GRADE SEVEN

UNIT PLAN

FORM AND FUNCTION

This unit covers the Understanding Structures and Mechanisms strand of the Grade 7 Ontario Science and Technology Curriculum, Form and Function.

This unit utilizes the Engineering Design Process, a universal approach to science and engineering problem solving. For more information and handouts on the Engineering Design Process, please see the Blackline Masters handouts.

LESSON SEQUENCE

1. **Classifying Structures**
2. **Forces**
3. **Understanding Gravity and Stability**
4. **Ergonomic Design**
5. **Failures and Today**

LESSON ONE
CLASSIFYING STRUCTURES

OVERALL AIMS OF LESSON

Students will gain a better understanding of the different types of structures

SPECIFIC CURRICULUM LINKS

Ontario Curriculum Grade 7 Science and Technology

Students will:

3.1 classify structures as solid structures, frame structures, or shell structures

3.describe ways in which the center of gravity of a structure affects the structure's stability

3.4 distinguishing between external forces (wind) and internal forces (tension) acting on a structure

LAUNCH

What is a structure?

Ask students to see what they think a structure is and keep notes on chart paper. Ask students to give ideas about types of structures they see every day, keep track of these.

What is function? Function is the main task or main purpose of a structure.

Ex. Steep slope of a roof allows heavy snow to slide off more easily

What is form? Form is the shape and appearance of the structure.

Why are these concepts important when it comes to structures?

Look at these pictures and decide what the function is of these different structure. (handout FF 7.3)

TALK TIME

From looking at the pictures, is there any way we can sort them based on how they look? Give students time to see if they can spot any similarities between the pictures. Ask students how they sorted them. Introduce students to the terms used to classify structures- frame, shell and solid

MATERIALS

chart paper
markers
handouts ready
pens, pencils
class set of "I'm a Mechanical Engineer" comic book
Glossary handout FF 7.1
Classifying Structures handout FF 7.2
Function handout FF 7.3

DEFINITIONS

Structure: Something which will support an object or a weight. It can also be described as anything that provides support and is made from more one or more parts. When classifying structures by design they can be divided into three groups: frame, solid and shell structures.

Frame: Frame structures are skeletal-looking structures. They use beams and columns as a network of connected parts to support loads.
Examples: snowshoes, bridge, bike, power lines, lacrosse net, lacrosse stick, balustrade

Advantages: strong and sturdy, cost less to build and widely used, easy to build and can be transported
Disadvantages: if damaged structure becomes unstable, one single part of the structure cannot support a load by itself, parts must work as a system

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Solid: Solid structures are sometimes called mass structures and are usually made from one solid piece of a strong material. Solid structures have little or no space inside and rely on their own mass to resist the forces that act upon them.

Examples: mound house, concrete dams, wooden telephone poles, maple tree,

Advantages: strong, lasts a long time, can withstand great forces
Disadvantages: expensive to build, materials heavy and difficult to move

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Shell: The outside layer of the structure holds the whole object together. Shell structures are made with thin material on the outside, but are hollow on the inside. They are hollow structures that provide high strength and rigidity.

Examples: helmet, box, eggs, can, drum, canoe, Igloo, rattle

Advantages: light weight, strong and rigid, can put things inside
Disadvantages: if it breaks then it will lose strength

CHALLENGE

Use the "I'm a Mechanical Engineer" book and have students fill out Classifying Structures (FF 7.2) chart from things they find while reading the comic book. Encourage students to read through the whole book before filling out the chart.

COMING TOGETHER

Bring the class back together and talk about the worksheet. Take up some of the answers students have found throughout the comic book. Talk about differing answers and listen to their ideas as to why they identified the structures as they did.

TO THINK ON

In the glossary handout FF 7.1, the definitions reference factors that are important in each structure. In a shell structure, why is it important to engineers to make sure they have the right balance of materials? Why do you think that a solid structure should be able to withstand erosion? What other factors might engineers think about when building structures?

EXTENSION

Can you think of anything that might have a combination of the different types of structures? This would be called a combination structure. Create a list and think of the advantages and disadvantages to this type of structure.

LESSON TWO
FORCES

OVERALL AIMS OF THE LESSON

Students will review what a force is and will take some time to better understand the different types of forces that act on structures, how it affect the form of a structure and why it is important to consider them when designing and building structures. Students will perform some activities that will help them identify forces.

SPECIFIC CURRICULUM LINKS

Ontario Curriculum Grade 7 Science and Technology

Students will:

3.4 distinguish between external forces and internal forces acting on a structure

3.6 identify and describe factors that can cause a structure to fail

LAUNCH

Review previous lesson on different types of structures. When we think about structures, is there anything else that needs to be considered when designing them?

Use questions to engage students in a discussion of forces:
What is force? Where do forces come from? What kind of forces effect structures? Are forces the result of natural occurrences or are they created by people?

TALK TIME

Forces are present in the world around us all the time. A force is a push or a pull. All forces have strength and direction. Some forces such as wind, rain, ice and snow are part of our natural environment while other forces are created by people. Forces can be both external and internal. External forces act upon structures from outside. Strong wind, heavy snow, ice and the weight of the structure itself are examples of naturally occurring external forces. Internal forces are from within a structure, the internal forces act between different parts of the same structure or object and may be affected by external forces acting upon the structure. Shear, torsion, tension and compression are internal forces. These internal forces, for example within a bridge, are affected by external forces such as high wind or ice which may cause the bridge to twist or buckle.

MATERIALS

rubber ball
different elastic bands
scrap paper
hand towel
20 bamboo skewers or twigs
1 m of string per group
1 m of masking tape per group
1 marshmallow per group
Fan to test structure
FF 7.4 Load
FF 7.5 Design Challenge

EXPLORING FORCES

These explorations may be done as a full class or in stations.

Compression and Tension

Students are given a squeeze ball and two different sized elastic bands.

Take the rubber ball and squish it, what do you feel?
Students should notice resistance they feel when squeezing the ball, and teacher can lead the students to relate this discussion to the concept of "COMPRESSION". Students should notice that the ball becomes smaller as the air is removed from the compressive force. Together as a class, write the definition for "compression".

*When forces push inwards in the same direction compression affects the structure; the object becomes smaller. Compression is a force that presses or squeezes the particles closer together; objects return to previous form when force is removed.
Next, use the rubber bands.
Take the different elastic bands and use your fingers to try and stretch them as far as possible.
What do you feel?

Students should notice the resistance they feel when trying to stretch the elastic band. The teacher leads the students to relate this discussion to the concept of "TENSION". Together as a class, write the definition for "tension".

*When forces pull in opposite directions, tension affects the structure. Tension is a force pulling the particles of an object apart. If object is pulled too far apart, the particles will break.
Students will be given 2 minutes to discuss in groups and answer the following question:
When thinking about structures, what examples can think of where tension and compression are occurring?

A teacher led discussion will occur, allowing all of the groups a chance to present their examples.

Torsion and Shear

Students are given hand towels and asked to twist them, as if wringing them out.
When twisting the towel, what do you feel?
Students discuss in their table groups what type of resistance they feel. The teacher leads the students to relate their discussion to the concept of "TORSION".
Together as a class, write the definition for "torsion".

*When opposite rotational forces are applied to an object, or when a rotational force is applied to one end of an anchored object, torsion occurs. Torsion is created by twisting or turning forces; one end can be twisted while the other remains still.
Students now take scrap paper, and slowly tear the ends by pulling in opposite directions.
When tearing the paper, what do you feel?

Students discuss in their table groups what type of resistance they feel. The teacher will lead the students to relate their discussion to the concept of "SHEAR".
Together as a class, write the definition for "shear".

*Shear forces are pushes or pulls which may cause a structure to tear. Forces act in an object as a result of pushes and/or pulls in opposite directions, usually causing bending, breaking or tearing.
In relation to structures, where would you see shear forces occurring?

Load

A load is a force acting on a structure. This force is created by gravity pulling on objects. Types of load includes:

Dead load- a static load caused by the weight of the structure itself
Live load- a static load caused by the weight of the objects it supports
Dynamic load- any load on a structure not caused by gravity (wind, rushing water).
Look through "I'm a Mechanical Engineer" and find five (5) examples of a structure, and list what external and internal forces act upon that structure when it is in

use. Be sure to write the page number, what the structure is, and what forces act upon the structure. Show teacher and hand in response sheet (FF 7.4 Load) before moving on to the building challenge.

CHALLENGE

Design Challenge: design a tower that will support a load at the top

In small groups, you will plan and construct a tower using skewers and marshmallows.
Your tower will be tested using different external forces and will be timed to see how long it can hold the load at the top without falling or breaking.
The forces it will be exposed to are created by WIND and EARTHQUAKE.

To test the structures after building, teacher will use a fan and a shaking table (small table such as a student desk, moved by volunteers)

COMING TOGETHER

After the design challenge, take some time and individually fill out the handout. Talk about the different types of forces that acted on your structures.

TO THINK ON

Besides internal and external forces, what else do you think that engineers have to think of when designing structures? Think back to the design challenge, is there anything else you would have liked to use that could have made your design stronger?

EXTENSION

Bridge Collapse and Failure Compilation video-
https://www.youtube.com/watch?v=ACRj2aFgb7Y
watch this video with students and talk about what happened, which forces impacted these bridges, and why they failed.

LESSON THREE UNDERSTANDING GRAVITY AND STABILITY

OVERALL AIMS OF LESSON

Students will learn about the ways in which the centre of gravity of a structure affects the stability of the structure.

SPECIFIC CURRICULUM LINKS

Ontario Curriculum Grade 7 Science and Technology

Students will:

3.2- describe ways in which the centre of gravity of a structure affects the structure's stability
3.3- identify the magnitude, direction, point of application, and plane of application of the forces applied to a structure

LAUNCH

Ask students some of the following questions to elicit prior knowledge:
What is gravity? Why is gravity important? How do you think that gravity helps us?
Thinking back to what we have learned in the previous lesson, how do you think gravity would affect the different types of structures?
What do you think stability means and why is this important?
How does gravity and stability affect the form and function of a building?
What is the centre of gravity?

WHOLE GROUP DEMONSTRATION ACTIVITIES

1. Ask students to sit in their chairs. In order to stand up, students must lean forward to shift the centre of gravity over their feet. Challenge students to stand up without using their hands or without leaning forward. This will not be possible because their centre of gravity is over the chair. In order to stand up, the centre of gravity will need to shift over their feet which will only happen when you learn forward.

2. Our ears and eyes help us balance. Canals in the ears are filled with fluid that detects any tilting of your head and feeds the information to the brain. Have students determine how our eyes contribute to balance by having them attempt to balance on one leg, first with their eyes closed, then with their eyes open.

MATERIALS

3 different sport balls (golf, basketball, baseball etc.)
ruler
pen, pencils
clay
paper for planning design
aluminum foil
container with water
marbles
tape
chairs
recording sheet/notebook
FF 7.6 Canoe Testing

3. Have students stand with the right side of their bodies touching the wall or specifically, their entire right arm and the side of their right foot. Ask them to lift their left legs and remain balanced. This will not be possible, because to balance on their right foot they would have to shift the centre of gravity over that foot. In order to do that they have to lean in that direction. Since they cannot lean through the wall, they will need their left foot on the ground in order to keep their balance.

4. Demonstrate the following with one student pair. One student will stand with heels and bottoms against the wall and legs straight. Their partner is to place a chair in front of them about one metre away. Challenge the student to bend over and try to pick up the chair while keeping their heels and bottoms on wall.

SAFETY NOTE: This activity will cause them to fall forward. Stay close enough to ensure the demonstrating student does not fall to the ground.

5. This last activity demonstrates center of gravity using a ruler. Support the ruler with both hands, resting the ends on just two fingers, one from each hand. Slowly slide your fingers together until they meet. Your fingers will meet under the ruler's center of gravity. Sit a weight or a piece of clay at some point on the ruler. Again support the stick on two fingers, and then slide your fingers together to locate the new center of gravity. Repeat the experiment.

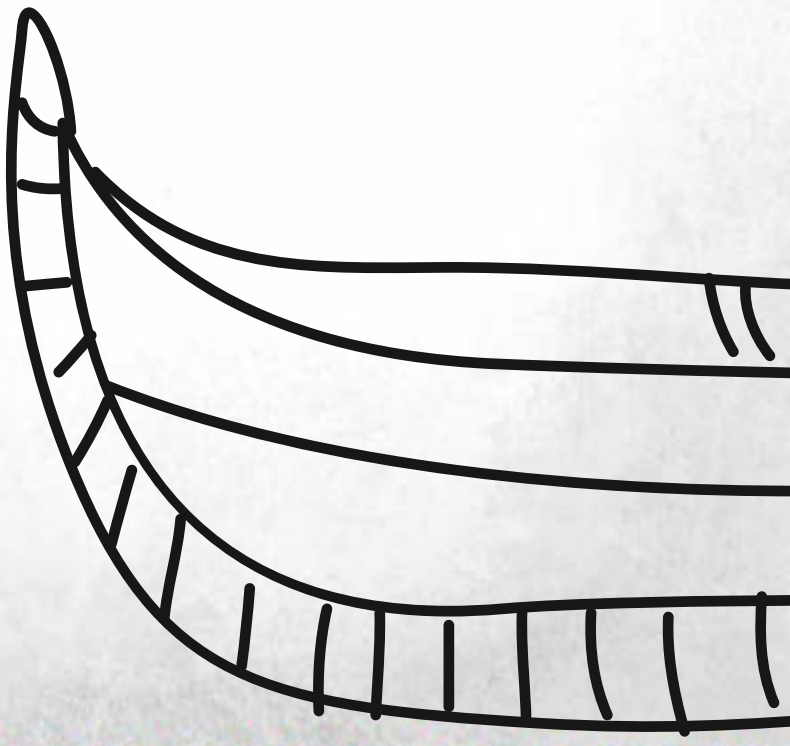
Students' fingers will always meet right under the centre of gravity. When they try to move their fingers closer together, the one that is carrying less weight will slide more easily. This finger will continue to slide more easily until it gets closer to the center of gravity than the other finger, at which point the situation will reverse and the other finger will begin to slide faster. Left and right fingers simply alternate moving until they meet at the center of gravity, where both fingers support equal weight.

The centre of gravity is the point around which a structure's mass is equally balanced in all directions. The centre of gravity helps determine the stability when designing and building structures and objects. When it comes to building structures and objects, it is important that forces are evenly spread out. This works the best when the structure or an object is symmetric. The best stability occurs when there is a wide support base and a low centre of gravity.

TALK TIME

Bring three volunteers up to the front of the class. Provide each volunteer with a different sized ball with various weights (eg. a golf ball, a basketball, a baseball). Tell the three volunteers to hold out the balls at the same level and height. Ask the class to predict which ball will hit the ground first. Why?

Have the volunteers release the sports balls at the same time. Discuss which ball fell to the ground first and why. Discuss that this is the basic principle of gravity. Ask students what they thought of the centre of gravity activities. Which one was the most difficult? Ensure the activities helped them better understand gravity and the importance of finding where the centre is.



DESIGN CHALLENGE

Challenge students to build a canoe which will sustain various loads. Explain that the canoe will be tested by adding a load to it at various points in the canoe. Students are asked to estimate how heavy the load will be before the canoe sinks. Students will use this activity to help them understand the importance of the center of balance and stability when it comes to structures.

Students will work in pairs or small groups to design and construct a simple canoe out of aluminum foil. Once this is done, students will test their canoe three different times. They will be asked to predict what is going to happen and estimate how heavy the load will be that the canoe will hold before it starts to sink. Students will record predictions in their notebook or on FF 7.6 Canoe Testing. Groups will test their design one at a time.

Test 1: Add the load to ONE end the canoe (the front or the back)-
record results
Test 2: Add the load to the CENTER of the canoe only – record results
Test 3: Add the load EVENLY throughout the canoe-record results

COMING TOGETHER

Talk about the findings of the canoe design as a whole group.
The point of application changed when we added the load to different spots of the canoe each time- what does this mean? The point of application is where the force connects with the structure.

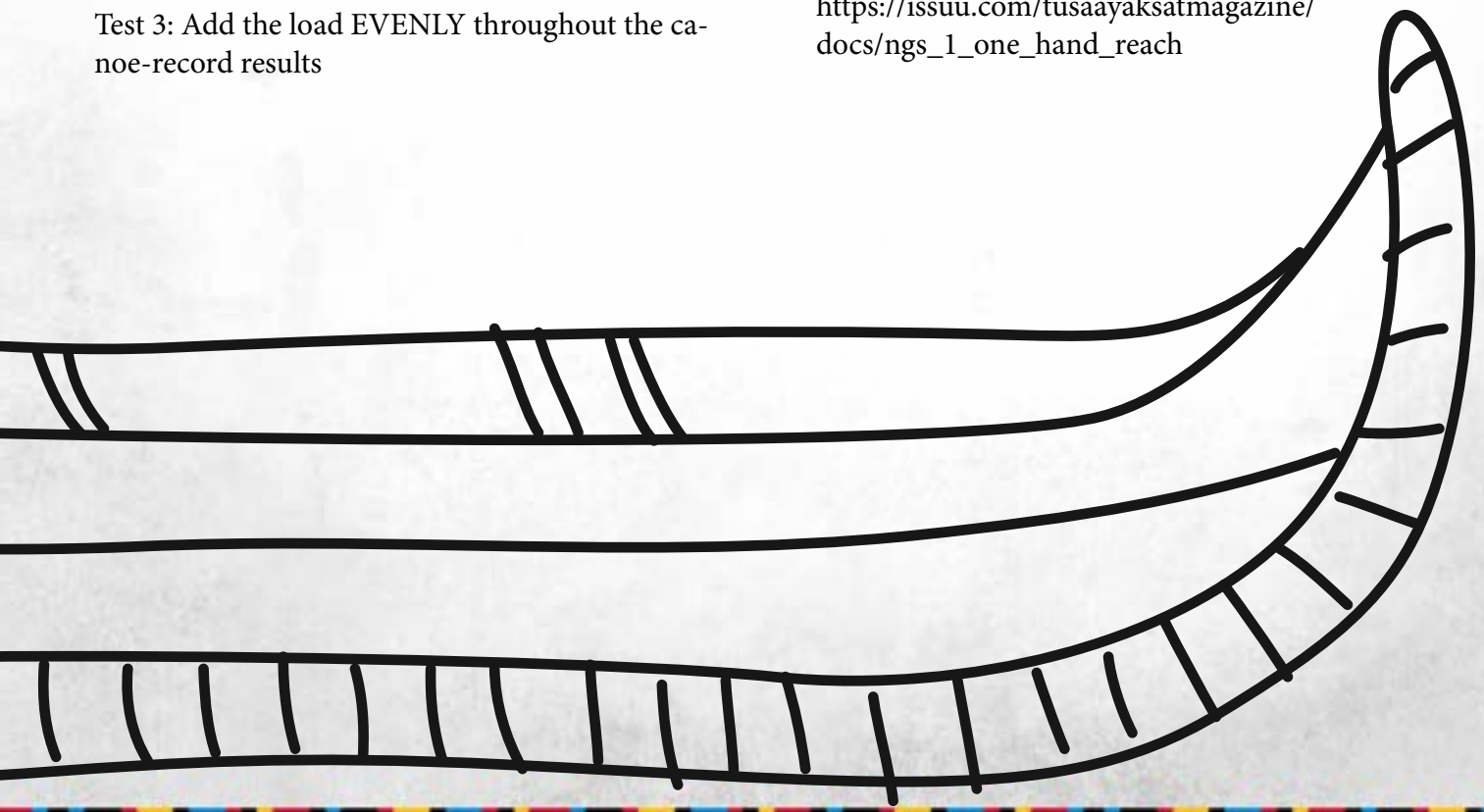
Was anyone surprised by their results? Was anyone correct in their predictions? Why do you think the results happened this way? What happened to the centre of gravity when you added a live load to the structure?

TO THINK ON

Why do you think this is important for engineers to consider centres of gravity when designing and building structures?

EXTENSION

Inuit and other circumpolar cultures have many different traditional games of strength that they play which requires people to have a good sense of where their center of gravity is.
https://issuu.com/tusaayaksatmagazine/docs/ngs_1_one_hand_reach



LESSON FOUR
ERGONOMIC DESIGN

OVERALL AIMS OF THE LESSON

Students will gain a better understanding about ergonomics through exploring and designing a safe and efficient structure.

SPECIFIC CURRICULUM LINKS

Ontario Curriculum Grade 7 Science and Technology

Students will:
1.2-evaulate the impact of ergonomic design on the safety and efficiency of workplaces, tools, and everyday objects.

LAUNCH

Ergonomics is the science of using human characteristics to design tools, structures, and systems that are comfortable, safe and efficient. Ergonomics also refers to the process of designing or arranging workplaces, products and systems to fit the people who use them. Ergonomics applies to the design of anything that involves people- workplaces, sports and leisure, transportation, health, etc.

Tools, workstations and systems should:
-allow people to change positions regularly and comfortably
-place equipment within easy reach
-reduce the force or efforts that a task requires,
-promote good posture for the body,
-help back, neck, and wrists remain straight,
-help arms remain close to body

TALK TIME

Show students pictures of different objects: some objects with a very general design and another picture of the same object that has a more ergonomic design. Let students decide which one is the more ergonomic between the two. Some images you could use include those of sports equipment, office chairs, desks, scissors, shovels, keyboards, backpacks, vehicles.

Once the students have decided which of the two pictures has a more ergonomic design, talk about why. Ask students why they chose that picture, have them explain their thinking.

MATERIALS

pictures of different items
paper
pencil, pens
computers, if researching

CHALLENGE

Students will use the "I'm a Mechanical Engineer" book, re-reading the pages on prosthetics and sports equipment. The challenge is to redesign an item, either a prosthetic or a piece of sporting equipment, while thinking ergonomically. This can be done individually or in pairs. Students may choose the same item as another student or group, as they might have different ideas about how to incorporate ergonomic design.

Students may research ahead to generate ideas. Students sketch their new design out and explain to the class the ergonomics behind their design. It is important for students to remember that this design must be able to be used by many different types of people - the new design for the item needs to be inclusive and safe.

COMING TOGETHER

Students will come together and present their sketch of the new ergonomic design to the class. Students are encouraged to ask questions and give feedback.

TO THINK ON

Why is ergonomics important? Can you think of any other examples that you use or you have seen that has an ergonomic design? Think about our classroom and universal design- is there any way or anything that we can change in our classroom to better our learning?

EXTENSION

Students can make a three-dimensional model of their sketch design. Provide materials to students.

LESSON
FAILURES AND TODAY

OVERALL AIMS OF THE LESSON

Students look at structures that have failed and investigate why they failed. Students research how engineers ensure safety using todays' resources.

SPECIFIC CURRICULUM LINKS

Ontario Curriculum Grade 7 Science and Technology

Students will:

2.5 investigate methods used by engineers to ensure structural safety
3.3 identify the magnitude, direction, point of application, and plane of application of the forces applied to a structure
3.4 distinguish between external forces and internal forces acting on a structure
3.5 describe the role of symmetry in structures
3.6 identify and describe factors that can cause a structure to fail

LAUNCH

Talk as a class about what can cause a structure to fail. Keeps notes of student ideas, encouraging them to think about to previous lessons.

https://www.youtube.com/watch?v=mb3DExis8xo– watch this video. After the video, add to notes.

TALK TIME

Many factors can cause a structure to fail. Structural failure is the result of the structure, or part of the structure, losing the ability to support the load. When this happens, structures will gain cracks, deform, break or collapse completely.

Bad design 40-60 % of all failures are from bad design. Incorrect materials, miscalculating the load, not accounting for forces and stresses all play a part in this.

Faulty Construction Using poor materials or poor installation can cause a structure to fail.

MATERIALS

paper
pencil
laptop

Loads and Forces Extreme weather or natural conditions can lead to failure. Engineers need to take into account the effects of Mother Nature on structures. What are some natural examples that engineers would need to think about? (earthquakes, tornados, hurricanes, floods, snow, etc.).

CHALLENGE

Work with a partner and research a structural failure. Some examples are: Leaning Tower of Pisa, Pier 34 Philadelphia, Quebec Bridge, Vdara Hotel and Spa in Vegas, Tacoma Narrows Bridge etc. These examples have different causes- challenge students to look at these structures for the different ways they failed, and not just building collapses.

Each group is to research a structural failure. Name the structure, state what the failure is, why this happened or what causes it, and how materials today could have helped these designs and/or structures.

Here are some links that can help when students need to research contemporary materials:
https://graduatedegrees.online.njit.edu/resources/msce/msce-infographics/high-tech-bridges-of-the-future/ -future of bridges

http://www.locksearchgroup.com/the-bright-future-for-building-and-construction-materials-in-canada/ - "The Future of Building and Construction in Canada" section

https://www.canada.ca/en/services/science/sciencesubjects/materialsmanufacturingconstructionscience.html - Government of Canada

https://www.roadsbridges.com/innovations-technology-0 - Innovations in Technology

http://www.dg.ca/blog/5-new-technologies-used-in-the-construction-industry-in-2017 - Technologies used in the Construction Industry

COMING TOGETHER

Students will share what they have learned about their structure and how they would look to improve the structure using contemporary technology and materials. Students will be encouraged to ask questions, add ideas if they thought of something different and be respectful of classmates.