Lesson: Civil Engineering: The Science Behind Bridges

Grade Level: 8-9 – **Time Required:** 40 minutes – **Lesson Dependency:** None

Subject Areas:

- Geometry
- Physics

Summary:

Students will learn about the nature of bridges and understand the forces and design choices behind them. One of which is the triangle, where it brings such structural strength when compared to other shapes due to its properties. An activity and worksheet follow the lesson and its contents. The activity is a method to expose the students to a firsthand experience of structure, compression, and the forces buildings must endure to be successful. The related worksheet will help review the concepts taught briefly and interactively.

Engineering Connection

Structure is integral across many engineering disciplines. The necessity of a structure or building to support not only its weight, but the weight of its load as well, is universally integral. The attributes a triangle has along with the repercussions of both tension and compression lead to the success of engineering marvels from the Eiffel Tower to even the International Space Station. Through this lesson and the accompanying activities, students will think critically while facilitating a unique perspective through the lenses of an engineer.

Learning Objectives

After this lesson, students should be able to:

- Identify the purpose and use of triangles in structural engineering.
- Identify and explain the forces behind a bridge's strength such as tension or compression.
- Be able to differentiate compression, tension.
- Engage in critical thinking to apply the previous concepts mentioned.
- Observe the forces for themselves during the activity.

Educational Standards

- MAFS.8.G.2.6- Explain a proof of the Pythagorean Theorem and its converse.
- MA.912.GR.1.3- Prove relationships and theorems about triangles. (Angles=180)
- International Technology and Engineering Educators Association- Technology- Infrastructure is the underlying base or basic framework of a system (grades 9-12)
- LAFS.910.SL.1.1- Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 9–10 topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.

Worksheets and Attachments

- Build-A-Bridge Worksheet
- Presentation Slides (Slides 1-9)

Materials List

- 1 Sheet of paper per student
- Books
- Scissors
- Glue, Stapler, Or Tape

Prerequisite Knowledge

Students should have a basic understanding of geometry and shapes, especially the familiarity with the concept of how many other regular shapes can be lessened into multiple triangles. They should also know the properties of triangles, including its traits surrounding its angles, sides, and the relationship between the two.

The pre-lesson assessment allows the instructor to gauge the understanding of the students before diving into the lesson with a simple question. This opens up conversation and interactivity between the instructor and student. Furthermore, with the awareness of how much the students know, the lecturer can either go in-depth, or simplify the lesson.

Lesson Background and Concepts for Teachers

The text and lessons that follow coordinate with the attached Google Slides Presentation. Starting from slides 1 to 9, each will break down the key objectives in each slide and the points/ideas supporting them and leading to their discussion. You may modify and adapt the examples and explanations to suit your classroom's needs.

Slide 1 -

To begin the lesson and incite discussion, ask the question "Why do you think civil engineers use triangles in their projects and bridges?" or a similar one. Try to get their participation and their thoughts on the matter and use the picture as an example of how it is used. Allow time to discuss their ideas or hypotheses before continuing.

Slide 2 -

The reason for the triangle's reputation as the strongest shape is its properties. The relationship between its sides and angles dictate its fortitude. The lecturer can either describe the properties at this time or ask the students if they can recall any before doing so.

One of the important properties the triangle has is the fact that its interior angles must add up to 180 degrees and another more famous property is that the triangle must be coherent with the laws of the Pythagorean Theorem: $A^2+B^2=C^2$. To demonstrate the laws, imagine a square and a triangle. If one were to put force on the axis of a square, the shape would shift and move. If you were to push on the axis of a triangle, the shape would stay the same. This is because the length of the sides of the square may stay the same, but the angles must change.

The triangle sum theorem, which says that the angles must add up to 180 degrees doesn't allow this. If one were to change the angles of a triangle, then the lengths of the sides would have to change and therefore, the Pythagorean theorem would be violated. Due to its inability to change and move, the triangle is perfect for bridges and trusses, where its constancy is needed. A square would bend and give way, leading to the bridge's demise.

However, notice the square itself can be changed into a triangle and therefore made stronger. Many other shapes can be reduced to triangles as well. (If the explanation is too complicated or many don't understand the concepts, try to simplify it or add numerical examples).

Slide 3 -

Now that we know why a triangle is used, we can analyze how bridges and trusses work. A truss is defined as a system of members or beams connected and structured to connect and its purpose is to incur axial force. Axial force is when a force, push or pull is acted on the axis of an assembly or part. One perfect example of this is a pencil. If one pulls or pushes on the sides, they would be incurring axial force and the pencil stays together. Bridges are the same way. Each member works together to distribute the weight and forces like the pencil does.

Slide 4 -

Axial Force has two main distinct forces: Tension and compression. They are the previously mentioned push and pull and they are exact opposites. Tension, which is the pull, can be described as a tug of war or a rubber band being stretched. Compression, also known as push, could be described as crushing a can or squeezing the juice out of a lemon. These two forces are incredibly common and can be seen everywhere, but how are they used concerning bridges?

Slide 5 -

Both tension and compression are used to combat gravity and are constantly acting on the bridges. Looking at the diagram, when a load pushes down on a bridge, the bottom segments are under stress and are under tension. This tension then pulls the top half down making those members under compression. If the forces are distributed enough, they can support the weight and handle the duress.

One prime example of this is the Golden Gate Bridge. The bottom supports are in constant compression due to the weight of the load and gravity, and the wire cables are in tension by being stretched as they pull the bridge up.

Slide 6 -

These concepts are used everywhere in the real world. One example you should know is the Eiffel Tower. (The presenter can ask students if any of them have seen the tower first hand. This can be done to promote their interest or grab their attention.) The tower is 1,063' tall and 133 years old. The reason why it still stands to this day is due to the strong truss structure used for the supports.

Another example is the International Space Station. The station has solar panels attached by trusses and without them, the station would be powerless. Revolving the Earth at 4.76 miles a second, the solar panels need to be strong to resist the inertia of the movement and any flying debris out in space.

Finally, even our own homes use the structure. Trusses can be found on the inside to support our houses and to make sure they stay standing for years to come.

Slide 7 -

To demonstrate all we've talked about, the students will become builders of their own in the Paper Bridge activity. Each student must get 1 sheet of paper and their objective is to make paper supports to stack books on top of. They can choose to make the supports as wide, thick, or tall as they want. They can also wrap the supports together using glue, staples, or tape. Encourage them to be as creative with their arrangement of the pillars and to see who can stack the most amount of books in 10 minutes. As students complete the activity keep track of the one with the most books or the most creative design.

Slide 8 -

To finish, assign the students the Build-A-Bridge Worksheet. It is a simple worksheet to review all that they have learned. They will have to print it out themselves and to complete it to turn it. It also could be used as homework. Then, they can turn it in via email or any other platform as you wish. However, remember that the worksheet is just an example of what you yourself can create and assign to your students.

Slide 9 -

There is an optional break slide if you choose to have it, or you could just move on and not use it.

Associated Activities

Paper Bridge- Students will use one sheet of paper to build and support a tower of books. They can cut and create the pillars whatever shape they want.

Build-A-Bridge Worksheet- Students will complete a simple worksheet to go over and demonstrate the information learned throughout the lesson. The worksheet is just an example of what you can do for your lesson and was created specifically for our purposes.

Lesson Closure

Lesson closure begins after the allotted 15 minutes for Build-A-Bridge Worksheet ends. Hopefully now with their increased understanding behind how bridges and trusses work, students will be able to view the world through an engineer's point of view. Moreover, the basic concepts of tension and compression and its role in the strength of bridges is an important lesson that can be used in future engineering classes.

Vocabulary/Definitions

Truss- *a system of members (beams) that are structured and connect in a triangular way.*

Axis- *The real or imaginary line which something rotates*

Axial Force- *A force acting along the axis of an assembly*

Perpendicular- *At an angle of 90° to a given line, plane, or surface.*

Tension- *The state of stress where an object is being pulled apart*

Compression- *When an object is being pushed against itself*

Load- *A heavy or bulky thing that is being carried or is about to be carried*

Assessment

Pre-lesson Assessment

The pre-lesson assessment allows the instructor to gauge the understanding of the students before diving into the lesson with a simple question. This opens up conversation and interactivity between the instructor and student. Furthermore, with the awareness of how much the students know, the lecturer can either go in-depth, or simplify the lesson.

During the Lesson

During the lesson, relating the topics to personal experiences could be a great way to interest the students and engage their critical thinking to expand their perspective. One example of this opportunity to do so is slide 6. The slide contains many diverse illustrations: one of which is the Eiffel Tower or the International Space Station. These provide you with ways to relate to the students, asking if they have ever ventured in Paris,

France, or wondered about exploring the stars. Another way to get them back into the lesson is by asking inquiries on what would happen if given a certain situation. For example, when presenting the diagram of different

Post-Lesson Assessment

The Build-A-Bridge activity worksheet is a great way to assess whether or not your students have fully understood the key elements of the lesson. The worksheet linked was made for our academy's summer program, but the template can easily be modified to suit your needs. A simple, yet brain-challenging, worksheet can reinforce the topics gone over while making it feel like less of a task. Consider making your worksheet as it also allows you to determine each student's progress individually, and it could even be sent as homework to reinforce the topic at home.

Lesson Extension

A way to extend the length or reinforcement of the lesson is through an interactive quiz such as Quizizz, Kahoot, or Nearpod's climb to the top. All these not only allow for a review of the lesson and its contents, but are also a well-liked method to simultaneously go over the material. What is recommended is to have around 20 questions, each with 30 seconds to answer. After all students have responded or the time runs out, the lecturer has an opportunity to revise the mistakes and further clarify the solution.

Another approach to extend the lesson would be to add an educational video relating to the topic. Periodic and strategic halts in the video would allow the presenter to ask critical thinking questions to rein in the students' attention. The video could also cause them to grow more interested and implore them to do their independent research on their own.

References

All of the references towards the pictures used during the lesson presentation have the credits in the slide notes.

Dictionary.com. Lexico Publishing Group, LLC.. (Source of most vocabulary definitions, most of which were done in my own words) http://www.dictionary.com

CPALMS Standards and Achievement Standards Network (Source of educational standards) https://www.cpalms.org/Public/search/Standard http://asn.jesandco.org/resources/ASNJurisdiction

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