectangles, trapezoids, rhombuses, parallelograms and kites. Recognize quadrilaterals in various contexts.

4.3.2 Angles

Understand angle and area as measurable attributes of real-world and mathematical objects. Use various tools to measure angles and areas.

Benchmark: 4.3.2.2 Compare & Classify Angles

Compare angles according to size. Classify angles as acute, right and obtuse.

Minnesota Science Standards: The Nature of Science and Engineering

4.1.2.2 Practice of Engineering

Engineering design is the process of identifying problems, developing multiple solutions, selecting the best possible solution, and building the product.

Benchmark: 4.1.2.2.1 Designs for Solving Problems

Identify and investigate a design solution and describe how it was used to solve an everyday problem.

Wisconsin Math Standards

4.MD.6 Geometric measurement: understand concepts of angles and measure angles.
Measure angles in whole-number degrees using a protractor.

4.G.2 Classify 2-dimensional figures based on the presence or absence of angles.

Wisconsin Science Standards

Science Connections: *A.4.2* When faced with a science-related problem, decide what evidence, models, or explanations previously studied can be used to better understand what is happening now.

Nature of Science: *B.4.1* Use encyclopedias, source books, texts, computers, teachers, parents, other adults, journals, popular press, and various other sources to help answer science-related questions and plan investigations.

Science Inquiry: *C.4.2* Use the science content being learned to ask questions, plan investigations, make observations, make predictions, and offer explanations.

Connections with Multimedia Program

Bridge Up! Geometry in Engineering
Bridge Up! iBook

Activity Description

In part one, students will look at images of existing Minnesota bridges and identify/tally the geometric shapes used in a variety of bridges. They will also identify angles used in the bridges. Part two of this activity was adapted from a Scholastic Engineering Activity on Bridge Design. Students will build bridge structures and identify how geometry (such as triangles, quadrilaterals, i-Shape and arches, and angles) affects bridge design and function. Students will track data either in groups or as a whole class using a chart/table. (Maximum weight, number of popsicle sticks, bridge type, geometric design used, and the positive/negative of their structure type.)

Vocabulary

See **http://www.dot.state.mn.us/stcroixcrossing/design.html#deck**
for specifics on the St. Croix Crossing Bridge Construction

Bridge deck – The surface of a bridge where vehicles and pedestrians travel.

Superstructure – This is made up of the deck, railings and any beams.

Substructure – This is made up of the piers, abutments and walls.

Acute angle – An angle with a degree measurement greater than 0 but less than 90.

Obtuse angle – An angle with a degree measurement greater than 90 but less than 180.

Right angle – An angle with a degree measurement of 90.

Straight angle – An angle that measures 180 degrees.

Truss bridge – This bridge type has a superstructure composed of elements connected to form triangles.

Arch bridge – A bridge made from one or more arches and abutments.

Beam bridge – Beam bridges are made of a flat piece, or beam, laid across two or more supports.

Suspension bridge – A bridge made of a platform that is held up by wires or ropes strung from the tops of piers.

Live load – Temporary loads on a bridge, such as automobiles or pedestrians.

Materials

Part 1:

- Picture cards (teacher will have to make these) OR
  Website with Minnesota bridge pictures
  - **http://www.dot.state.mn.us/historicbridges/search.html**
  - Google: Images of Minnesota and Wisconsin Bridges
- Protractors

Part 2:

- Popsicle sticks
- Glue
- Duct tape
- Metal washers for the weight bearing
- Design sheet
- Data collection sheet

Procedure

Part 1:

- Students will be provided with pictures (either on laminated cards or internet) of various bridges to identify geometric shapes (arches, triangles and rectangles) within each bridge.
- Students will tally which shape and how many times they see each shape on the various bridges. Have students discuss in small groups or with partners why engineers might choose to use the various shapes – this is a basic introduction.
- Next, introduce the bridge types and shape specific names for the various bridge types. Students can find some of these bridge shape names on the MnDOT Bridge website: **http://www.dot.state.mn.us/bridge/**

Part 2:

- Challenge students in groups of 3-4 to build a bridge structure that will withstand the greatest amount of load (weight).
- Students will first discuss/brainstorm which bridge type they want to design or the teacher can assign each group using a specific geometric shape or combination of shapes to build their bridge.
- Students will draw/design the bridge in their science notebooks or on the provided design sheet.
- Students should include a bridge deck to their design for the testing process.
- Students will gather materials and build their bridge allowing for drying time. During this time, teacher will walk around asking questions about student design, why they chose it, etc.

Part 3:

- Student groups will test the bridges using weights. Use pre-determined weights (pennies or metal washers from FOSS kit) to keep variables the same per group. Track the data as weight/load is added to the bridge deck. This would be done as a whole group and students will test their bridges one at a time.
- Watch for sagging and fracturing as additional weight/loads are added to the platforms.
- If the structure breaks or fractures, that is considered a "failed" design. On the worksheet provided, students will discuss and think about why the bridge could not hold the weight/load and what they would do differently to improve the design.

Assessment

Teacher can use the worksheets provided and observations throughout as a formative assessment.

Extensions

Students can also identify acute, obtuse, and right angles found within the bridge types. This could be extended to have students use a protractor to identify measurements of specific angles. If there are pictures from MnDOT of bridges with triangles used in the structure, students could determine the angles and whether they are acute or obtuse.

Other Resources

Minnesota Department of Transportation
http://wisconsindot.gov/Pages/home.aspx

Engineering a Bridge
http://www.scholastic.com/browse/lessonplan.jsp?id=1509

Lesson: Designing Bridges
https://www.teachengineering.org/view_lesson.php?url=collection/cub_/lessons/cub_brid/cub_brid_lesson02.xml

Name: ______________________________

Class: ______________________________

Date: ______________________________

Geometry of a Bridge: Data Sheet

BRIDGE NAME (Most bridges have an identifying name)	WHERE IS IT LOCATED? (City, State)	KEY SHAPES IN BRIDGE DESIGN (write down shapes and angle types you see in the image)

Tally of Shapes Seen in Bridges

SQUARE	RECTANGLE	TRIANGLE	ARCH	TRAPEZOID

Name: ______________________________

Class: ______________________________

Date: ______________________________

POPSICLE STICK BRIDGE DATA WORKSHEET

TEAM NAME (3-4) students per group	WHAT SHAPE(S) DID YOU USE?	HOW MANY POPSICLE STICKS WERE USED?	HOW MUCH WEIGHT? (Trial 1)	HOW MUCH WEIGHT? (Trial 2)	HOW MUCH WEIGHT? (Trial 3)

Group: ______________________________

Class: ______________________________

Date: ______________________________

BRIDGE DESIGN SHEET

Draw your bridge design here:

Number of popsicle sticks you plan on using:

Now that your design has been completed, it is time to get to work and build your model. Work together.

Name: ______________________________

Popsicle Bridge Worksheet

Let's test the bridge! If your engineering team is successful, your bridge model should withstand the given weight for at least 1 minute. For teams who find success with the first weight trial, they will continue with additional weight for two more trials.

1. Was your bridge successful? If not, why does your team think it failed?

   Trial 1: YES or NO

   Trial 2: YES or NO

   Trial 3: YES or NO

2. Did your team make any changes from the design process while you were actually building your bridge structure? If so, why?

3. How many popsicle sticks did you actually use in your model? Was this different from the design plan? If so, why was there a difference?

   Number in Model: ________________

   Number in Design Plan: ______________

4. Do you think that engineers have to change their original plans during the actual construction? Why might changes be made?

5. If you had a chance to improve your popsicle stick bridge, how would you change it? Why?

6. Were you inspired by any other groups as you were creating your design or during your actual constructing of the model?

7. If you had a choice to work alone or work with others on a project, which would you prefer and why?

BRIDGE UP!
ENGINEERING

LESSON 5 – GRADE 5

LESSON 5 – GRADE 5: Runoff Management

Big Idea

For the safety of vehicles, pedestrians, and structures, bridge designs include plans that help prevent the pooling or collection of water on bridge decks.

Essential Questions

What are the hazards of water collecting on a bridge deck?

What happens to water on a bridge when it rains, snow melts, or an event like a flash flood occurs?

Can water on a bridge deck be controlled or directed (diverted) somewhere else?

Where does the water go once it is removed from a bridge deck?

Background Information

Water can collect on all types of surfaces including those which are porous, such as soil in fields or impermeable, such as concrete and asphalt. On bridges, which are made of impermeable materials, the ability to control water movement and collection is an important part of the design process to ensure the safety of vehicles, their occupants, and the structure itself. Drainage systems can range from simple to complex; some drainage systems allow excess water to drain out directly below the bridge deck, while others divert water to a collecting pond or other reservoir.

Seasonal changes, as well as catastrophic events like flash flooding, change the amounts of water flowing across surfaces day to day and sometimes minute to minute. Drainage systems need to be able to accommodate those changes so that the rate of flow allows for steady draining of water. Both the drainage system and the catchment system, where diverted water is collected, need to be able to handle the flow of water. Pooling of water can be a problem by causing hydroplaning or ice patches depending on the season.

Not all bridge sites use a drainage system. When they do, the system is kept to a minimum in order to maintain integrity of the bridge structure and to avoid excessive maintenance issues, such as plugging of pipes. Slopes along the bridge deck, from the center to the shoulders, can aid in drainage rates and help keep drainage pipes clear.

Standards & Benchmarks

Minnesota Science Standards
5.1.1.2 Inquiry
Scientific inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations.

Benchmark: 5.1.1.2.1 Planning Investigations
Generate a scientific question and plan an appropriate scientific investigation, such as systematic observations, field studies, open-ended exploration or controlled experiments to answer the question.

Benchmark: 5.1.1.2.2 Collecting Relevant Evidence
Identify and collect relevant evidence, make systematic observations and accurate measurements, and identify variables in a scientific investigation.

3-5 ETS1-2 Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem

3-5-ETS1-3 Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved

Wisconsin Science Standards
A.8.6 Use models and explanations to predict actions and events in the natural world.

B.8.3 Explain how the general rules of science apply to the development and use of evidence in science investigations, model-making, and applications.

C.8.3 Design and safely conduct investigations that provide reliable quantitative or qualitative data, as appropriate, to answer their questions.

C.8.4 Use inferences to help decide possible results of their investigations, use observations to check their inferences.

C.8.6 State what they have learned from investigations, relating their inferences to scientific knowledge and to data they have collected.

C.8.10 Discuss the importance of their results and implications of their work with peers, teachers, and other adults.

C.8.11 Raise further questions which still need to be answered.

G.8.5 Investigate a specific local problem to which there has been a scientific or technological solution, including proposals for alternative courses of action, the choices that were made, reasons for the choices, any new problems created, and subsequent community satisfaction.

Connections with Multimedia Program

Not applicable.

Activity Description

Students will explore how water moves across the surface of a bridge and how it can be directed to a specific place for collection.

Vocabulary

Bridge deck – The surface of a bridge where vehicles and pedestrians travel.

Divert – To change the direction of.

Drainage – The removal of surface water from an area or structure.

Slope – A surface with an incline so that one end or side is higher than the other.

Stormwater runoff – The movement of water over impervious structures that is directed to a specific location.

Materials

Per Group

- 1 strip of cardboard - 1 foot long and 3 inches wide - covered on all sides and ends with duct tape (see preparation section)* have extra covered strips prepared and available in case of leaks or failure during the activity
- 2 wooden blocks or 2 small bricks/pavers
- 4 large (9mm or 10mm diameter) drinking straws
- Strips of duct tape (as needed)
- 1 pair of scissors
- Shallow basin or pan to catch water as activity is conducted (this could also be done outside preventing the need for basins). Examples include water tables, baking sheets or aluminum pans.
- Measuring cup with pouring spout
- Quart container filled with water

Individual Materials

- Science journal
- Pencil

For adult use only

- Very sharp scissors, razor blade, or small awl

Preparation

Cover strips of cardboard along the middle of both sides with a strip of duct tape. On each side, lay a strip of duct tape so that it overlaps the center tape – this will be the top of the bridge deck. Before wrapping the tape over to cover the bottom side, pinch the tape together along the edge so that there is a rim that is about ¼" to ½" in height and then press the rest of the tape edge around to cover the bottom side of the cardboard. You should end up with a rim on both sides of the top of the cardboard creating a small gutter for the bridge deck.

Procedure

Introduction

- Discuss the basic structure of a bridge and the surface on which vehicles or people can move across it (bridge deck).
- Ask students to identify weather conditions and seasonal changes that occur in their region and how water plays a part in these conditions.
- Tell students they will be exploring how water moves on bridge decks.

Activity description

- Introduce materials. The strip of cardboard covered in duct tape will represent a bridge deck and the two blocks or bricks/pavers will act as support for the simple bridge they are testing.
- Ask student groups to set up their bridges so that the cardboard strip lays across the blocks or pavers. If indoors, this will be done in the basin or pan provided. If outdoors, blocks can be set on a level surface.
- Direct students to pour water onto the cardboard strips using the spouted measuring cups in multiple ways and observe what happens. *Students are looking for where the water is flowing and how it moves across the surface of the bridge deck.*
- Can the water be controlled just by pouring? Does the flow rate (how fast or slowly the water is poured) make a difference? Does it matter where the water is poured (one end or in the middle)? Allow time for groups to test different ways of pouring water, remind them to empty their basins as needed.
- How does this relate to a bridge deck? *Seasonal precipitation, water is landing on or moving along the bridge deck and it ends up somewhere else.*
- Ask students what happens when there is a larger volume/amount of water on the bridge deck (flash floods or very heavy rains)?
- Why might there be problems with water just overflowing from bridge decks into the river or land below the bridge? *Pollutants can be washed into surrounding waterways, erosion can occur where water continually drains at either end of the bridge, vehicles on the bridges could slide, hydroplane, or lose control.*

- Discuss drainage systems and how they might work on a bridge deck to help manage water when unusual levels occur as well as during regular seasonal water flow amounts. *This would include the idea of pooling water collecting during steady rains that may not overflow the bridge deck edges.*
- Allow time for groups to sketch a plan for a drainage system in their science journals and collect materials (straws, duct tape, scissors) with the goal of directing water to at least one specific site. Does the slope of the system matter? *Would the bridge be at a slope or would the drainage system have a slope to it?*
- Groups will come to consensus on the plan to use and then add the drainage system to their bridge deck. *Students can cut holes along the straw and/or punch holes (with help of teacher using an awl or other instrument) into the cardboard strips depending on where their drainage system is to be placed. Drainage can be along the sides or down through the bridge deck. Duct tape can be used to connect the drainage systems to the bridge decks.*
- Student groups will test their designs by pouring water on their bridges, noting what works and what could be improved. *Did the water flow where you wanted it to? Why or why not? What would you do to change or improve your design?*
- Groups will share their designs with the class either by demonstrating each design or by walking around the room or area to see what other groups have designed.
- Students reflect on what they learned in their science journals, noting improvements they would make to their original designs.
- As an exit slip, ask students: Why is controlling water on a bridge important? *Health of local water and ecosystem, managing erosion, safety for vehicles and people using bridges, managing the amount of water that is allowed to remain on the bridge at any given time, response to seasonal changes.*

Assessment

Science journal sketches and responses completed or exit slip responses.

Extensions

Research local bridges to determine how water is moved away from the bridge deck.

Other Resources

Bridge Deck Drainage

http://www.dot.ca.gov/hq/esc/techpubs/manual/bridgemanuals/bridge-memo-to-designer/page/Section%2018/18-1m.pdf

http://www.iowadot.gov/bridge/policy/584DeckDrainJu11.pdf

http://www.fhwa.dot.gov/engineering/hydraulics/pubs/hec/hec21.pdf

Stormwater Runoff

http://water.epa.gov/polwaste/npdes/stormwater/index.cfm

http://nc.water.usgs.gov/projects/bridge_runoff/overview.html

BRIDGE UP!
ENGINEERING

LESSON 6 – GRADE 6

LESSON 6 – GRADE 6: Tension and Compression Forces

Big Idea

There are a variety of bridge types and each bears a load. Tension and compression forces occur fluidly across a bridge structure as a load passes over the deck surface.

Essential Questions

How does a bridge support the weight of vehicles?

Does a bridge support a load the same way across its entire structure?

Why are different bridge designs used?

What bridge design is best?

Background Information

Tension and compression forces occur fluidly across a bridge structure as a load passes over the deck surface. A bridge must be able to bear the load of its own materials.

Different types of bridges are used for different settings. While there is not a "best" bridge design, there are specific reasons for using a bridge type depending on the setting and needs of the site.

Arch Bridges

Arch bridges are made from one or more arches and abutments. The arches put the material that make up the bridge into compression. Most arch bridges are made of steel or concrete, which are good for compression.

Suspension Bridges

A suspension bridge is made of a platform that is held up by wires or ropes strung from the tops of piers. More recent suspension bridges use steel plates and steel cables that put material into tension. Steel is used for suspension bridges, because steel is strong in tension and concrete is not.

Truss Bridges
A truss bridge has a superstructure composed of elements connected to form triangles. Usually made of steel bars, truss bridges use a combination of compression and tension forces.

Beam Bridges
Beam bridges are made of a flat piece, or beam, laid across two or more supports. Newer beam bridges are typically made of steel or concrete and are often I-shaped. In the beam – which is horizontal - part of the material is in tension and part of the material is in compression.

Standards & Benchmarks

Minnesota Science Standards
6.1.2.1 Engineers
Engineers create, develop and manufacture machines, structures, processes and systems that impact society and may make humans more productive.

Benchmark: 6.1.2.1.4 Learning from Failures
Explain the importance of learning from past failures, in order to inform future designs of similar products or systems.

6.1.2.2 Practice of Engineering
Engineering design is the process of devising products, processes and systems that address a need, capitalize on an opportunity, or solve a specific problem.

Benchmark: 6.1.2.2.1 Applying a Design Process
Apply and document an engineering design process that includes identifying criteria and constraints, making representations, testing and evaluation, and refining the design as needed to construct a product or system that solves a problem.

MS-ETS1-3 Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

Wisconsin Science Standards
B.8.3 Explain how the general rules of science apply to the development and use of evidence in science investigations, model-making, and applications.

C.8.4 Use inferences to help decide possible results of their investigations, use observations to check their inferences.

C.8.6 State what they have learned from investigations, relating their inferences to scientific knowledge and to data they have collected.

C.8.11 Raise further questions which still need to be answered.

Connections with Multimedia Program

Bridge Up! Fundamental Forces

Activity Description

Teams of students will be assigned a specific type of bridge model to build and test the strength of their design with a load. The areas where tension and compression forces occur will be identified as the load is moved along the structure.

Vocabulary

Arch bridge – A bridge made from one or more arches and abutments.

Bridge deck – The surface of a bridge where vehicles and pedestrians travel.

Buckling – Occurs when an object is not able to withstand compressive forces.

Compression – Pressure or force applied inward to points within a structure with a tendency to reduce the size of the section where force is applied.

Dead load – Loads that are constant over time, including the weight of a structure itself.

Extradosed bridge – A combination of a girder bridge and a cable stayed bridge. Instead of relying just on cables, the bridge deck is supported by tower sections and acts as a continuous beam. The cable tension compacts the bridge deck instead of supporting vertically, and girders provide additional support.

Live load – Temporary loads, as in a vehicle moving over a bridge.

Load – Forces applied to a structure.

Load distribution – When the force of a load is spread across an entire structure.

Mechanical stress – A measure of internal forces when an external force is applied to a structure or component of a structure.

Beam bridge – Beam bridges are made of a flat piece, or beam, laid across two or more supports.

Snapping – Occurs when an object is unable to withstand tension forces.

Suspension bridge – A bridge made of a platform that is held up by wires or ropes strung from the tops of piers.

Structural failure – Inability to support the load a structure experiences.

System – A set of interdependent parts that work as a whole.

Tension – A pulling force on an object or system with energy moving towards the ends or edges.

Transfer – How the energy of a load moves through a system.

Truss bridge – This bridge type has a superstructure composed of elements connected to form triangles.

Materials (for teams to choose from)

- Popsicle sticks (large, regular and small sizes)
- Glue (white and/or for glue gun) woodworking or Gorilla glue may be an option if suitable for group
- Glue gun(s)
- String
- Cardstock or cardboard
- Rubber bands in multiple sizes
- Small diameter dowels
- String or twine
- Pipe cleaners
- Wooden skewers (with pointed ends dulled with sandpaper or clipped off and smoothed)
- Water basin (for soaking dowels or skewers if students plan to bend them)
- Wire in assorted gauges
- Wire clippers
- Gram weights
- Pictures or illustrations of four bridge types:
  - Arch bridge
  - Beam bridge
  - Suspension bridge
  - Truss bridge

Individual materials

- Science journals
- Pencils

Optional materials per group (to hold bridges upright for testing)

- Sand
- Bucket

Procedure

Introduction

- Ask students to draw or sketch different types of bridges they have seen or traveled over in their science journals.
- As a group, share what they know and note similarities and differences in structures.

Activity Description

- Tell students that they will be working in groups to build four different types of bridges. The goal is that each bridge will be able to support a load (using gram pieces). Discuss what a load is, including live and dead loads.
- Divide class into four groups and assign them one of the following:
    - Arch bridge
    - Beam bridge
    - Suspension bridge
    - Truss bridge
- Depending on the size of your class and the amount of materials you have available, each of the four groups can then be divided into smaller working groups (three or four students per group).
- Give groups time to look at bridge types using sketches or drawings (see Other Resources section for links you can print from). Direct them to sketch a plan in their science journals before beginning to build, including materials they plan to use.
- Allow groups to collect needed materials and build their models. This part may take more than one day depending on glue used, if groups soak skewers or dowels in order to bend them or other factors.
- Introduce the terms tension and compression.
- Direct groups to determine where tension and compression may occur on their models and have them indicate the areas on their sketches in their journals.
- Using gram pieces, test different load weights either by placing the weights on top of their bridges or suspending them from the structures using string or rubber bands (this will depend on the design built).
- Have groups share their structures with the class, indicating what they noticed about load bearing abilities and any changes they would make to their design.
- Using the CGEE Bridge Up! site, students will work through the Fundamental Forces section to learn about the four bridge types listed above and identify tension and compression forces for each. Students will make sketches of the types with arrows indicating tension and compression sites for each in their science journals.

Assessment

On a blank sheet of paper, ask students to sketch one of the four bridge types with arrows and labels showing where tension and compression forces occur and what the terms mean.

Extensions

Research where different types of bridges are used and why or what types of bridges are used locally.

Other Resources

Five Bridge Types: Arch, Suspension, Beam, Truss, Cable-Stayed
http://www.aiacincinnati.org/community/ABC/curriculum/FiveBridgeTypes.pdf

Build a Bridge
http://www.pbs.org/wgbh/nova/tech/build-bridge-p3.html

How Bridges Work
http://science.howstuffworks.com/engineering/civil/bridge2.htm

History of Bridges
http://www.historyofbridges.com/

Bridge Basics
http://www.pghbridges.com/basics.htm

BRIDGE UP! ENGINEERING

LESSON 7 – GRADE 7

LESSON 7 – GRADE 7: Bridge Building

Big Idea

Engineers use a process when designing bridges. The process is used to create products, processes and systems that meet a need.

Essential Questions

What are the different types of bridges and what are basic strengths and weaknesses of each?

What are some factors that engineers consider when designing bridges?

How does the engineering process work?

Ask (What are the problems? What are the constraints?)

Imagine (Brainstorm ideas, choose the best one)

Plan (Draw a diagram, gather needed materials)

Create (Follow the plan, test it out)

Improve (Discuss what can work better, repeat steps to make changes)

Can you make predictions about how a design modification can change the results?

Background Information

Engineers need to consider the strength of materials used to create a bridge and the load capacity of the completed structure. This is necessary to make sure the structure is strong enough to provide a safe venue for those using it. You may see signs that specify the load limits before crossing a bridge.

Standards

Minnesota Science Standards

6.1.2.2 Practice of Engineering

Engineering design is the process of devising products, processes and systems that address a need, capitalize on an opportunity, or solve a specific problem.

Benchmark: 6.1.2.2.1 Applying a Design Process

Apply and document an engineering design process that includes identifying criteria and constraints, making representations, testing and evaluation, and refining the design as needed to construct a product or system that solves a problem.

6.1.3.4 Emerging Technologies

Current and emerging technologies have enabled humans to develop and use models to understand and communicate how natural and designed systems work and interact.

Benchmark: 6.1.3.4.2 Units of Measurement
Demonstrate the conversion of units within the International System of Units (SI, or metric) and estimate the magnitude of common objects and quantities using metric units.

8.1.3.4 Emerging Technologies
Current and emerging technologies have enabled humans to develop and use models to understand and communicate how natural and designed systems work and interact.

Benchmark: 8.1.3.4.2 Procedures for Investigations
Determine and use appropriate safety procedures, tools, measurements, graphs and mathematical analyses to describe and investigate natural and designed systems in Earth and physical science contexts.

8.1.1.2 Inquiry
Scientific inquiry uses multiple interrelated processes to investigate questions and propose explanations about the natural world.

Benchmark: 8.1.1.2.1 Reasoning based on Evidence
Use logical reasoning and imagination to develop descriptions, explanations, predictions and models based on evidence.

Wisconsin Standards
C.8.1 Identify questions they can investigate using resources and equipment they have available.

C.8.3 Design and safely conduct investigations that provide reliable quantitative or qualitative data, as appropriate, to answer their questions.

C.8.5 Use accepted scientific knowledge, models, and theories to explain their results and to raise further questions about their investigations.

C.8.6 State what they have learned from investigations, relating their inferences to scientific knowledge and to data they have collected.

C.8.7 Explain their data and conclusions in ways that allow an audience to understand the questions they selected for investigation and the answers they have developed.

C.8.9 Evaluate, explain, and defend the validity of questions, hypotheses, and conclusions to their investigations.

C.8.10 Discuss the importance of their results and implications of their work with peers, teachers, and other adults.

C.8.11 Raise further questions which still need to be answered.

Standard H (Science in Personal and Social Perspectives)

Content Standard: Students in Wisconsin will use scientific information and skills to make decisions about themselves, Wisconsin, and the world in which they live.

Rationale

An important purpose of science education is to give students a means to understand and act on personal, economic, social, political, and international issues. Knowledge and methodology of the earth and space, life and environmental, and physical sciences facilitate analysis of topics related to personal health, environment, and management of resources, and help evaluate the merits of alternative courses of action.

Connections with Multimedia Program

Bridge Up! Geometry in Engineering and Fundamental Forces

Activity Description

Students will build a bridge using plastic straws and scotch tape – the span is set at 24 cm. Bridge strength will be tested using bolts. The initial build will be followed by one day of learning how bridges are designed and built. The final bridge will have more constraints: limited number of straws and less building time. Bridges strength of each will be compared.

Vocabulary

Engineer – A person who uses his/her understanding of math and science to create things for the benefit of humanity and our world.

Design – To form in the mind. Make drawings or plans for a work, make a new product or improve on current product or process.

Model – A representation of a person or thing or of a proposed structure, usually on a smaller scale than the original.

Bridge – A structure carrying a road, path, railroad, or canal across a river, ravine, road, railroad, or other obstacle.

Suspension bridge – A bridge made of a platform that is held up by wires or ropes strung from the tops of piers.

Truss bridge – This bridge type has a superstructure composed of elements connected to form triangles.

Arch bridge – A bridge made from one or more arches and abutments.

Cable-stayed bridge – A bridge in which the weight of the deck is supported by vertical cables suspended from larger cables that run between towers and are anchored in abutments at each end.

Beam bridge – Beam bridges are made of a flat piece, or beams, laid across two or more supports.

Tension – A stretching or pulling force that usually lengthens an object.

Compression – A pushing force that usually shortens the object.

Abutment - A mass receiving the arch, beam, truss, etc., at each end of a bridge.

Beam – A long, rigid horizontal support part of a structure.

Column – A long, rigid, vertical (upright) support part of the structure.

Bridge deck – The surface of a bridge where vehicles and pedestrians travel.

Span – The length of the a bridge from one pier to another.

Truss – Part of the structure frame based on the geometry of the strength of the triangle.

Materials

- Each group needs:
- 20 non-bendy straws/group
- Tape
- Scissors
- Measuring stick or ruler
- Bridge Lab Report

Whole class needs to share:

- Large bolts
- Four textbooks

Procedure

Day 1 - Bridge Lab Report

- Each student should draw a plan of a bridge they might build on his/her Bridge Lab Report.
- Put students into groups of 4 and have them decide on the style of bridge they might like to build.
- Pass out the materials.
- Hypothesize the mass your bridge will hold. Record your estimation on your Bridge Lab Report.
- Set up desks to be 24 cm apart OR 2 books placed 24 cm apart (simulate the span for the bridge).
- 20 minutes to build the bridge using the 20 straws; they can be cut at any length. However, students will not be given additional straws.
- Test the load your bridge will hold and document the mass on your Bridge Lab Report.
- Reflection: What do you think went well?

Investigating Questions (as homework)

1. Describe the shapes involved in the bridge you constructed.
2. Why did you choose that type of bridge?
3. Did the bridge meet your load predictions? What do you think went well?
4. What made this activity difficult?
5. What would have made this activity easier?

Day 2 - Vocabulary Worksheet and Types of Bridges

- Have students share investigating questions with the class.
- Pass out vocabulary worksheet.
- Teacher provides definition and examples of bridge terms from vocabulary list.
- Students complete vocabulary worksheet. Assign as homework if not completed during class.

Day 2 – (continued)

- Have students note bridge types and brief pros and cons of each on board. Images available at **http://kids.britannica.com/elementary/art-88577/There-are-six-basic-bridge-forms**
  - Suspension
  - Truss
  - Arch
  - Cable-stayed
  - Beam
- Have students make plans (blueprint) for a new bridge to build the next day.
- Have them identify the terms as they relate to their bridge. Students are still limited to the same materials.

Day 3 – Improve

- Students collect materials.
- Now that students know a little more about bridge design, improve the current bridge they previously built. Mass the bridges and test the load capacity.
- Have students note the change in load the bridge can hold with the new design.
  - Take data showing the class average on change in load capacity after learning more about bridges.
  - Help students understand that each bridge that engineers design and build is done with an expansive amount of science and knowledge.

Assessment

- Show slides and have students identify different types of bridges and their parts. Images available at **http://kids.britannica.com/elementary/art-88577/There-are-six-basic-bridge-forms**
- Student-generated blueprints
- Investigating questions
- Improvements made to bridge
- Vocabulary sheet

Extensions

Home Project – Have students create a bridge using recycled materials at home to test strength of additional material. Optional - Take a field trip to a bridge construction site.

Other Resources

BUILDING BIG: Bridges
www.pbs.org/wgbh/buildingbig/bridge

ENGINEERING ENCOUNTERS: Bridge Design Contest
https://bridgecontest.org/

Name: ______________________________

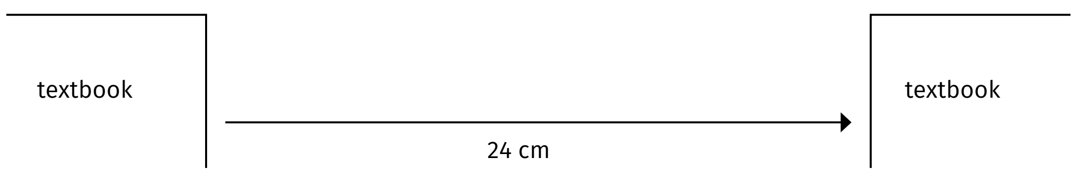
Bridge Lab Report

Day 1

ASK: What is the problem?

Supplies: meter stick for measuring, 20 straws, tape and scissors (optional). Will need bolts later to test bridge strength.

1. **Imagine:** Draw a bridge to span 24 cm (use textbooks)



2. Have your teacher initial the diagram. Your teacher will give you supplies when you have initials.

3. Build bridge – you have as much time as you need, but shouldn't be more than 45 minutes. Put bolts on bridge. They only rest on span, not on the books.

4. **Estimate:** How many bolts do you think it will hold?

5. **Test:** Put bolts on bridge - they only rest on span - not on the books. Measure and record 3 times.

   Test 1: ______________ Test 2: ______________ Test 3: ______________

6. **Compare:** How did the two bridges compare? ______________________________

Name: ______________________________

Vocabulary Worksheet

Day 2

Vocabulary Term	Brief Definition *(Must be in your OWN words)*	Examples/Drawing
Engineer		
Design		
Model		
Bridge		
Tension		
Compression		

Name: ______________________________

Vocabulary Worksheet
Day 2

Vocabulary Term	Brief Definition	Examples/Drawing
Abutment		
Cement		
Concrete		
Beam		
Deck		
Span		
Truss		

Name: ______________________________

Types of Bridges: Day 2

Instructions: Draw each type of bridge. Use Wikipedia as a guide to draw.

Suspension Bridge	Truss Bridge
Arch Bridge	Cable-Stayed Bridge
Beam Bridge	

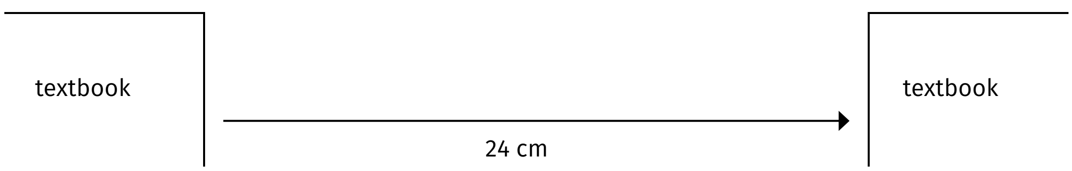
Name: ______________________________

Improve Bridge Design
Day 3

Instructions: Now that you know a little more about bridge design,
you will try to construct a better one.

Supplies: Meter stick, 15 straws and tape.
Will need bolts later to test bridge strength.

1. **Imagine:** Draw a bridge to span 24 cm (use textbooks)



2. Have your teacher initial the diagram, then you can get your supplies.

3. Build bridge – you have as much time as you need, but shouldn't be more than 45 minutes. You may not tape bridge to textbooks or desks.

4. **Estimate:** How many bolts will it hold?

5. **Test:** Compare which parts of the bridge were stronger than the first? Weaker than the first? Measure and record 3 times.

   Test 1: ______________ Test 2: ______________ Test 3: ______________

6. **Compare:** Which parts of bridge were strong than the first? ________________
   Weaker than the first? ______________________________

BRIDGE UP!
ENGINEERING

LESSON 8 – GRADE 8

LESSON 8 – GRADE 8: Making Concrete

Big Idea

How do concrete and cement work? Use concrete to make parts of bridges to see how they work together.

Essential Questions

What materials would be needed to build a bridge?

What is important for bridge materials to do?

How would the deck be different than the foundations, piers?

Background Information

Cement is the "glue" that holds the aggregate together to make concrete. Different types of concrete are made into piers, decking and roadways.

Standards & Benchmarks

Minnesota Science Standards

8.1.1.2 Inquiry

Scientific inquiry uses multiple interrelated processes to investigate questions and propose explanations about the natural world.

8.1.3.3 Science and engineering operate in the context of society and both influence and are influenced by this context.

8.1.3.4 Current and emerging technologies have enabled humans to develop and use models to understand and communicate how natural and designed systems work and interact.

Wisconsin Science Standards

A.8.1 Show that technology has allowed us to further the efforts of science and, in turn, science has enabled us to develop better technology.

A.8.7 Discover that human will or desire can lead to the design of new technology in order to seize an opportunity or solve a problem.

Connections with Multimedia Program

Bridge Up! Mastering Materials

Bridge Up! iBook

Activity Description

- Students will make concrete (modified from Bridges! by Johmann & Rieth).
- Activity after brainstorming essential questions, watch Tacoma Bridge at http://www.youtube.com/watch?v=3mclp9QmCGs&safe=active
- Read about cement at **http://en.wikipedia.org/wiki/Cement**

Vocabulary

Cement – A substance that sets and hardens and can bind other materials together.

Hydraulic cement – Will set/dry in wet condition or underwater.

Non-hydraulic cement – Will not set in wet conditions, reacts with CO2 in air to dry.

Aggregate – Sand, gravel, crushed stone and recycled crushed concrete.

Concrete – Composed mainly of water, aggregate and cement.

Pozzolana – Cement made with ash erupted from Mt. Vesuvius, named after the town, Pozzuoli, where it was found. It is waterproof and will harden even when wet.

Arch – A curved structure that spans a space and may or may not support weight above it.

Pier – A vertical support member for a bridge.

Bridge Deck - The surface of a bridge where vehicles and pedestrians travel.

Beam Bridge - Beam bridges are made of a flat piece, or beam, laid across two or more supports.

Materials

- Tea kettle (or other pan to boil water) and double boiler, cookie sheet
- Mixing spoon and spatula
- Sand, pebbles and cornstarch
  (fine sand works better, pebbles should be small - pea gravel at any home store)
- Centering frame (a round oatmeal container or peanut butter jar)

Procedure

- Boil water in bottom pot of double boiler - boil additional water in a separate pan or kettle
- Mix sand and cornstarch in top pot.
- Add 125 ml of water from kettle to the mixture.
- Stir mixture as it cooks - stop when it is too thick. You may need to add a little more hot water.
- Let it cool until you can touch it.
- You have made mortar, try and make an arch.
- Add some pebbles to the mortar to make concrete. Shape it into 2 piers and 2 rectangular beams. Curve one beam into an arch.
- Place on cookie sheet (place in oven at 275 °). Bake until dry.
- Make a beam bridge and test by adding weights.
- Make an arch bridge and test by adding weights.
- Compare the strength of each.
- Put one of the piers in water - is it waterproof?

Assessment

Student notes

Teacher observations

Extensions

Building an arch (from Bridges! by Johmann & Rieth)

Materials

· Clay/Play Doh (or mortar from above, step 6)

· Small rocks of similar size (flatter ones are easier to layer)

· Centering block - rounded oatmeal container, peanut butter jar)

Procedure

· Lay a cylinder (PB jar or oatmeal container) on its side.

· Set a rock on either side of the cylinder (centering block).

· Add a layer of mortar (or clay/Play Doh).

· Continue to layer rocks and mortar until you reach the top.

· Slide out the centering block - does it stay up?

· Can you identify the keystone?

Other Resources

Read about arches at **http://science.howstuffworks.com/engineering/civil/bridge5.htm**

LESSON 8.2 – GRADE 8: Native Americans

Big Idea

Native Americans are very good at working at heights and held important jobs in bridge building history.

Essential Questions

How are bridges and buildings constructed?

What kind of physical attributes would be required of the people that built these structures?

Do you think you could work in this environment?

Background Information

Native Americans were very important in construction of bridges and other tall structures because of their physical and mental strength.

Standards & Benchmarks

Minnesota Science Standards

8.1.3.2 Culture

Men and women throughout the history of all cultures, including Minnesota American Indian tribes and communities, have been involved in engineering design and scientific inquiry.

Benchmark 8.1.3.2.1 Contributions of Cultures

Describe examples of important contributions to the advancement of science, engineering and technology made by individuals representing different groups and cultures at different times in history.

Minnesota English Language Arts Standards

Standards for Literacy in History/Social Studies, Science, and Technical Subjects 6-12

Reading Benchmark 6.13.2.2. Literacy in Science and Technical Subjects

Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.

Connections with multimedia program

Bridge Up! iBook

Bridge Up! Web Modules

Activity Description

Native Americans contributed much to the building of tall structures throughout history. This activity will enable students to better understand their contributions.

Materials

- Computer
- Article found at **http://sonicmemorial.org/public/mohawk/mohawk.html**

Procedure

Part 1:

- Show images of construction workers on skyscrapers and bridges - there are many available in Google searches.
- As students watch, have them write down thoughts about how pictures make them feel. Compile a list from all when done.

Part 2:

- Next, brainstorm on how bridges and skyscrapers are built. What kind of attributes would a person need in order to be a construction worker on these sites? Do you think you would be good at working in this environment?

Part 3:

- Read **http://sonicmemorial.org/public/mohawk/mohawk.html**. If you are able to print the article, students can underline and highlight text. Project article on Smart Board.
- Read through article one time together – ask for volunteers to read a paragraph. Have a short discussion.
- Some questions for discussion:
  - Which state and year did Mohawk Indians begin?
  - How did they get started working on bridges?
  - Which attributes did the Mohawks have that enabled them to be successful?

Part 4:

- Watch **https://www.nfb.ca/film/high_steel**
- Ask students to write a short summary of what they learned from the article and video.

Extensions

Watch Build a Bridge **http://www.pbs.org/wgbh/nova/tech/build-bridge-p3.html**

BRIDGE UP!
ENGINEERING

LESSON 9 – GRADES 9-12

LESSON 9 – GRADES 9-12: Geometry in Engineering

Big Idea

Bridge design focuses on several basic geometric structures.

Essential Questions

What fundamental shapes drive bridge design?

Why do engineers use these shapes?

Background Information

Bridges have been around since the first tree fell across a stream. Design has evolved over time as new designs and materials have been developed.

Minnesota has more than 20,000 bridges. According to the Minnesota Department of Transportation, for a structured to be considered a bridge by the State of Minnesota, it must have a span of 10 feet or more.

The Wisconsin Department of Transportation says it generally defines a bridge as any structure spanning 20 feet or more that carries motor vehicle traffic.

Wisconsin has about 13,600 bridges spanning state and local roadways. Of these, about 4,900 are along the state highway system (numbered state and federal highways) and are the responsibility of the Wisconsin Department of Transportation.

The Minnesota Department of Transportation says that, as structures, bridges can be classified in several different ways: by use, span type, or construction material. The types of use can include pedestrian, bicycle, vehicular (automobiles and trucks), railroad, or a combination. Over time, the load capacity of a bridge has increased with the increase of use and types of vehicles that cross bridges.

Standards & Benchmarks

Minnesota Science Standards

9.1.2.1 Addressing Human Need

Engineering is a way of addressing human needs by applying science concepts and mathematical techniques to develop new products, tools, processes and systems.

Benchmark 9.1.2.1.1 Refinement of Designs

Understand that engineering designs and products are often continually checked and critiqued for alternatives, risks, costs and benefits, so that subsequent designs are refined and improved.

Benchmark 9.1.2.1.3 Considerations in Devices

Explain and give examples of how, in the design of a device, engineers consider how it is to be manufactured, operated, maintained, replaced and disposed of.

9.1.2.2 Practice of Engineering
Engineering design is an analytical and creative process of devising a solution to meet a need or solve a specific problem.

Benchmark 9.1.2.2.1 Constraints on Designs
Identify a problem and the associated constraints on possible design solutions.

Standard 9.1.3.1 Systems
Natural and designed systems are made up of components that act within a system and interact with other systems.

Benchmark 9.1.3.1.1 System Relationships
Describe a system, including specifications of boundaries and subsystems, relationships to other systems, and identification of inputs and expected outputs.

9.1.3.2 Culture
Men and women throughout the history of all cultures, including Minnesota American Indian tribes and communities, have been involved in scientific inquiry and engineering design.

Benchmark 9.1.3.2.2 Careers
Analyze possible careers in science and engineering in terms of education requirements, working practices and rewards.

9.1.3.3 Society
Science and engineering operate in the context of society and both influence and are influenced by this context.

Benchmark 9.1.3.3.1 Role of Values and Constraints
Describe how values and constraints affect science and engineering.

9.3.4.1 Benefits vs Risks
People consider potential benefits, costs and risks to make decisions on how they interact with natural systems.

Benchmark 9.3.4.1.1 Natural Hazards
Analyze the benefits, costs, risks and tradeoffs associated with natural hazards, including the selection of land use and engineering mitigation.

9P.2.3.1 Waves & Sound
Sound waves are generated from mechanical oscillations of objects and travel through a medium.

Benchmark 9P.2.3.1.1 Oscillatory Systems
Analyze the frequency, period and amplitude of an oscillatory system.

Connections with Multimedia Program

Bridge Up! Geometry in Engineering

Activity Description

The teacher provides initial introduction to the topic by brainstorming what students know about local bridges. Review those bridges and basic bridge designs. Use Multimedia program and pictures of local bridges to highlight shapes in engineering. Students then are assigned bridge designs to research in small groups. Jigsaw follows to build comparisons and differences between bridge designs and uses.

Vocabulary

Arch – A curved symmetrical structure spanning an opening and typically supporting the weight of a bridge, roof or wall.

Support – A thing that bears the weight of something or keeps it upright.

Keystone – A central stone at the summit of an arch, locking the whole together.

Structural failure – Point at which a structure no longer supports the load applied to it.

Arch bridge – A bridge made from one or more arches and abutments.

Truss bridge – This bridge type has a superstructure composed of elements connected to form triangles.

Suspension bridge – A bridge made of a platform that is held up by wires or ropes strung from the tops of piers.

Hybrid – A structural component comprised of more than one material.

Materials

- Bridge Up! Media links
- Access to pictures of local bridge structures that illustrate specific geometric shapes (**http://www.dot.state.mn.us/historicbridges/**)
- Video links to bridge failures (see under Other Resources)

Procedure

Teacher Led Brainstorming (15-30 Minutes)

- How do bridges affect your life?
- What are the cultural impacts of a new bridge?
- Why does bridge design matter?

Building Background Knowledge (2 periods)

- Students are provided data sources (articles, drawings/pictures of old and new, Google search, opinion pieces, technical stories, environmental impact studies).
- Jigsaw to share data findings.
- Groups present poster and share question of interest/importance.

Bridge Design (1 period)
Basic bridge designs

- Give each person in a group an example of different bridge design (arch, truss, suspension, hybrid designs).
- Jigsaw how designs are alike, unlike each other.
- Discuss how designs overlap and are used in several examples.
- Students determine what they think will be important – What do they need to know to build a bridge?

Bridge designs that fail

- Share clips showing failure (Tacoma Narrows, 35W).
- General tension/compression discussion here.

Extensions

Try testing multiple sizes/configurations of a truss bridge, but exclude other bridge types. Give everyone exactly the same amount of material and have them design different shapes of bridges to see the effect shape has beyond material.

Other Resources

Design Software
Johns Hopkins Truss Builder
http://pages.jh.edu/~virtlab/bridge/truss.htm

West Point Bridge Designer
https://bridgecontest.org/resources/download/

Bridge Fails
Tacoma Narrows
http://youtu.be/j-zczJXSxnw

Silver Bridge
http://youtu.be/dGQfUWvP0II

Bridge Construction Methods
Incremental launch
http://youtu.be/S3Kf9e6JgF4

Alconetar Bridge construction
http://youtu.be/o4eM0qoUhaE

Megastructure – Denmark to Sweden Bridge
http://youtu.be/X8_VQbOh7go

Concrete arch bridge in St. Paul, Minn. Photo credit: Minnesota Department of Transportation

Truss bridge in Waterford Township (Dakota County, MN) Photo credit: Minnesota Department of Transportation

Suspension bridge in Minneapolis, Minn. Photo credit: Minnesota Department of Transportation

BRIDGE UP!
ENGINEERING

LESSON 10 – GRADES 9-12

LESSON 10 – GRADES 9-12: Fundamental Forces

Big Idea
Students will examine the fundamental forces that impact the construction of bridges.

Essential Questions
What are the forces that need to be considered when building a bridge?

Background Information
Bridges are designed for specific purposes and loads. They are designed to have service lives and maximum load capacities. Some can be modified over time, others need to be replaced. Engineers consider several factors when deciding on bridge designs, including location (cold climates) and the different kinds of loads it will carry – people, cars, trucks, or trains.

Standards & Benchmarks

Minnesota Science Standards

9.1.2.1 Addressing Human Need
Engineering is a way of addressing human needs by applying science concepts and mathematical techniques to develop new products, tools, processes and systems.

Benchmark 9.1.2.1.1 Refinement of Designs
Understand that engineering designs and products are often continually checked and critiqued for alternatives, risks, costs and benefits, so that subsequent designs are refined and improved.

9.2.2.2 Motion
An object's mass and the forces on it affect the motion of an object.

Benchmark 9.2.2.2.3 Action/Reaction
Demonstrate that whenever one object exerts force on another, a force equal in magnitude and opposite in direction is exerted by the second object back on the first object.

9P.2.2.1 Forces
Forces and inertia determine the motion of objects.

Benchmark 9P.2.2.1.3 Gravity & Motions
Use gravitational force to explain the motion of objects near Earth and in the universe.

9.1.2.2 Practice of Engineering
Engineering design is an analytical and creative process of devising a solution to meet a need or solve a specific problem.

Benchmark 9.1.2.2.2 Using Models in Designing
Develop possible solutions to an engineering problem and evaluate them using conceptual, physical and mathematical models to determine the extent to which the solutions meet the design specifications.

9.1.3.4 Knowledge & Understanding
Science, technology, engineering and mathematics rely on each other to enhance knowledge and understanding.

Benchmark 9.1.3.4.6 Analysis of Models
Analyze the strengths and limitations of physical, conceptual, mathematical and computer models used by scientists and engineers.

9P.2.2.1 Forces
Forces and inertia determine the motion of objects.

Benchmark 9P.2.2.1.1
Vectors Use vectors and free-body diagrams to describe force, position, velocity and acceleration of objects in two-dimensional space.

Connections with Multimedia Program

Bridge Up! Fundamental Forces

Activity Description

Students will explore, virtually, the forces that bridges experience. They will apply what they learn in a computer design challenge to build the least expensive bridge that will support a standard moving load. Several days are needed to complete this lesson.

Vocabulary

Force terms

Compression – Pushing forces aligned along the axis of a member.

Tension – Pulling forces aligned along the axis of a member.

Shear – Pushing or pulling forces aligned perpendicular to the axis of a member.

Balanced – Sum of net forces = zero.

Unbalanced - Sum of net forces NOT = zero.

Load terms

Static – Load that is not moving, may be the bridge itself.

Dynamic – Load that is moving, as in a truck crossing a bridge.

Mechanical equilibrium - Sum of net force = zero.

Truss terms

Member – A component part of a bridge or other structure, complete in itself.

Node – The steel joint on a bridge where multiple members of a truss connect, typically held together by two gusset plates.

Gusset plate – Sheets of steel that are used to connect beams and girders to columns or to connect truss members.

Materials

- Textbook
  - Chapters that cover basic forces
- Physicsclassroom.com
- Access to computers with Java technology. Java is a browser plug-in that may need to be downloaded in order to play the West Point Bridge Designer program. Java is free to download at **https://www.java.com/en/**.
- Johns Hopkins Truss design
- West Point Bridge Designer

Procedure

This lesson is content – focused on teaching students about forces. Resources are listed that can be used to illustrate how forces are applied in bridges.

A basic introduction of forces should be provided using the resources you currently use. The rest of this procedure will focus on web-based activities to help students develop an understanding of truss and bridge design.

Johns Hopkins Truss Builder (1 day) – Computer-aided design system that helps students design trusses by showing how compression and tension forces interact in a truss system. The website will calculate forces based on loads applied. It also shows which forces are in compression and which are in tension.

Use this site to have students build a simple truss as illustrated in the site instructions. This will allow students to grasp the basics of truss design. From there, have students experiment with different designs. This helps them see that, as they are designing, some members have little or no impact on the strength of a truss, while others are crucial. As students plan a truss design, have them predict the types of forces in each member as a result of the applied load. Values and force types will be displayed when the simulation is run.

West Point Bridge Builder (2 days) – Computer-aided design system that has students build a virtual bridge to meet certain design challenges. This is an actual annual competition, but the competition makes previous years' competition software available for educational use.

https://bridgecontest.org/resources/previous-versions-of-the-software/

Use the previous years' software versions to issue student challenges. Attached is a sample activity where students need to design a bridge that has the lowest cost, yet is able to sustain a load as the load crosses the bridge. This activity assumes that the students have had an opportunity to work with the Bridge designer software before attempting the activity.

Assessment

- Computer results (have students show screen when assignment is complete)
- Science journal entries
- Student notes

Extensions

- Have students actually compete in the West Point Competition. Scholarships and prizes are available.
- Have students build trusses out of spaghetti, balsa wood, toothpicks, straws, or any other supplies that would simulate truss members. Test with hanging masses.

West Point Bridge Designer Competition

Name of team:

Members of team (2 max: $100,000 added to bridge cost for each additional)

Your team has been tasked with solving the problem of building a bridge to transport cargo across a river. You will use the West Point Bridge designer software to complete this task. You have 20 minutes to design the lowest cost bridge to achieve the goal. You may start with a predesigned bridge or you may build from scratch. Once your design is complete, you will set the simulation to loop so that we can watch the truck safely cross your bridge. The definition of safe that will be used is that your truck does not fall through the bridge into the water.

At the completion of this activity, we will discuss how the designs varied and decide if the above definition of safe is truly enough and how these definitions cause design plans to account for more than just the minimum safe load.

Make a drawing of your bridge. Make sure that you include the land on each side of the bridge, showing any excavation that has been done.

Starting cost of bridge:

Ending cost of bridge:

Describe one aspect of your design that caused you significant challenges and how you were able to solve it. This description should use complete sentences and fully develop your ideas.

BRIDGE UP! ENGINEERING

LESSON 11 – GRADES 9-12

LESSON 11 – GRADES 9-12: Mastering Materials

Big Idea

Engineers must choose materials that will make a bridge stable, safe and durable.

Essential Questions

Which materials should be selected for the construction of bridges?

What are their properties and how can those properties be tested?

Background Information

The most common materials used for building bridges are steel and concrete. Engineers consider several factors when deciding on bridge designs, including location (cold climates) and the different kinds of loads it will carry – people, cars, trucks, or trains. Engineers also consider the distance the bridge must span.

Standards & Benchmarks

Minnesota Science Standards

9.1.2.1 Addressing Human Need

Engineering is a way of addressing human needs by applying science concepts and mathematical techniques to develop new products, tools, processes and systems.

Benchmark 9.1.2.1.1 Refinement of Designs

Understand that engineering designs and products are often continually checked and critiqued for alternatives, risks, costs and benefits, so that subsequent designs are refined and improved.

9.2.2.2 Motion

An object's mass and the forces on it affect the motion of an object.

Benchmark 9.2.2.2.3 Action/Reaction

Demonstrate that whenever one object exerts force on another, a force equal in magnitude and opposite in direction is exerted by the second object back on the first object.

9P.2.2.1 Forces

Forces and inertia determine the motion of objects.

Benchmark 9P.2.2.1.3 Gravity & Motions

Use gravitational force to explain the motion of objects near Earth and in the universe.

9.1.3.3 Society

Science and engineering operate in the context of society and both influence and are influenced by this context.

Benchmark 9.1.3.3.2 Persuasive Communications
Communicate, justify and defend the procedures and results of a scientific inquiry or engineering design project using verbal, graphic, quantitative, virtual or written means.

9.1.2.2 Practice of Engineering
Engineering design is an analytical and creative process of devising a solution to meet a need or solve a specific problem.

Benchmark 9.1.2.2.2 Using Models in Designing
Develop possible solutions to an engineering problem and evaluate them using conceptual, physical and mathematical models to determine the extent to which the solutions meet the design specifications.

Activity Description

This activity will help students understand some of the processes that can be used to test materials. This activity will demonstrate shear force testing of some materials used to simulate members of a truss.

Vocabulary

Shear force – Force acting on a substance in a direction perpendicular to the extension of the substance, such as the pressure of air along the front of an airplane wing.

Compression – A pushing force usually shortening the object.

Tension – A stretching or pulling force usually lengthens an object.

Materials

- Spring scale
- Balsa wood (various thicknesses)
- Glue
- Spaghetti
- Other materials for snapping

Preparation

Laminate some of the samples with glue so that the thickness of the material is doubled.

Assessment

Student learning can be gauged by the accuracy of their data recording and how well their explanations reflect an understanding of forces they are applying to the materials in the activity.

Extensions

Use small snack cups, Portland cement, sand, small gravel, and water to conduct slump tests. Record data to find which combination of materials produce an adequate slump test for concrete.

Other Resources

How Bridges Work; Additional Bridge Forces: Torsion and Shear
http://science.howstuffworks.com/engineering/civil/bridge9.htm

Shear and Torsion on small scale bridge piers
https://www.youtube.com/watch?v=5UPJ3waHtp4

Name: ______________________________

Date: ______________________________

Period:______________________________

Shear Force Materials Testing Activity:

This activity will help you understand one of the processes used to test materials. Compression, tension and shear force all play a role in the design of a bridge. We will use spring scales to find shear forces required to snap various materials.

Define Shear Force:

Before you begin, you should have a sample of materials, 2 large wooden blocks and a spring scale at your station. The large blocks are your testing station. You will test your materials first at 20 cm separation and then at 10 cm separation of the blocks. Please reuse the materials for as many tests as possible.

Team members: Material tester, data recorder and spring scale observer.

Place the blocks so that they are separated by a distance of 20 cm. Your samples will be placed on top of the blocks. You will hook the spring scale to the sample and then SLOWLY pull down on the spring scale until the sample snaps.

The spring scale observer needs to carefully watch the scale so that they can capture the maximum force used just before the material snaps.

Find the maximum value just before the break and record it below.

Name of Material	20 cm	10 cm

Analysis: (Use complete sentences to answer the questions)

Were the values for double combinations equal to double the force required to break the singles? Explain your answer.

How would you use this data when deciding how to build a bridge?

BRIDGE UP!
ENGINEERING

ADDITIONAL RESOURCES

Additional Resources

BOOKS

Grade and grade equivalents from Scholastic Books

Bridges by Seymour Simon.

Bridge Building: Bridge Designs and How They Work (High Five Reading) by Diana Briscoe.

Bridges: Amazing Structures to Design, Build & Test by Carol A. Johmann
(nonfiction; grades 2 - 9; grade equivalent - not available).

Bridges are to Cross by Philemon Sturges and Giles Laroche.

Bridges: The Science and Art of the World's Most Inspiring Structures by David Blockley.

Bridges and Tunnels: Investigate Feats of Engineering by Donna Latham.

Bridging the World by Robert S. Cortright.

Brooklyn Bridge by Lynn Curlee (Informational; grade 3 - 5; grade level equivalent 7.5).

Brooklyn Bridge by Elaine Pascoe and Elaine Pacoe (Nonfiction; grades 6-8; grade equivalent 7.5).

The Brooklyn Bridge: The story of the world's most famous bridge and the remarkable family that built it.
By Elizabeth Mann (nonfiction; grades 3-5; grade equivalent 5.5).

Building Big: Bridges by David Macaulay.

Building the Golden Gate Bridge (You Choose: Engineering Marvels) by Blake Hoena and Angie Kaelberer.

Building Toothpick Bridges (Math Projects: grades 5-8) by Dale Seymour Publications.

Engineering the ABCs: How Engineers Shape Our World by Patty O'Brien Novak.

Engineering the City: How Infrastructure Works by Matthys Levy.

Famous Bridges of the World: Measuring Length, Weight, and Volume (Powermath) by Yolonda Maxwell.

The Golden Gate Bridge by Jeffrey Zuehlke.

The Great Bridge: The Epic Story of the Building of the Brooklyn Bridge by David McCullough.

How to Read Bridges: A Crash Course In Engineering and Architecture by Edward Denison and Ian Stewart.

BOOKS (continued)

Mackinac Bridge: The Story of the Fie Mile Poem by Gloria Whelan and Gijsbert van Frankenhuyzen.

Twenty-One Elephants and Still Standing by April Jones Prince.

Pop's Bridge by Eve Bunting (Historical fiction; grades K-2; grade equivalent 3.4).

The World's Most Amazing Bridges by Michael Hurley.

You Wouldn't Want to Work on the Brooklyn Bridge by Tom Ratliff.

VIDEO

Brooklyn Bridge; Ken Burns America Collection, Ken Burns.

ONLINE VIDEOS

Bridge Building Video – National Geography video, shows arch, suspension and Cable Stay Bridge.

http://www.sciencekids.co.nz/videos/engineering/bridgebuilding.html

Official San Francisco-Oakland Bay Bridge Construction Time Lapse – shows the construction of the bridge in a 4 minute video.

INTERNET

Building Big: Bridges (information and interactives).
http://www.pbs.org/wgbh/buildingbig/bridge/

How Bridges Work by Robert Lamb and Michael Morrissey (Information).
http://science.howstuffworks.com/engineering/civil/bridge.htm

Everyday Science: Bridge Quiz (interactive).
http://science.howstuffworks.com/engineering/structural/bridge-quiz.htm

How Floating Bridges Work by Nathan Chandler (Information).
http://science.howstuffworks.com/engineering/structural/floating-bridge2.htm

Floating Bridges on the Brain: The Ultimate Floating Bridge Quiz (interactive).
http://science.howstuffworks.com/engineering/structural/floating-bridge-quiz.htm

FREE APPS

Bridge Constructor – construct bridges within a given budget.
Bridge Constructor Playground – similar to Bridge Constructor without budget constraints.
Fat Birds Build a Bridge! – build bridges to help overweight birds get home.

Director, MnDOT Office of Communications
395 John Ireland Boulevard
Saint Paul, MN 55155