Science and Technology
Understanding Structures and Mechanisms

Grade 7 – Form and Function

TEACHER'S RESOURCE GUIDE

CN Tower Education Program - Grade 7 – Form and Function

Uncover the mysteries of the CN Tower while students learn about the importance of form, function, strength, and stability to a structure's design. Students will embark on a fact-finding mission to uncover the various factors that had an impact on the design and construction of the CN Tower. Students will have an opportunity to explore the CN Tower themselves as they survey the city from above and search in groups for the answers to various curriculum-linked questions.

Bookings include:

- An educator's guide with pre and post-visit activities to tie your class outing back to learning in the classroom
- Self-guided tour of the CN Tower including the observation levels
- Curriculum-linked worksheets
- Lunch options available

The Grade 7 - Structures program explores the three Big Ideas outlined in the Ontario Curriculum as they relate to CN Tower:

Big Ideas	CN Tower Program Content
Structures have a purpose	The primary purpose for the construction of the CN Tower was to transmit radio signals above all the other tall buildings being built in the city of Toronto. The architects wanted to build something that would be able to showcase the great advances in Science and Technology being developed in Toronto, while at the same time providing locals and tourists with spectacular views of the city. This became the secondary purpose of the CN Tower, to provide observation levels for viewing the city below.
The form of a structure is dependent on its function	The CN Tower was to be a communications Tower, transmitting signals over the tall buildings in Toronto, therefore it had to be tall. In order to provide visitors with viewing opportunities, large observation areas were also required.
The interaction between structures and forces is predictable	The CN Tower was to be taller than any other in the world and was to hold the weight of visitors as well as a variety of equipment. Wind, rain, lightning, and weight were among the various forces that would need to be considered in the design and construction of the CN Tower.

Pre-Visit Preparation

The Grade 7 Structures program at the CN Tower has been designed to assist students in their understanding of the relationship between a structures form and its function. This program will also provide students with an understanding of the various trades people involved in all stages of the construction of such a structure and the importance of teamwork to ensure the successful completion of such an enormous project.

Prior to your arrival, please have your students form teams of 5. Once on-site each team will receive a package containing a set of 5 worksheets, each worksheet specific to a trade; architect, builder, engineer, industrial designer, scientist. In preparing the class for their visit, we recommend that you ensure students are familiar with the roles and responsibilities of each position using the definitions below.

You may choose to assign a team leader to each group (or have the group select one person as team leader). The team leader can be responsible for distributing the assigned tasks (worksheets) on-site, for keeping track of time, keeping the group together, etc.

While completing the onsite assignments, students can consult with members of their team and / or consult with members from other teams with the same job title.

Career	Definition
Architect	An **architect** is trained and licensed in the planning and designing of buildings, and participates in supervising the construction of a building. Architecture is a business in which technical knowledge, management, and an understanding of business are as important as design.
Builder	A **builder** is a person in the business of constructing buildings. Can be a general contractor, construction worker, or carpenter.
Engineer	An **engineer** is a person skilled or occupied in a. the science concerned with putting scientific knowledge to practical uses, divided into different branches, as civil, electrical, mechanical, and chemical engineering b. the planning, designing, construction, or management of machinery, roads, bridges, buildings, etc. **Engineers** work to develop economic and safe solutions to practical problems, by applying mathematics, scientific knowledge and ingenuity while considering technical constraints. The work of engineers is the link between perceived needs of society and commercial applications.
Industrial Designer	**Industrial designers** are basically conceptual engineers. They study both function and form, and the connection between product and the user. They do not design the gears or motors that make machines move, or the circuits that control the movement, but they can affect technical aspects through usability design and form relationships. They usually partner with engineers and marketers to identify and fulfill needs, wants and expectations.
Scientist	A **scientist**, in the broadest sense, is any person who engages in a systematic activity to acquire knowledge or an individual that engages in such practices and traditions that are linked to schools of thought or philosophy. In a more restricted sense, a scientist is an individual who uses the scientific method. The person may be an expert in one or more areas of science.

Vocabulary

The vocabulary below will assist the students in their study of structures. It is recommended that this list be reviewed prior to your field trip to the CN Tower to assist the students in their understanding of the presentation and completion of the worksheets.

Word	Definition
Aesthetic Appeal	Having to do with beauty; pertaining to beautiful appearances. Relating to the enjoyment or study of beauty.
Centre of Gravity	The point around which a body's mass is equally balanced in all directions. The total mass of the object is concentrated at this point.
Ergonomics	The science of designing equipment that people can use more efficiently and safely.
Load	The mass or weight of an object that is moved by a machine, or the resistance to movement that a machine has to overcome.
Stability	The ability of a mechanism to maintain equilibrium or a structure to resume its original, upright position after displacement by a force.
Strength	The capacity to withstand forces, such as tension, compression, torsion, and shear, that tend to break an object or change its shape; an objects ability to hold its shape without collapsing.
Structure	Something make up of parts that are put together in a particular way for a particular purpose or purposes.
Symmetry	Correspondence in size, shape, and relative position of parts on opposite sides of a dividing line or median plane or about a center or axis.
Tension	A force that acts to expand or lengthen the thing that it is acting on. Tension involves stretching or straining.
Torsion	A force that acts on an object to twist its axis.
Truss	A rigid framework, usually of wood or metal, designed to support a structure. A truss may derive its strength from the rigidity of the triangle and be composed of straight that are subject only to longitudinal compression, tension, or both, or it may derive its strength from other factors such as the rigidity of the joints, the abutment of masonry, or the stiffness of beams.

Now that your students have been assigned to a team and are armed with the knowledge required to complete their assignments at the CN Tower, you are ready for your field trip!

Arrival Instructions

Groups are to access the CN Tower via Bremner Blvd, one block south of Front St West, between York St and Spadina Ave. Bus drop off and pick up is located on the north side, westbound lanes on Bremner Blvd. From the curb it is a short walk to the main entrance.

All guests must pass through our security screening, which includes the use of metal detectors and a bag check.

Upon arrival at the CN Tower, your group will be asked to wait outside while the teacher or group leader checks in at the Group Desk (open seasonally – please check in at Guest Services Desk if Group Desk is unavailable).

When you check in you will need to provide:

- Actual number of students and chaperones
- Final payment for your group (unless prepayment has been arranged in advance)

You will be given ONE ticket for each person in your group, which are to be distributed prior to elevation.

Your group will be directed to the elevators that will take them to the observation levels.

What to Bring

Please ensure that students bring a pen or pencil to write with and something to write on (ie: a clipboard or binder). There is an on-site gift shop for those who forget to bring a writing utensil with them.

On-Site Facilities

The CN Tower does not offer lockers or storage for students while on-site. Students are asked to bring only what is needed as they will have to keep their belongings with them at all times.

Dining - The CN Tower offers a variety of dining options including Le Café at the base of the CN Tower. Student group meal and snack packages can be ordered in advance, or students can order and pay on-site.

Completing the Assignments

Each student will have a set of worksheets that make up the Assignment to be completed while on-site at the CN Tower. Answers to the assignment questions can be found in written information about the CN Tower and other structures on the walls throughout the CN Tower (starting on the mezzanine level before the students board the elevators), and in the views of the city from the Observation Levels.

The entire visit, from arrival to departure, should take approximately 1.5 – 2 hours. Add another 45 minutes if you plan on having lunch at the CN Tower as well.

Facts at a glance

Construction
- Started on February 6, 1973
- Antenna finished on April 2, 1975
- Opened on June 26, 1976
- 1537 workers helped build

Materials
- Total weight = 117,910 metric tonnes or 130,000 tons
- Volume of concrete = 40,524 m³ or 53,000 cubic yds
- 998 km or 620 miles of post-tensioned steel cables
- 4,535 metric tonnes or 5,000 tons of reinforcing steel
- 544.2 metric tonnes or 600 tons of structural steel
- Radome: Teflon-coated fibreglass membrane

Tower by the numbers
- 1976-2010: World's Tallest Tower, Building and Free-standing structure
- Over 1.9 million annual visitors
- 1776 stairs
- 8 public elevators
- 8 cables per elevator car
- 58 seconds to reach the observation level
- 22km/h - top speed of the elevator
- 360 Restaurant revolves every 72 min
- 75 lightning strikes per year

DID YOU KNOW

The CN Tower currently holds two Guinness World Records!

Answer Key – Note, questions vary in each project role. Several are duplicated.

The form of a structure is dependent on its function. Explain why is it important to consider the function of an object before developing the design?
In considering the function of an object first, you can better assess the most appropriate materials to use in its construction. This may apply limitations to the design. Also, aspects of the function may limit elements of the form. In the case of the CN Tower, a tall, tapered design allowed the Tower to have a low centre of gravity, which affords it greater stability.

Why did the CN Tower need to be the tallest unobstructed building in Toronto?
With many tall buildings being built, radio and tv broadcast, which was reliant on unobstructed transmission, Toronto was starting to have trouble with broadcast signal strength. A tall building would provide the ideal antenna for these broadcasts.

How would you test the structural stability of the CN Tower against the forces of wind?
A wind tunnel would be the ideal way of testing a scale model of the CN Tower. Being able to control variables such as material in construction, temperature, humidity and wind speed would provide the necessary results to assess how stable the design was.

The Radome is made of a Teflon-coated fiberglass membrane. What is housed in the Radome? Why was this material used?
The Radome houses various transmitters for radio and television broadcast. Teflon-coated fibreglass membrane was chosen so the Radome could be inflated, eliminating the effects of wind on these transmitters. The Radome also protects this equipment from snow and ice build-up during the winter.

The curve of the CN Tower's legs and the height of its antenna posed a challenge for the original builders. How would you construct them?
This will be subjective, but the CN Tower builders used a "slip-form", which rose slowly up using hydraulic jacks. As form rose, the outside edges also slopped inward, forming the taper.

Why was it important to test the forces of nature on the CN Tower before it was built? (wind, lightning, gravity, temperature) How would you do this?
Testing the design under various conditions, be it in computer models, conducting materials tests or with physical scale models, each would provide data for engineers to determine if elements of the design were helpful or dangerous for the final design. Wind tunnels were very helpful. Some materials don't scale well but understanding how many lightning strikes occur around Toronto would help determine how many times the CN Tower might be struck and what might be needed to mitigate these strikes.

What natural forces would have been considered before building the CN Tower?
As above, forces of wind, temperature, gravity, moisture (weather) are all important considerations. Geology of the land beneath the Tower, as well as hydrology or how water flows around and beneath it were important considerations.

How would you test the impact of these forces on the CN Tower design?
Testing materials at various scales, under various conditions would provide data useful to scientists and engineers. Scale models can help determine how the shape would be impacted under certain conditions, but some materials do not scale well, so this must be understood as a limitation.

If you were to design and build a structure that resembled the CN Tower using household objects, what would you use to make your accurate representation? Describe what objects you would use and explain why you would choose those materials.
A subjective question, but understanding how different materials could support different weights, depending on their shape, would be a great start.

Use the space below to begin designing your structure. Consider what you have learned about form and function, as well as where it might be located.
Answers may vary

The CN Tower is symmetrical; when standing outside looking at the Tower, regardless of where you are standing, all sides look the same (the size, form and arrangement of the CN Towers parts on one side correspond to those on another side). Explain why symmetry is important to the design and construction of the CN Tower. Tell this from the perspective of your role in the project group. Feel free to draw.
Answers may vary

Consider your groups new structure. What would be the ideal location based on its purpose? Indicate that location on the map and describe how it would impact the area around it.
Answers may vary

Post Visit Activities

1. **Design and Build** In this activity, students will use technological problem-solving skills to design and construct a physical model of a structure of their choosing using recycled materials. Reassemble the teams that were put together for the field trip to the CN Tower. Working as a group, ask the students do the following:
    i. Develop the blueprint for a structure of their choosing (i.e.: tower, bridge, vehicle, etc) to be built using recycled materials. The sketch should include measurements that will be used in building a model to scale.
    ii. Once the blueprint has been designed, ask the students to bring the recyclable materials from home so that they can build a model of their structure. The model should be capable of holding a predetermined load (block, ball, doll, action figure).
    iii. Once built, use a fan to test the strength and stability of the structure.
    iv. Have the students prepare a report (verbal and/or written) outlining:
        a. The purpose of their structure
        b. The impact of the purpose on the design
        c. The process behind designing and building the structure
        d. Identify the external forces that may act on the structure
        e. Identify the internal forces that may affect the structure
        f. Which design features were used in order to ensure the structure is strong
        g. The centre of gravity – where it's located and how it affects stability
        h. The environmental impact of the structure
        i. List the tools required to build the structure and the safety precautions that had to be taken into consideration
        j. Why they chose that type of structure in particular

2. **Mind Mapping Exercise** Using a graphic organizer, ask the students to map their experience and / or learnings from their field trip. Sample topics include CN Tower, Famous Structures, Structures and the Environment, Building a Structure, etc. This exercise can be done on it's own or can be used to complement any of the other activities listed here (to be used by the students in formulating their thoughts and structuring their activity). Attached is a sample cluster / word web organiser to use as a template.

3. **Research Project** Have each student select 3 different towers or 3 different Wonders of the World and prepare a written report on the similarities and differences between them, their size and location, when they were built, their purpose, materials used to build them, their key design features, how they are reinforced to protect against the elements, the impact on the environment.

4. **Design Competition** Have a competition in your class to see who can build the tallest structure. Working individually or with a partner, provide each student / pair with 60 straws, 60 paper clips, tape, and scissors. Give the students 1 hour to complete the task of building the tallest structure using the materials provided. At the end of the hour measure each structure to determine which is the tallest. To add to the difficulty, tell the students that their structure must also be able to hold the weight of a walnut-sized piece of clay.

5. **Research Project** Ask students to write a report describing the roles and responsibilities of an architect, builder, engineer, industrial designer, and scientist in the design and construction of a structure. What were some of the challenges encountered in the construction of the CN Tower? What impact does the CN Tower have on locals, tourists, and the economy? If you were to build a structure, where would you build it and why? What steps would need to be made prior to beginning construction?

Online Resources and Books

http://www.great-towers.com
World Federation of Great Towers – provides information on towers around the world

http://www.pbs.org/wgbh/buildingbig/index.html
A great website with a variety of teaching tools and fun learning activities including

- Interactive labs that allow students to experiment with forces, materials, loads, and shapes
- Online challenges that gives students an opportunity to fix and build a bridge, dome, skyscraper, dam, tunnel
- A Wonder of the Worlds databank
- Interviews with engineers
- An educators guide with planning ideas and hands on activities (try the Newspaper Tower)

http://www.youtube.com/watch?v=JBpUZH5bZ_E
"Measure the height of any object" - A YouTube video on how to make your own height measuring gadget using everyday materials.

http://www.greatbuildings.com/
A great resource listing different types of structures, images and history of famous buildings, bridges and other structures.

http://www.pbslearningmedia.org/resource/arct14.sci.dsrise/high-rise/
Fun activity has students building a tower that can support a tennis ball at least 18 inches off the ground while withstanding the wind from a fan.

http://school.discoveryeducation.com/lessonplans/programs/stableandunstable/
Stable and unstable structures - a fun lesson plan for the classroom in which students determine what factors need to be considered in building a stable structure and review various bridge building materials. This page also has a list of helpful links.

http://www.wonderclub.com/AllWorldWonders.html
Complete listing of world wonders (including ancient, medieval, natural, modern, and underwater)

https://skyscraperpage.com/
Online collection of the tallest structures on the planet!

http://online.onetcenter.org/
Online tool for career exploration and job analysis!

The Random House Book of How Things Were Built
Brown, David J. New York: Random House, 1992.
Detailed, cutaway illustrations tell the stories of great structures throughout history and across the globe. Diagrams explain the basic principles behind these engineering feats.

Build It!: Activities for Setting Up Super Structures.
Keith Good. Lerner Publications, 1999.
The simple, illustrated projects in this book will provide an understanding of how different structural elements, designs, and materials affect the stability, strength, and balance of a variety of structures when they are subjected to varying forces and loads.

Building Big
David Macaulay. Houghton Mifflin, 2000.
The celebrated author/illustrator of this book examines the construction of some of the most famous examples of the structures we see or use every day - bridges, tunnels, skyscrapers, dams, and domes. He looks at the problems the builders of each structures faced and how those problems were overcome by ingenious design, use of materials, and construction methods.