Robogals
Science Challenge

Minor Challenge Set #4
STEM Field: Civil Engineering
Level: Intermediate
Challenge Name: The Science of Trusses
Project Cost: 0-20 USD
Materials Required:
- At least 7 sticks (for example, popsicle sticks, toothpicks)
- At least 7 small binder clips, or blu tack

Duration:
- The challenge take approximately 1-2 hours to finish, however, the time guideline is an estimation only, and students and mentors can complete the tasks around their schedules

Introduction:

When designing large structures such as bridges and buildings, civil engineers need to consider how forces will act on the building material. For example, when you are driven across a bridge, you are exerting some weight on the bridge structure. Therefore, large structures need to be built properly for everyone's safety!

These large structures usually have their frames built as a **truss.** A truss is a structure that is made up of connected elements to form a series of triangles. Trusses can be used to strengthen the structure of bridges and buildings.

The pictures below show examples of truss structures in real life.

Figure 1. Railroad truss bridge at Texas, USA

Figure 2. The Blackfriars Bridge, a bowstring truss bridge in Ontario, Canada

Engineers' goal is to design a truss that will not break even with strong forces acting on it. In this project you will make trusses using sticks and binder clips (or blu tack).

Other experiments suggest that you may find it very easy to push, rotate, or twist the sticks in the square truss. When you rotate two adjacent sticks, or slide the sticks that are opposite to one another, you may find that the square shape is deformed. This might be fine for a truss made from sticks, but disastrous for a building!

However, in the triangular truss, you may find that they are more stable. The design is "stronger", and not easy to rotate. Let's find out if your experimental results match this background research!

Instructions:

1. Use a binder clip to clip, or use blu tack to join two sticks together end to end.

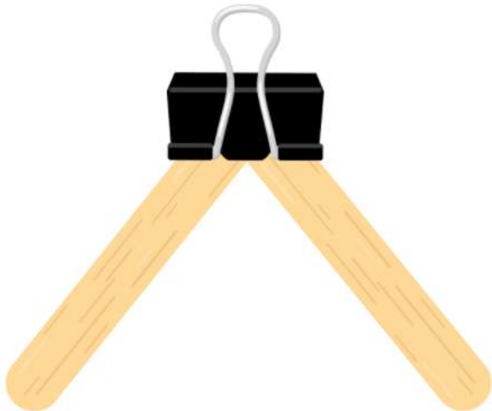

Figure 3. Join two sticks end to end

2. Hold one end of each stick in each hand. Gently twist them back and forth. Note down your observation: How easy is it to rotate the sticks about the joint?

3. Make a square by joining four sticks together (as shown in Figure 4). Gently twist two adjacent sticks. Note down your observation: How easy is it to twist the sticks?

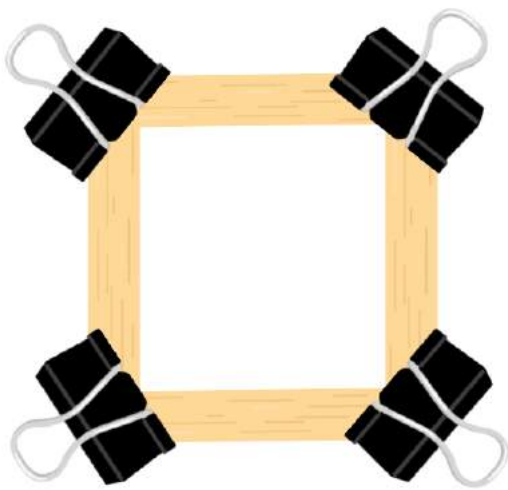

Figure 4. A square truss

4. With the square shape, hold two sticks that are opposite to one another. Gently try to slide them back and forth parallel to one another. Note down your observation: How easy is it to slide the sticks back and forth?

5. Now make a triangle out of three sticks (as shown in Figure 5).

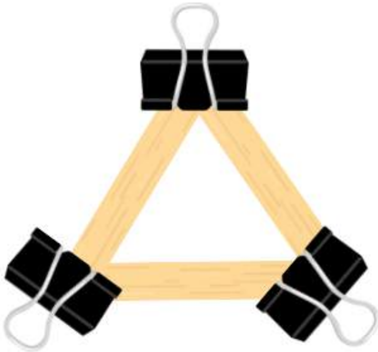

Figure 5. A triangle truss

6. Grip two adjacent sticks and try to rotate them like you did with the square shape. Note down your observation: Can you rotate the sticks? What happens to the triangular shape?

7. Now make a larger truss structure by joining two square shapes together (Figure 6). Gently try to pull, or twist different parts of the truss. What happens to the shape of the truss?

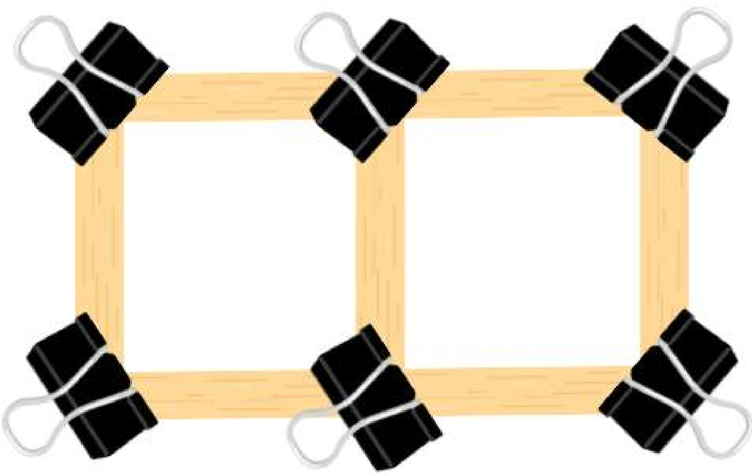

Figure 6. Make one large structure by joining two square trusses

8. Try adding a diagonal across each square (Figure 7). By doing this, you are dividing the square into triangles. Can you still easily pull, or twist the truss structure?

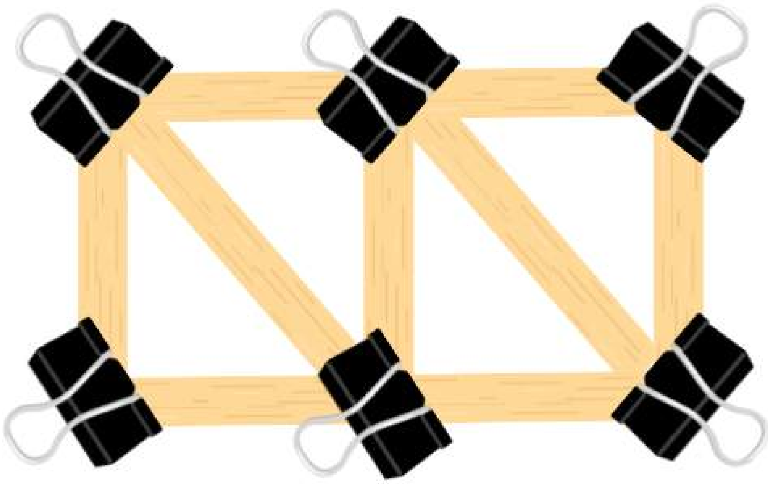

Figure 7. Divide each square into two triangles by adding diagonal lines

9. Make a larger truss structure by joining two triangular shapes together (Figure 8). Gently try to pull, or twist different parts of the truss. What happens to the shape of the truss?

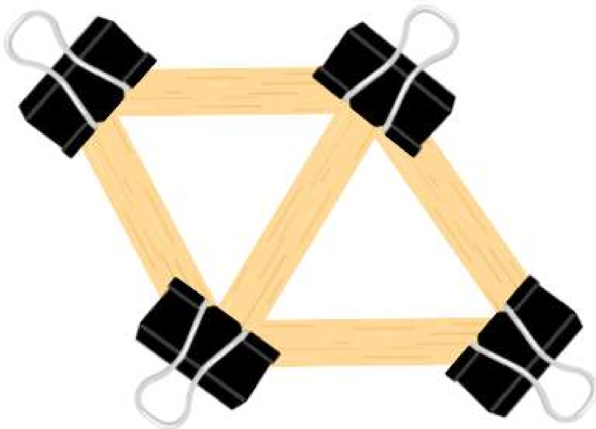

Figure 8. A large truss from joining two triangle trusses together

So, what happened?

All the stability of the truss happens because of something in engineering called **degrees of freedom**. The square truss has one degree of freedom, meaning it can move in one direction. When you rotate the square truss, you can rotate it from a square to a parallelogram. In the case of a square truss, if you use very strong binder clips at the joints, you may find that it prevents the square from rotating and moving. In the triangle truss, there are zero degrees of freedom. All of the sticks are fixed in place and cannot rotate.

You can learn more about how architects use triangles in their designs with this Google Earth activity. This is a presentation on Google Earth, featuring how triangles are incorporated in designs of buildings around the world.

Google Earth - Triangular Structures

Extension

You can apply what you learned from this activity into the tower building challenge in the Civil Engineering - Senior project.

You can also try to build a bridge from a series of trusses, and test much weight your bridge can withstand!

Reflection Questions:

- Are there any improvements you would make to this challenge?
- What real world application/s can you apply this challenge to?
- What are the key science and engineering concepts that relate to this challenge?

- Which truss structure was the strongest? Which one was the weakest?
- Did your experimental results match the information given in the Introduction section?
- Do some research on how triangles transfer force. Why are triangles a strong shape? Can you describe how a force is

distributed in a triangular shape? This website may be useful for this question:
Let's Talk Science - Why are Triangles a Strong Shape

- Other than trusses in large structures such as bridges, in which other structures can you find triangles in their designs?

Submission Guidelines:

- Submit your observations at each step in the Instructions section. You may like to include photos of your experimental setup. Include a short summary that addresses the reflection questions.

> Note: Remember, if you want to upload pictures of your Minor Challenge that also include you, please check if it is OK with your parent or guardian first.

- The submission form is on the Minor Challenges page:
https://sciencechallenge.org.au/index.php/minor-challenges/
Fill out the details and make sure you upload your submission.

Learn More! Resources:

- If you enjoyed this challenge, you may like to read more on what civil engineers and architects work on:

  Civil engineer:
  https://careerdiscovery.sciencebuddies.org/science-engineering-careers/engineering/civil-engineers

  Architect:

https://careerdiscovery.sciencebuddies.org/science-engineering-careers/engineering/architect

Bibliography:

- Buddies, S., 2015. *Popsicle Stick Trusses: What Shape Is Strongest?*. [online] Scientific American. Available at: <https://www.scientificamerican.com/article/popsicle-stick-trusses-what-shape-is-strongest/> [Accessed 8 April 2022].
- Evans, J., 2006. *Abandoned Railroad Truss bridge over trinity river near Goodrich, Texas*. [image] Available at: <https://upload.wikimedia.org/wikipedia/commons/4/4b/Railroad_Truss_bridge_over_trinity_river_near_Goodrich%2C_Texas.jpg> [Accessed 8 April 2022].
- Forsyth, B., 2021. *Blackfriars Bridge*. [image] Available at: <https://militarybruce.com/blackfriars-bridge-a-historic-bowstring-truss-bridge-in-london-ontario/> [Accessed 8 April 2022].