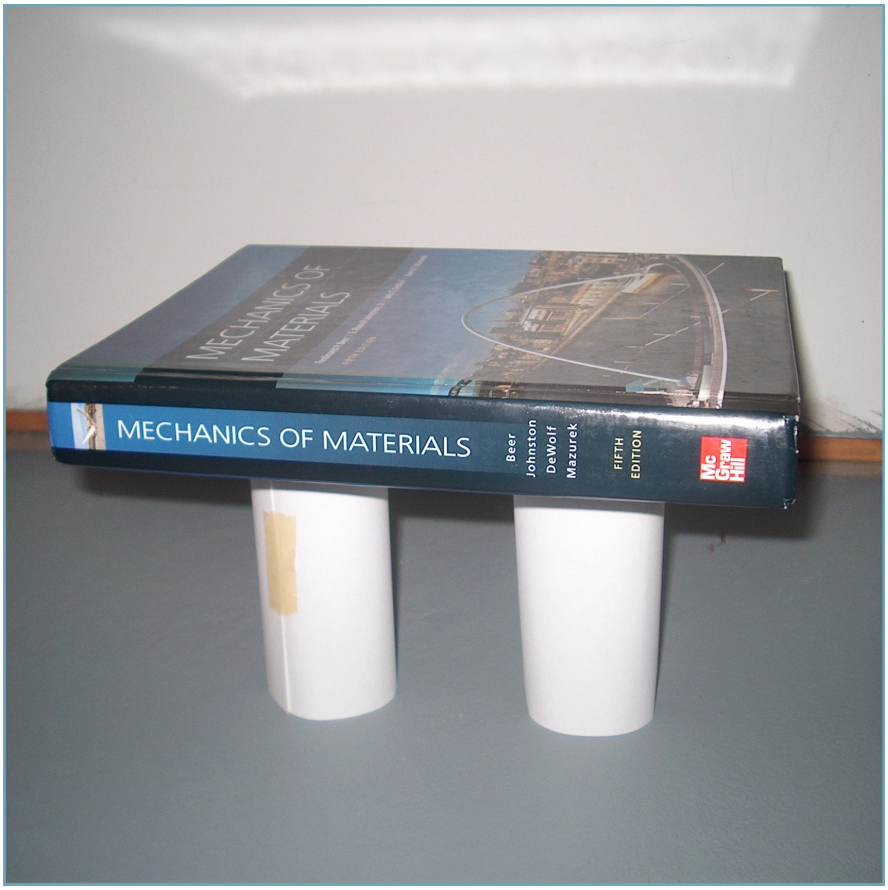
Paper Structures

Outreach Program Lesson Plan



WAAW foundation

Working To Advance STEM Education for African Girls

WAAW Foundation is non-profit organization dedicated to bringing hands-on STEM education to girls all over Africa.

Our Mission: To increase the pipeline of African women in Science, Technology, Engineering and Math (STEM) disciplines and to ensure this talent is engaged in African innovation.

Our Vision: To eradicate poverty in African through female education and science and technology innovation.

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Paper Structures

Class Description-

In this class, students will act as civil engineers, using simple materials to create load-bearing structures. They will go through the design process to build and test the strength of a paper tower. They will explore the concept of using a "Factor of Safety" when designing.

Total class time: 90 minutes

Class Outcomes-

-Students will discover the strength of various structural shapes.
-Students will experience the engineering design process through planning, building, and testing their own designs.
-Students will understand the purpose of designing with a "Factor of Safety."

Materials List-

The kit to teach this class should include:
-9 sheets of copy or construction paper per student (8 1/2 x 11 or similar size)
-1 pair of scissors per every 3-4 students
-1 roll of masking or scotch (clear) tape per every 3-4 students
-books to use as weights
-a scale
-small prizes for student designs (optional)
-rulers or tape measures

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Pre-Class Preparation and Set-Up

To prepare to teach this class, go through the activities yourself. Try out different structures so that you are familiar with what the students will be doing.

Before class, gather supplies and divide up paper to make it quick to hand out to students. Arrange chairs and tables to best create group work space (for 3-4 students in a group.)

Introduction (5 minutes)

Today we are all going to be Civil Engineers! Civil engineers design, build, and maintain things that benefit us every day: Things like buildings, roads, bridges, and dams are all built by civil engineers. These structures can be made out of all sorts of different materials in the real world, but today, we are going to use one simple material: PAPER!

Simple Structures (25 minutes)

Divide students into groups of 3-4. Give each group one sheet of paper, a pair of scissors, and a 10 cm piece of tape. Groups have about 15 minutes to build a structure that can hold a book at least 5 cm above the surface of their desk. Students may not attach the paper to the desk.

After the 15 minutes is up, gather the class together to discuss the designs. Below are some possible questions to get the conversation started:

- What design did your group eventually end up with? Did your group try multiple designs before picking one?
- How difficult was this task? Did you initially think it would be easier or more difficult than it ended up being?
- Are all the designs the same? What shapes do you see in different people's structures? Do we see these shapes in real world structures?
- How did your team work together as a group? Did anyone have different ideas about how you should build your structure? How did you decide what to build?

If students have trouble getting started, ask them to think about the shapes they see in buildings. How do the walls of a room hold the roof up?

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Simple Structures (continued...)

Now it's time to really test our structures: They can hold up one book, but what about multiple books? How much weight can your structure take before it breaks? Let each group go back to their structures and add books one at a time until their structure fails. Then weigh the stack of books that each structure could hold. (Be sure to remove the top book that made it collapse before you weigh the stack!) As a class, compare the results. Some points to reflect on:

- Which designs were the strongest? Are there any similarities between these designs?
- If you were to do this activity again, what would you change about your design?
- If your design could not hold much weight, is that a bad thing? NO! It is just as valuable to us as a team of engineers to know what does not work as it is to know what does.
- How did different shapes compare? How did a square or triangle compare to a circle? (Circles and cylinders generally make for the strongest structures.

Be sure to step back and let the students carry the conversation once it has begun. It's not necessary to use all of the questions, they are simply a guideline to help spark discussion.

Congratulations! You have now gone through the process that real engineers go through to test their ideas on a small scale. Now it's time to move on to a bigger challenge.

Tower Time (45 minutes)

Now that we have an idea of what shapes and configurations can best support weight, we're going to design, build, and test a bigger tower! Each group now gets 20 sheets of paper (you can adjust the number based on your resources and the number of teams if you need to), scissors, and a whole role of tape. They can also use books to test as they build. The goal is to build the tallest, strongest tower that you can. Each tower must be at least 20 cm high. Encourage groups to take 5 minutes to plan before they start to build. Allow about 30 minutes of work time.

Encourage students to try new ideas, even if they don't think that they will work.

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Tower Time (continued...)

Once towers are finished, gather the students together again to discuss:

- Did you base any design decisions on the results from the previous test? What were they?
- I gave you two design requirements: height and strength. How did your group choose to balance those things? Sometimes engineers don't get enough information and they need to ask more questions. If this was a real building, what sort of questions would you need to ask?
- As you are testing the strength of your towers, sometimes you can just tell that the next book will be the one to break it. What are the things you noticed that told you when you were close to structural failure?

Using a Factor of Safety (5 minutes)

Let's imagine that we were building a larger version of this tower in the real world for people to live in. Through your testing, you know how much weight the tower can hold, but would you want to push it to the limit? That could be dangerous! Engineers limit the loads on their designs to make sure that they will stay safe. Just how safe? A "Factor of Safety" is a number that engineers use to show how close something is to its failure point. It is calculated by dividing the strength of a design (the maximum load it can bear) by the actual design (the load you will put on it.) For example, if you know through testing that your tower can hold 6 books, and you limit it to only 3 books, you used a Factor of Safety of 2 in your design (max load of 6 divided by applied load of 3.)

Think about some different things designed by engineers that you use. What would you want to have a higher Factor of Safety? What are some things that wouldn't need a high Factor of Safety? Create a list of items for the class to consider: A building, a chair, a bed, a bookshelf, an airplane wing, a toy, a coat hook or clothes hanger, a rope, etc.

What would be the disadvantage of having a Factor of Safety that is too high? (Could be very expensive, take too long to build, etc.)

Conclusion (10 minutes)

Your wrap up with the students should be a discussion about the design process that they went through to build their towers. Once again, ask some questions to start the conversation:

- What steps did you need to go through to design your tower? The process used for real life engineering projects may have a lot more detail, but it has the same essential parts. A diagram like the one on the right can help to illustrate these pieces of the process.
- Would you change anything about your approach to the challenge if you could do it over again?
- Do you think your tower design would have been different if we had not done the simple structures activity at the beginning? What difference (if any) did that make?
- What might be some similarities between our class today and working on a project in the real world?