

## Structures – Bridge Building

This lesson is part of a 3<sup>rd</sup> grade Unit of Inquiry into Structures. The expected time frame is 4-5 80-minute periods over 4-5 days. (We have double blocks of time for our inquiry units in the afternoon, i.e. 2x40 minutes).

### *Transdisciplinary Theme - How the World Works*

An inquiry into the natural world and its laws; the interaction between the natural world (physical and biological) and human societies; how humans use their understanding of scientific principles; the impact of scientific and technological advances on society and on the environment.

### *Central Idea*

The design of structures involves consideration of different factors.

### *Lines of Inquiry*

- Designs and materials of structures
- Factors that impact structures
- Structures and their uses

## Shanghai Community International School Unit Outcomes

### *Skills*

- a. Use a variety of instruments and tools to measure data accurately.
- b. Use scientific vocabulary to explain their observations and experiences.
- c. Identify or generate a question or problem to be explored.
- d. Plan and carry out systematic investigations, manipulating variables as necessary.
- d. Make and test predictions.

### *Overall Expectations*

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

### *Learning Outcomes*

3.1.1 Assess effects of strong and stable structures on society and the environment (e.g., reliable load-bearing structures are essential in all areas of life for shelter, transportation, and many other everyday purposes; strong and stable structures can endure for long periods of time and provide a historical record of other societies and cultures; strong and stable structures can be hard to dispose of when their usefulness is ended and may then have a negative effect on the environment).

3.1.2 Assess the environmental impact of structures built by various animals and those built by humans.

3.2.1 Follow established safety procedures during science investigations (e.g., carry scissors and other cutting tools in a safe manner).

3.2.2 Investigate, through experimentation, how various materials (e.g., paper and wood) and construction techniques (e.g., folding, adding layers, twisting/braiding, changing shapes) can be used to add strength to structures.

3.2.3 Investigate, through experimentation, the effects of pushing, pulling, and other forces on the shape and stability of simple structures (e.g., the effect of adding one or more struts on the strength of a tower; the effect of adding ties on the strength of a bridge; the effect of adding weight to the base of a tower on the stability of the tower).

3.2.4 Use technological problem-solving skills, and knowledge acquired from previous investigations, to design and build a strong and stable structure that serves a purpose (e.g., a place to store lunch bags, a place to put wet boots).

3.2.5 Use appropriate science vocabulary, including compression, tension, strut, ties, strength, and stability, in oral and written communication.

3.2.6 Use a variety of forms (e.g., oral, written, graphic, multimedia) to communicate with different audiences and for a variety of purposes (e.g., an oral report to the class on the results of experiments to strengthen materials).

3.3.1 Define a structure as a supporting framework, with a definite size, shape, and purpose, that holds a load (e.g., a running shoe, a tepee, a bicycle, an igloo).

3.3.2 Identify structures in the natural environment (e.g., a tree, a bees' nest/hive) and in the built environment (e.g., a totem pole, a fence, a pyramid, the CN Tower).

3.3.3 Identify the strength of a structure and its ability to support a load.

3.3.4 Identify the stability of a structure as its ability to maintain balance and stay fixed in one spot.

3.3.5 Identify properties of materials (e.g., strength, flexibility, durability) that need to be considered when building structures.

3.3.6 Describe ways in which the strength of different materials can be altered (e.g., by folding, adding layers, twisting/braiding, changing their shape).

3.3.7 Describe ways to improve a structure's strength (e.g., by using triangulation or cross-members) and stability (e.g., by lowering the center of gravity).

3.3.8 Explain how strength and stability enable a structure (e.g., bridge, tent) to perform a specific function.

3.3.9 Describe ways in which different forces can affect the shape, balance, or position of structures (e.g., a load may cause a cardboard box to buckle).

3.3.10 Identify the role of struts and ties in structures under load (e.g., a strut is added to a wooden frame to resist compression that might cause its collapse; a tie is added to a roof truss to resist tension that might cause the roof to collapse from the weight of the shingles).

NGSS	Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p>3-5-ETS1-1 Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes several criteria for success and constraints on materials, time, or cost.</p> <p>3-5-ETS1-3 Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered.</p> <p>3-5-ETS1-2 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.</p>	<p>Asking Questions and Defining Problems</p> <p>Planning and Carrying Out Investigations</p> <p>Constructing Explanations and Designing Solutions</p>	<p><i>ETS1.A: Defining and Delimiting Engineering Problems</i></p> <ul style="list-style-type: none"> <li>• Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account. (3-5-ETS1-1)</li> </ul> <p><i>ETS1.B: Developing Possible Solutions</i></p> <ul style="list-style-type: none"> <li>• Research on a problem should be carried out before beginning to design a solution. Testing a solution involves investigating how well it performs under a range of likely conditions. (3-5-ETS1-2)</li> <li>• At whatever stage, communicating with peers about proposed solutions is an important part of the design process, and shared ideas can lead to improved designs. (3-5-ETS1-2)</li> <li>• Tests are often designed to identify failure points or difficulties, which suggest the elements of the design that need to be improved. (3-5-ETS1-3)</li> </ul> <p><i>ETS1.C: Optimizing the Design Solution</i></p> <ul style="list-style-type: none"> <li>• Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints. (3-5-ETS1-3)</li> </ul>	<p><i>Influence of Science, Engineering, and Technology on Society and the Natural World</i></p> <ul style="list-style-type: none"> <li>• People’s needs and wants change over time, as do their demands for new and improved technologies. (3-5-ETS1-1)</li> <li>• Engineers improve existing technologies or develop new ones to increase their benefits, decrease known risks, and meet societal demands. (3-5-ETS1-2)</li> </ul>

## *Nature of Science*

### Scientific Investigations Use a Variety of Methods

- Science investigations use a variety of tools and techniques

### Scientific Knowledge is Based on Empirical Evidence

- Science uses tools and technologies to make accurate measurements and observations

### Science is a Human Endeavor

- Most scientists and engineers work in teams
- Creativity and imagination are important to science

## *CCSS*

3.NBT.A.2 Fluently add and subtract within 1000 using strategies and algorithms based on place value, properties of operations, and/or the relationship between addition and subtraction.

3.MD.4 Generate measurement data by measuring lengths using rulers marked with halves and fourths of an inch. Show the data by making a line plot, where the horizontal scale is marked off in appropriate units – whole numbers, halves, or quarters.

3.G.1 Understand that shapes in different categories (e.g., rhombuses, rectangles, and others) may share attributes (e.g., having four sides), and that the shared attributes can define a larger category (e.g., quadrilaterals). Recognize rhombuses, rectangles, and squares as examples of quadrilaterals, and draw examples of quadrilaterals that do not belong to any of these subcategories.

MP5 Use appropriate tools strategically.

MP6 Attend to precision.

W.3.2 Write informative/explanatory texts to examine a topic and convey ideas and information clearly.

- W.3.2.A Introduce a topic and group related information together; include illustrations when useful to aiding comprehension.
- W.3.2.B Develop the topic with facts, definitions, and details.
- W.3.2.C Use linking words and phrases (e.g., *also*, *another*, *and*, *more*, *but*) to connect ideas within categories of information.
- W.3.2.D Provide a concluding statement or section.

SL.3.4 Report on a topic or text, tell a story, or recount an experience with appropriate facts and relevant, descriptive details, speaking clearly at an understandable pace.

### **Engage (Day 1 ~40minutes)**

At this point of the unit, the students will already be familiar with much of the vocabulary (compression, tension, strut, ties, strength, stability, etc.), and will have already worked collaboratively on short building activities using index cards (flat, as well as folded). To engage students in preparation for their own bridge building, the class will listen to the story *Twenty-one Elephants and Still Standing* by April Jones Prince that tells the story of the building of the Brooklyn Bridge and PT Barnum sending twenty-one elephants across the bridge to prove the bridge's strength and stability. The class will also watch the following short videos on YouTube, projected on the Smartboard.

Time-lapse video: Road-rail bridge completed in SW China <https://www.youtube.com/watch?v=KuAvFDGED3k>

15 World's Coolest Bridges - <https://www.youtube.com/watch?v=sar7FnGWJL0>

Following the videos, students will use the Visible Thinking strategy of “Think, Pair, Share”. Students will be given about 30-40 seconds to individually think about each video before turning to the person beside them to “pair and share” their observations and ideas on how the videos connect to our unit on Structures. Students will be given about 1 minute (30 seconds each) to share their ideas with each other. Students will then be invited to share their thoughts and ideas with the class. The hope/expectation being that the idea that “Bridges are important structures that allow an obstacle (water, road, railway, etc.) to be safely crossed by people and/or different types of vehicles.” will naturally come up during the class sharing. If not, the teacher will share the statement with the class and elicit student thoughts on whether they agree or not, and why.

### **Explore (Day 1 ~40 minutes, Day 2 ~80 minutes, Day 3 ~80 minutes)**

Students will be assigned to teams of 3 (class size is 18, so there will be 6 teams at work), and told that their task is to investigate and explore the different types of bridges (the beam, the truss, the arch, the suspension, the cantilever, and the cable-stay), taking individual notes in their inquiry notebooks on the description of each, along with any notable advantages and/or disadvantages. For each bridge type, students will also add a basic sketch to go along with their notes. The following websites will guide each team in their research:

What makes bridges so strong? <https://www.youtube.com/watch?v=oVOnRPefcno>

All about bridges: importance and types <https://easyscienceforkids.com/all-about-bridges/>

Bridge basics <https://www.pbs.org/wgbh/buildingbig/bridge/basics.html>

Bridge engineering <https://www.britannica.com/technology/bridge-engineering>

How bridges work <https://science.howstuffworks.com/engineering/civil/bridge1.htm>

Types of bridges <http://www.historyofbridges.com/facts-about-bridges/types-of-bridges/>

Bridge design and destruction! (part 1)

<https://www.khanacademy.org/partner-content/mit-k12/mit-k12-physics/v/bridge-design-and-destruction-part-1>

Bridge design and destruction! (part 2)

<https://www.khanacademy.org/partner-content/mit-k12/mit-k12-physics/v/bridge-design-and-destruction-part-2>

Half way through the second day of research and note taking, the teams will pause their work and the class will come together for a debrief. Teams will be asked to share their findings, thus far. After the debrief, the teacher will ask, “Which bridges do you think we could attempt to build models of using only 200 popsicle sticks and glue?” The intent is that students will gravitate towards the ‘beam’ and ‘truss’ bridge when faced with limited building materials. However, the teacher should be prepared to listen to arguments and have teams debate their ideas.

After the discussion, teams will be told that after they have completed their bridge research, each team will be building either a ‘beam’ or ‘truss’ bridge using 200 popsicle sticks and glue. As each team completes their research and shows the teacher their work, they will select 1 of 6 folded pieces of paper (3 ‘beam’ and 3 ‘truss’) and build the bridge selected. Each bridge will need to be 30cm in length (we don’t have inch rulers at my school in China) and will need to hold a 2.5kg weight for 30 seconds. Students will be told they do not need to use all 200 popsicle sticks in their build, and they will have the opportunity to examine the 2.5kg weight before and during their build. Teams will be expected to present an initial sketch of their bridge model before receiving their materials.

#### **Explain (Day 4 ~80 minutes)**

All teams will present their completed bridge to the class, where it will undergo testing with the 2.5kg weight. Each team will reflect collaboratively on their success or failure after each team has presented, self-assessing using the following rubric, which the teacher will also use to assess each team. (\*PYP refers to the Primary Years Program of the International Baccalaureate, which is our curriculum framework.)

	4- EE- Exceeds Expectations	3- ME- Meets Expectations	2- AE- Approaching Expectations	1-NME- Not Meeting Expectations
<b>Form</b> What are effective designs and materials of structures?	Student used a highly effective design and strong materials to ensure the structure's strength and stability.  Structure stood for a long period of time, and was designed to survive changing environment conditions.	Student used a relatively effective design and strong materials to ensure the structure's strength and stability.  Structure stood up for a while in stable environment conditions.	Student needed help to design and pick materials that made the structure strong and stable.  Student's initial structure stood up briefly while in stable environment conditions.	Student used an ineffective design and/or weak materials. The structure was not strong or stable.  Structure did not stand up in stable environment conditions.
<b>Function</b> What is a structure? How is a structure used?	Student's structure served a thoughtful function that fit its environment. Student identified the specific load his/her structure carries.	Student's structure had a clear function. Student identified the load his/her structure carries.	Student's structure had a function that made little sense for its environment. Student needed support to identify the load his/her structure carries.	Student's structure did not have a clear function. Structure was not built to carry a load.
<b>Causation</b> What factors impact structures?	Student's reflection and work demonstrate in-depth understanding of the various factors that impact structures.	Student's reflection and work demonstrate understanding of the various factors that impact structures.	Student's reflection and work demonstrate limited understanding of the various factors that impact structures.	Student's reflection and work do not demonstrate understanding of the various factors that impact structures.
<b>PYP Skills</b> Self-Management (Fine Motor, Spatial Awareness, Organization, Time Management, Safety)	Student utilized fine motor skills and spatial awareness to produce a highly detailed and well constructed structure. Student made very safe decisions, managed time well, and kept his/her materials organized.	Student utilized fine motor skills and spatial awareness to produce a mostly well-constructed structure with some details. Student usually made safe decisions, managed time, and kept his/her materials organized.	Student needed help to use fine motor skills and spatial awareness to construct his/her structure. Student usually made safe decisions, but needed extra help managing time and keeping materials organized.	Student had difficulty using fine motor skills and spatial awareness to construct a structure. Student did not make safe decisions, manage time well, or keep materials organized.
<b>PYP Skills</b> Social Skills (Group Decision Making)	Student cooperated very well with his/her group by negotiating and mutually agreeing upon ideas, and delegating tasks.	Student usually cooperated with his/her group by negotiating and mutually agreeing upon ideas, and delegating tasks.	Student needed help to cooperate with his/her group by negotiating and mutually agreeing upon ideas, and delegating tasks.	Student did not cooperate with his/her group. Student refused to negotiate, agree upon ideas, or share tasks.
<b>PYP Attitudes</b> Cooperation, Curiosity, Creativity	Student demonstrates a high-level of cooperation, curiosity, and creativity, which led to the creation of a well-designed and stable structure.	Student's cooperation, curiosity, and creativity allowed him/her to complete a strong and stable structure.	Student demonstrates limited cooperation, curiosity, and/or creativity, which hindered the completion of his/her structure.	Student did not demonstrate cooperation, curiosity, and/or creativity when building his/her structure.

Students will also reflect independently using the “Sample Self-Assessment Matrix: Collaboration” rubric from *The Power of Inquiry* by Kath Murdoch.

**SAMPLE SELF-ASSESSMENT MATRIX: COLLABORATION**

SKILL					EVIDENCE WHEN DID YOU DO THIS? HOW DO YOU KNOW YOU DID THIS? (KEEP A RECORD.)
	NOT OFTEN	MOST OF THE TIME	ALL OF THE TIME	I CAN TEACH OTHERS	
I wait my turn to speak.					
I contribute ideas to the group.					
I am willing to compromise.					
I encourage others.					
I listen well to others.					
I stay focused on the task.					
I can take on different roles.					
I can collaborate – even when I don't choose my team.					

## **Extend**

Knowledge gained during their bridge building will be extended into their summative structure building. In teams (self-selected) or independently, students will plan and design a purposeful structure of their choosing that uses their knowledge and understanding gained throughout the unit (in particular, their knowledge of beam and truss bridges). Teams or individual students will have the opportunity to use the computer aided design program SketchUp or pencil/paper to develop a visual plan of their intended structure before building. Once again, their structure will be expected to hold a pre-determined weight (no less than 1kg, no more than 2.5kg) for a period of 30 seconds. Materials will include: popsicle sticks, glue, cardboard. To further integrate math, students will need to plan their structure with the knowledge that they have a budget of \$250. Each popsicle stick costs \$1 and each 30cm<sup>2</sup> of cardboard costs \$2. One bottle of glue will be provided free of charge to each build, and each additional bottle will cost \$5.

## **Evaluate**

Formative assessment is ongoing throughout the lesson through check-ins and debriefings with teams during the research phase, along with teacher observations.

In addition to the final structure build, students will write a short paper (1-2 pages) explaining what their task was, the steps they took to complete it, and how successful the build was in meeting the criteria.

Once again, students will self-assess with the same rubric from their bridge build, and the teacher will also assess using the same rubric.

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## Resources

*Bridge basics.* (n.d.). Retrieved from <https://www.pbs.org/wgbh/buildingbig/bridge/basics.html>

*Bridge design and destruction! (part 1).* [Video file] (n.d.). Retrieved from <https://www.khanacademy.org/partner-content/mit-k12/mit-k12-physics/v/bridge-design-and-destruction-part-1>

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