

Model Water Tower Competition
Lesson Plan

Grades 9 – 12

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Dear Florida teacher, educator and/or parent,

Whether this is your first or your tenth time participating in the Florida Section of the American Water Works Association's (FSAWWA) Model Water Tower Competition, we hope you find this lesson plan helpful! It was written by a fellow teacher with you in mind! The goal of this lesson plan was to help teachers and educators introduce this exciting competition into their classrooms with ease, confidence, and of course—fun! Not only is the lesson plan correlated with the Next Generation Sunshine State Standards for Science Education, it also introduces students to the water engineering profession!

This lesson plan is designed for a school or group setting (i.e. homeschool group or afterschool STEM/STEAM program) and challenges students working in teams to build a functioning water tower. Water towers are an important part of the US' infrastructure as they help store and deliver safe drinking (also called potable) water to our homes, schools, businesses and industries. In this lesson plan, students will learn how water towers function by building their own. Students are encouraged to decorate their water towers and create an "iconic" structure much like some of the notable ones across the state from the giant strawberry in Plant City to the giant beach ball in Jacksonville.

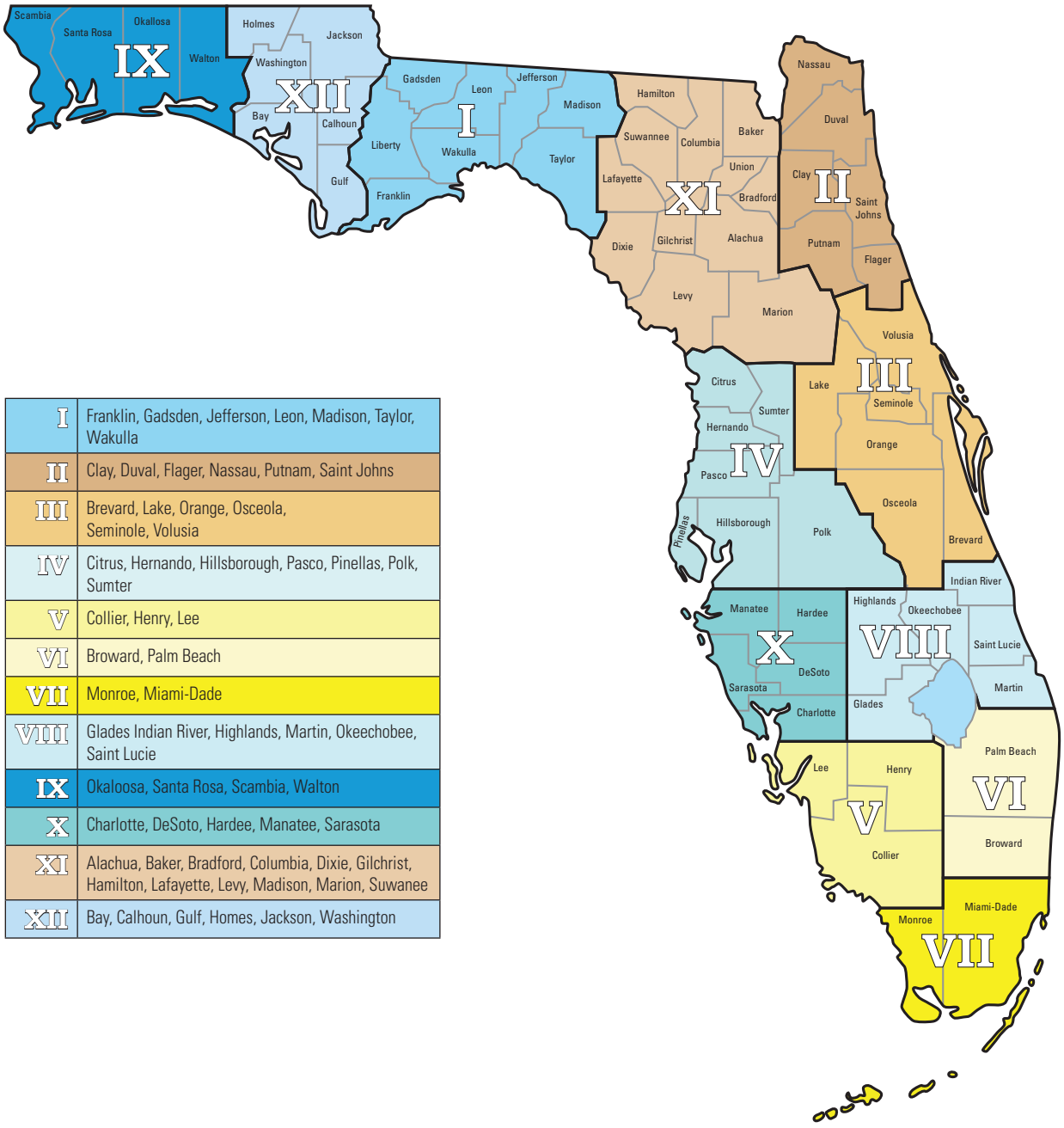
Did you know that many of the FSAWWA's twelve regions (see map below) host Model Water Tower Competitions? To find out if your region hosts a competition and how to get registered, please visit https://www.fsawwa.org/page/MWTC. In this lesson plan, we included the requirements (design standards and penalties) used in the regional competitions in the Assessment section of this lesson plan (please check with your region to ensure they do not have additional requirements).

If participating in a regional competition, towers must include a $^{3}/_{8}$" diameter push-on connector that is provided by the FSAWWA at the time of registration. Similar connectors may be purchased at local hardware stores for this lesson plan but if students intend to compete in their region, they must use the connector provided to them by the FSAWWA or they may be disqualified. For more information, please contact your FSAWWA region.

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FSAWWA Regions



I	Franklin, Gadsden, Jefferson, Leon, Madison, Taylor, Wakulla
II	Clay, Duval, Flager, Nassau, Putnam, Saint Johns
III	Brevard, Lake, Orange, Osceola, Seminole, Volusia
IV	Citrus, Hernando, Hillsborough, Pasco, Pinellas, Polk, Sumter
V	Collier, Henry, Lee
VI	Broward, Palm Beach
VII	Monroe, Miami-Dade
VIII	Glades Indian River, Highlands, Martin, Okeechobee, Saint Lucie
IX	Okaloosa, Santa Rosa, Scambia, Walton
X	Charlotte, DeSoto, Hardee, Manatee, Sarasota
XI	Alachua, Baker, Bradford, Columbia, Dixie, Gilchrist, Hamilton, Lafayette, Levy, Madison, Marion, Suwanee
XII	Bay, Calhoun, Gulf, Homes, Jackson, Washington

The mission of the FSAWWA is "Uniting the water community and providing solutions to effectively manage WATER, the world's most important resource." To learn more about the FSAWWA, please visit: https://www.fsawwa.org/

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Next Generation Sunshine State Standards (NGSSS)

Model Water Tower Competition

Big Idea: The "Model Water Tower" lesson explores how engineers work to solve the challenges of a society, such as delivering safe drinking water. Students work in teams to devise a system using every day materials that can deliver pressurized water in a controlled manner to a paper cup that is about 36 inches or 90 cm away. They sketch their plans, build their system, test it, reflect on the challenge, and present to their class.

Science Education Standards Grade 9 – 12 (age 14 – 18)

SC.912.N.1.3: Recognize that the strength or usefulness of a scientific claim is evaluated through scientific argumentation, which depends on critical and logical thinking, and the active consideration of alternative scientific explanations to explain the data presented.

SC.912.P.12.2: Analyze the motion of an object in terms of its position, velocity, and acceleration (with respect to a frame of reference) as functions of time.

SC.912.P.10.1: Differentiate among the various forms of energy and recognize that they can be transformed from one form to others.

SC.912.N.1.2: Describe and explain what characterizes science and its methods.

Technology Literacy Standards Grades 9 – 12 (ages 14 – 18): Course 8401100 Applied Engineering Technology

1.0 Demonstrate an understanding of the characteristics, scope and core concepts of technology.

2.0 Demonstrate an understanding of the attributes of design and the engineering design process.

17.0 Demonstrate the abilities to apply the design process.

22.0 Demonstrate fundamental math and science knowledge and skills for mechanical, fluid, thermal, and/or electrical/electronic systems.

24.0 Demonstrate an understanding of the cultural, social, economic, and political effects of technology.

25.0 Demonstrate an understanding of the effects of technology on the environment.

26.0 Demonstrate the abilities to assess the impact of products and systems.

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Lesson Focus

This lesson focuses on how engineering helps communities store and distribute water to its populations. Students work in teams to design and build a water tower out of everyday materials that can "supply" and "shut off" water as needed. The system will need to deliver water in a pressurized, controlled manner to a paper cup that is about 36 inches or 90 cm away. They design their tower, build and test their system, evaluate their results, and share observations with their class.

Vocabulary

- ***Engineers:*** Inventors and problem-solvers of the world. Twenty-five major specialties are recognized in engineering (Figure 1).
- ***Engineering Habits of Mind (EHM):*** Six unique ways that engineers think (Figure 2).
- ***Engineering Design Process (EDP):*** Process engineers use to solve problems (Figure 3).
- ***Criteria:*** Conditions that the design must satisfy like its overall size, etc.
- ***Constraints:*** Limitations with material, time, size of team, etc.
- ***Prototype:*** A working model of the solution to be tested.
- ***Iteration:*** Test & redesign is one iteration. Repeat (multiple iterations).
- ***Weight:*** The force exerted on the object by gravity. (Units: lbs/Newtons).
- ***Percentage:*** Part of a whole expressed in hundreds (½ = 50%).
- ***Hydrostatic Pressure:*** The pressure exerted by a fluid at equilibrium due to the force of gravity (Figure 5).
- ***Water Distribution System:*** A part of water supply network with components that carry potable water from a centralized treatment plant or wells to water consumers to adequately deliver water to satisfy residential, commercial, industrial and firefighting requirements
- ***Pump Station:*** Facilities including pumps and equipment for pumping fluids from one place to another; also called a pumphouse in situations such as drilled wells and drinking water.

Materials Needed

(for the Demonstration and 5 – 7 groups of 3 – 4 for the Investigation)

- Teacher Presentation Resource (PowerPoint)
- Student Worksheets
- Classroom Materials (water source, bucket or sink area)
- Student Team Materials: paper cups, straws, paper towels, rubber bands, paper clips, tape, balloons, soda bottle, glue, string, foil, plastic wrap, pens, pencils, paper, hose or tubes, siphon materials, paper towels, the ⅜" hose connector, and other items available in the classroom or from student's homes.

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Time Needed

Three to five, 45-minute sessions

KNOW	UNDERSTAND	DO
• Learn about engineering design and redesign. • Learn about water delivery systems. • Learn how engineering can help solve society's challenges. • Learn about teamwork and problem solving.	• Engineering design • Water systems • Teamwork • The function of a water tower. • How a water tower works.	• ***Develop*** a water tower out of everyday materials than can deliver water in a controlled manner. • ***Evaluate*** results, and the results of other teams. • ***Identify*** how engineers have solved societal problems such as water delivery and storage. • ***Present*** reflections with the class.

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Engineers are the inventors and problem solvers of the world. More than twenty–five major specialties are recognized in the field of engineering.

How will *you* change the world?

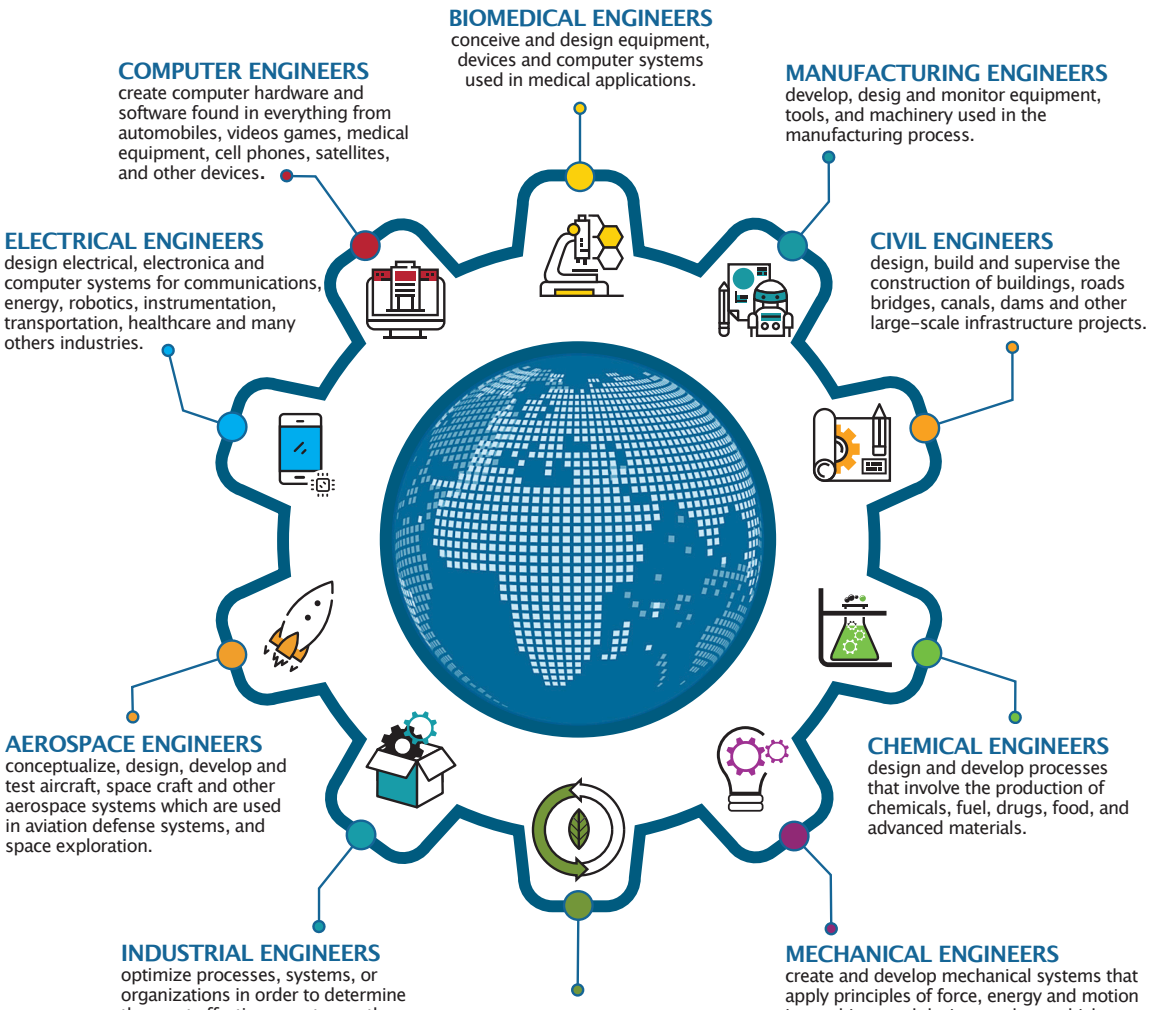


Figure 1: Change the World

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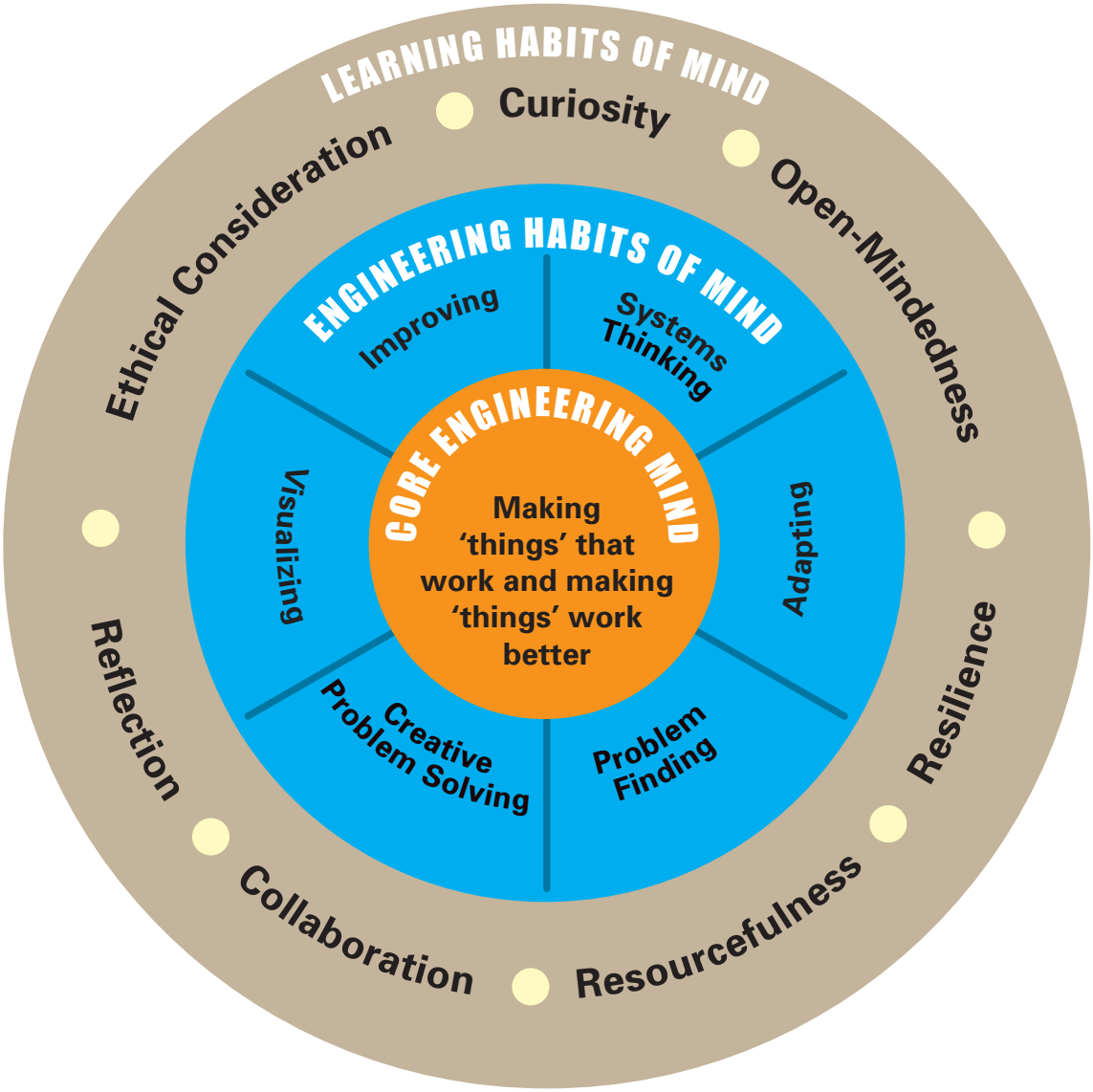


Figure 2: Engineering habits of mind

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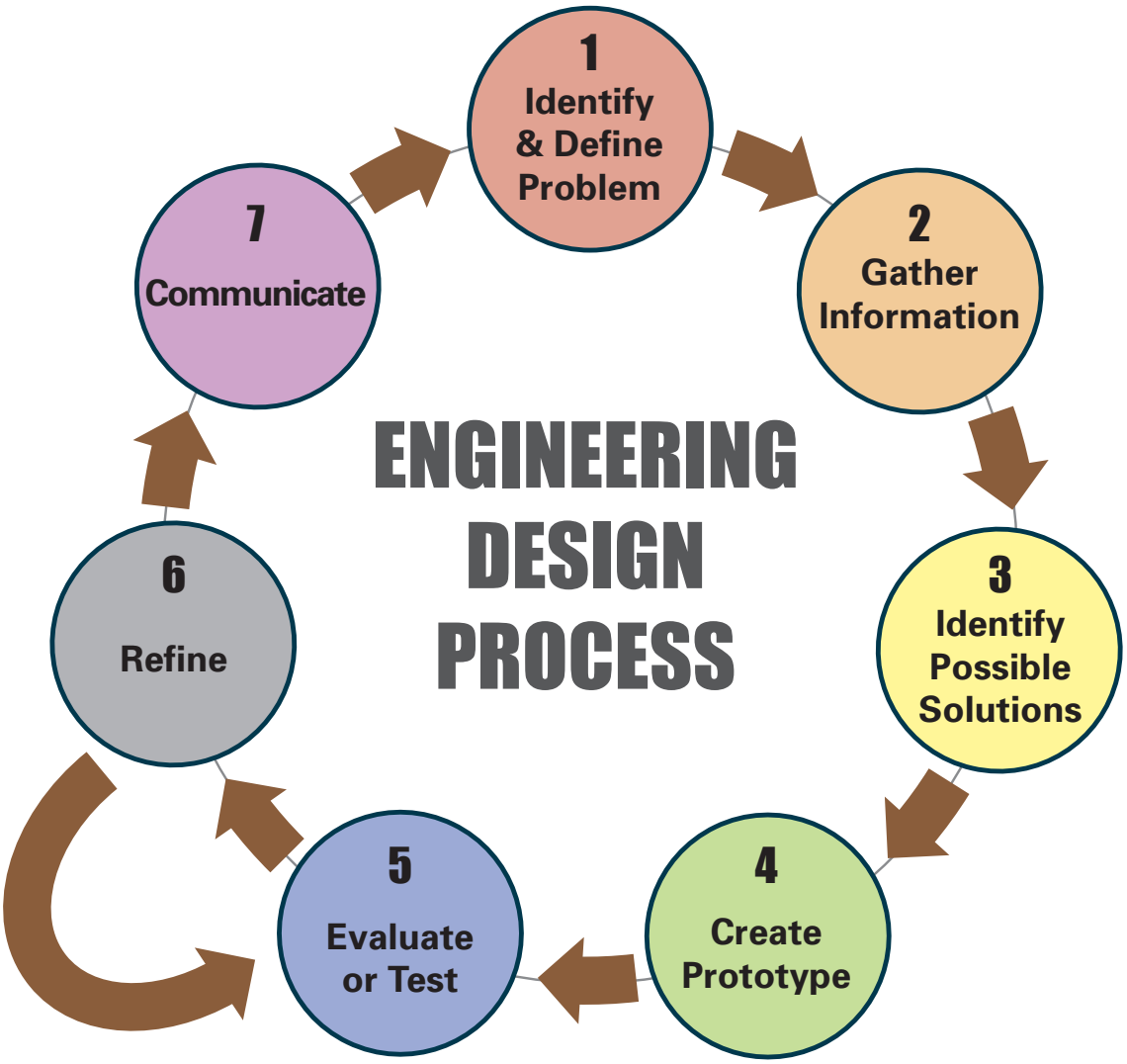


Figure 3: Engineering Design Process

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ENGAGE

Water Towers and Hydrostatic Pressure

What is a Water Tower?

A water tower is a large elevated drinking water storage container that is engineered to safely hold a water supply at a height sufficient to pressurize a water distribution system. It needs to be big enough to supply residents of a community, or a building, with water, and also maintain the quality of the water that is stored and delivered. There are many designs for water towers all over the world. Some have become landmarks and are decorated whimsically. In certain areas, such as large cities, smaller water towers are constructed for individual buildings. Early water towers were often designed as part of a building. What does the one in your town/city look like?

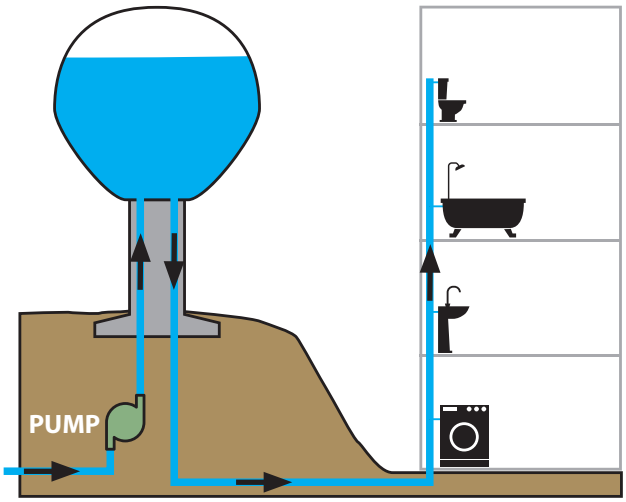


Figure 4: Water Tower Distribution Diagram

Why do water towers look different?

Early water towers were functional. They provided water pressure for drinking and for fire protection. They used to be adjacent to pumping stations and were made from stone and concrete. However, they had relatively short life spans.

In the 20th Century improvements in steel construction made metal a preferred material for water tower construction. In time, engineers began to design standpipes that blended with the landscapes and started to create interesting water tower designs. Steel tanks last for approximately 100 years.

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Steel reinforced, concrete tanks provided avenues to obtain structural designs that take advantage of qualities of both concrete and steel. Reinforced tanks began appearing around 1930. Engineering advances provide opportunities to design interesting water towers: golf ball on a long skinny tee, a witch's hat, a flashlight, a spaceship, or a peach. No matter how a water tower looks, it will always serve the same function: to readily provide water to people in a reliable and safe supply.

What types of water towers can you find in an internet search? Are the whimsical? Why would different tower designs be necessary or wanted?

Water Quality and Distribution Systems

The first municipal water utility built in the US was in Boston. It was established in 1652 and provided residential drinking water and water for fire protection. Most water systems that were originally built were for fire prevention. In time, the water utilities would include drinking water for homes and water for business use. Most of these water systems provided safe, disease free water to people.

Around the end of the 19th Century waterborne diseases became significant in industrialized river valleys. Since the late 1890s, waterborne disease and uncontrolled water pollution have regularly become part of political discussions. The politics of the time have created laws at federal, state, and local levels to protect people from disease being introduced through water supplies. By the 1960s each State had created laws to protect drinking water; however, these laws were inconsistent and largely were concerned with only the water discharge from water treatment plants. In 1974 the US Congress passed the Safe Drinking Water Act (SDWA), which provided an opportunity for the Environmental Protection Agency (EPA) to establish water quality standards that must be met at various points in the water distribution system versus only at the water treatment plant discharge.

So how do water utilities get the safe drinking water to you? Water distribution systems include "all water utility components for the distribution of finished or potable water by means of gravity storage feed or pumps through distribution pumping networks to customers or other users…" (American Water Works Association definition). These distribution systems must also include nonpotable uses (fire suppression and irrigation for landscaping). Distribution system infrastructure is generally considered to consist of the pipes, pumps, valves, storage tanks, reservoirs, meters, fittings, and other hydraulic bits and pieces that connect treatment plants or well supplies to people's homes.
Why is water quality important? Does the water distribution system assist in preventing waterborne diseases?

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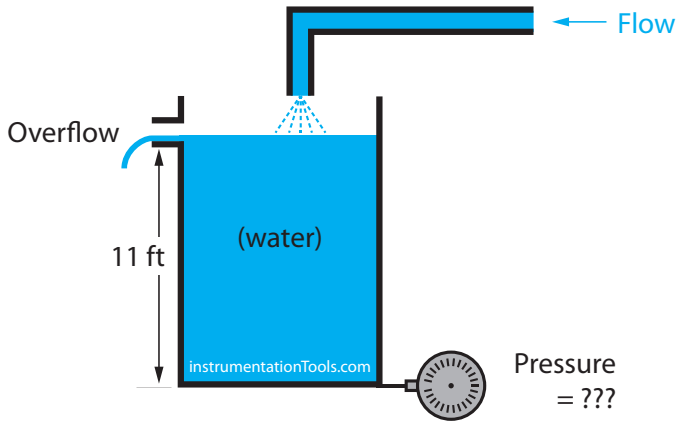
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Building a Water Tower

A wide range of materials are used to construct water towers—including steel and reinforced concrete, with an interior coating to protect the water from any effects from the building material. The reservoir in the tower may be in many shapes, and they usually have a minimum height of approximately 6 meters (20 ft) and are a minimum of 4 m (13 ft) in diameter. Most water towers have a height of about 40 m (130 ft). The illustration of Figure 4 shows: 1. A pumping station to push water up into the water, 2. A reservoir to hold the water, and 3. Examples of how the water might be used in a home, office, or apartment building.

What is Hydrostatic Pressure?

Hydrostatic pressure is the pressure exerted by a fluid at equilibrium due to the force of gravity (Figure 5). It is the pressure of the water that forces water to flow through pipes into homes. If the pressure is not strong enough, water will not be delivered, or will be delivered too weakly to suffice for some applications such as fire hoses or showers. The higher the tank is the more pressure and force that the water will have. Sometimes pumps are also used to push water through the water delivery system, especially at peak usage times. When engineers design a water tower, they know that every vertical foot adds .43 pounds per square inch to the water pressure. (Note: 1 psi equals 6,894.76 Pascals.) Most towns regulate water pressure at between fifty and one-hundred pounds per square inch, so a simple equation tells them how high to build the tower.



7.48 gal = 1 cu. ft.
8.34 lbs = 1 gal

Figure 5: Hydrostatic Pressure

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$$\text{Pressure}\left(\frac{\text{lb}}{\text{in}^2}\right) = \frac{\text{Force (weight)}}{\text{Area}}$$

EXPLORE

Water Tower Design Investigation Procedure
(students working in lab groups of 3 – 4 students)

1. Show students the student handout. These may be read in class or provided as reading material for the prior night's homework.
2. To introduce the lesson, consider asking the students how water is supplied to their homes. Ask them to think about the buildings and systems (i.e. infrastructure) required to deliver safe drinking water to their home.
3. Teams of 3 – 4 students will consider their challenge and conduct research into how water towers operate.
4. Teams then consider available materials and develop a detailed drawing showing their water tower including a list of materials they will need to build it.
5. Students build their water tower, test it, and observe the systems developed and tested by other student teams.
6. Teams reflect on the challenge and present their experiences to the class.

EXPLAIN

(NOTE: Explain, Elaborate, and Evaluate portions of this assignment align to the engineering design/redesign processes).

Engineering Teamwork and Planning

Tell students they are part of a team of engineers given the challenge of developing their own water tower than can deliver water to a paper cup that is about 36 inches or 90 cm away in a controlled manner. This means they must be able to stop and start the flow and fill the cup up just half way. They'll be given a range of items to build with, but first they'll design their system on paper so they know what materials they'll need, then build it and test it. They'll then reflect on the experience and present their designs to the class.

Research Phase

If you have access to the internet, explore your town's water delivery system and see how engineers designed your local water tower.

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ELABORATE

Planning and Design Phase

Engineers have built many different designs for water towers, but they all achieve the same goal of delivering water in a controlled manner to homes and businesses. Now it is the students turn! On a piece of paper, have the students draw a detailed diagram showing the plans for their water tower.

On the back of the same sheet of paper, have the students make a list of all the materials they will need using the heading.

Materials you will need:

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EVALUATE

Presentation Phase

Students will present their plans and drawings to the class and consider the plans of other teams. They may wish to fine tune your own design.

Build it! Test it!

Next students will build their towers and test them. They may share unused building materials with other teams, and trade materials too. Be sure to encourage students to observe what other teams are doing and consider the aspects of different designs that might be an improvement on their team's plans/design.

Reflection

Ask students the following questions:

1. How similar was your original design to the actual water tower your team built?
2. If you found you needed to make changes during the construction phase, describe why your team decided to make revisions.
3. Which water tower that another team made was the most interesting to you? Why?
4. Do you think that this activity was more rewarding to do as a team, or would you have preferred to work alone on it? Why?
5. If you could have used one additional material (tape, glue, wood sticks, foil—as examples) which would you choose and why?
6. Do you think your design is scalable? Would it work efficiently if the cup were 360 inches or 900 cm away from the water source? Why? Why not?

Once you have surveyed your students based upon their learner profiles, you can design assessments to evaluate the students' mastery of the concepts.

Use the assessment to identify student's preparedness to complete the formative assessment for this assignment.

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ASSESSMENT

The objective of the water tower lesson is to make students aware of the importance of **reliable drinking water** and the rewarding career opportunities available in the **water profession**. This lesson plan meets this objective by having students develop an idea into a functioning water tower, just like what water engineers do in the real world. **The lowest scores obtain the best grades** (like a golf score!). Assessment is based on **four criteria**—structural score, hydraulic efficiency, cost efficiency, and design ingenuity. There is an additional section to indicate required design standards with suggested penalties; this scoring mimics the FSAWWA Model Water Tower Competition guidelines and may be used to assist the students in the regional competitions.

Structural Score

Structural efficiency is calculated by **dividing** the weight of the model when it is empty by the average height of the tank **times** the amount of water it holds.
The lower this number, the better.
This is shown with the following formula:

$$\text{Structural Efficiency} = \frac{\text{Weight of Tower (Empty, lb)}}{\text{Average Tank Height (ft)} \times \text{Volume of Water Tower Holds (gal)}}$$

Remember the tower should be between 1.5 feet and 2.5 feet high. A more structurally efficient tower will have a better structural score. The lower the number is the better the efficiency.

Hydraulic Efficiency

Hydraulic efficiency is the amount of **time it takes** to fill and drain the model with one (1) gallon of water. The tank is filled by pumping water through the 3/8-inch connector. The tank will be drained by letting the water flow out of the tank **by gravity only**. The less time it takes to fill and drain the tank through the connector the better. **The tank must have a vent or a cover, so the teacher can see into the tower**. **Coverless towers will not be considered vented**. Each tank will be tested (filled and drained) twice and the **average** of the two fill and drain times (in minutes) will equal the hydraulic efficiency score. The hydraulic efficiency formula is as follows:

$$\text{Hydraulic Efficiency (min)} = \frac{\text{1st fill and drain (min)} + \text{2nd fill and drain (min)}}{2}$$

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Cost Efficiency

Cost efficiency measures the student's ability to save money while building your model. Students must provide **receipts** for all items purchased for their model. Points will be assigned as follows (the lower the score the better—recycled items are $0):

$0.00 – $5.00	1 point
$5.01 – $10.00	2 point
$10.01 – $15.00	3 point
$15.01 – $20.00	4 point
More than $ 20.00	5 point

Regardless of cost, list all items used in the model and their costs on the **Materials List Form**. This form is required for the assessment. Where recycled items are used, put the letter "R" in the cost column. Students may use as many recycled materials as they wish. A penalty of 1 point will be given for each missing receipt for items purchased new specifically for tower construction. A 3-point penalty will be added to the student's score if the Materials list form is missing. No receipt is necessary for recycled items; however, the items must be accounted for on the materials list form. The cost of glue, nails, screws, general adhesives, and items used to decorate the tower should not be counted towards the tower's total cost. The cost of the tower should **not** include tax.

Design Ingenuity

Ingenuity is how much **imagination and skill** were used in the student's model. Water professionals must often use ingenuity; they use skill and imagination to solve difficult problems. The teacher will look at several items:

- Craftsmanship (is the model sturdy, do the parts fit together nicely)?
- Imagination (are the design and materials unique)?
- Artistic merit (does the model have creative ideas, colors or themes)?

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Required Design Standards and Penalties

Keep to the following standards when designing and constructing the model:

- ***Footprint:*** The base of the model must fit in a square 1 foot on each side. If not, a 2-point penalty will be assessed.
- ***Tank Height:*** The tank must be between 1.5 and 2.5 feet high (See Drawing). If not, a 2-point penalty will be assessed.
- ***Tank Volume:*** When full, the tank must hold between 1 and 2.5 gallons of water. Hint: test the model to make sure the tower can hold the weight of the water! If not, a 2-point penalty will be assessed.
- ***Leaks:*** The tank should not leak. If any part of the tower leaks (e.g. tank, piping, connector), then a 2-point penalty will be assessed.
- ***Vent/Lid:*** The tank must have a vent or removable lid so the judges can tell when it is full. Uncovered towers or non-vented towers will result in a penalty of 1 point.
- ***⅜-Inch Connector:*** The model must use the ⅜-inch connector. If the tower does not have this ⅜-inch connector, then a 1-point penalty will be assessed.
- ***Receipts:*** Bring receipts for all materials purchased for your model. A one-point penalty will be assessed for each item not having a receipt (Maximum of 3 penalty points).
- ***Materials' List:*** Complete the materials' list. If the materials' list is not provided a 3-point penalty will be assessed.
- ***Structural Stability:*** The tower should be structurally stable. If the tower exhibits structural instability (e.g. tower must be supported by a person during filling of water or during any part of the testing), then a 2-point penalty will be assessed.

Penalties will be assessed for not following the standards described above and these penalties will be directly added to the tower's score. These standards are demonstrated in the diagram attached to this handout.

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Materials List Form

Team Name: _____

Participants: _____

Complete and bring this form and all receipts on the day of the contest. List the materials and costs used to construct the model water tower. Put an 'R' in the cost column where recycled materials were used.

MATERIAL	COST
	$
	$
	$
	$
	$
	$
	$
	$
	$
TOTAL	$

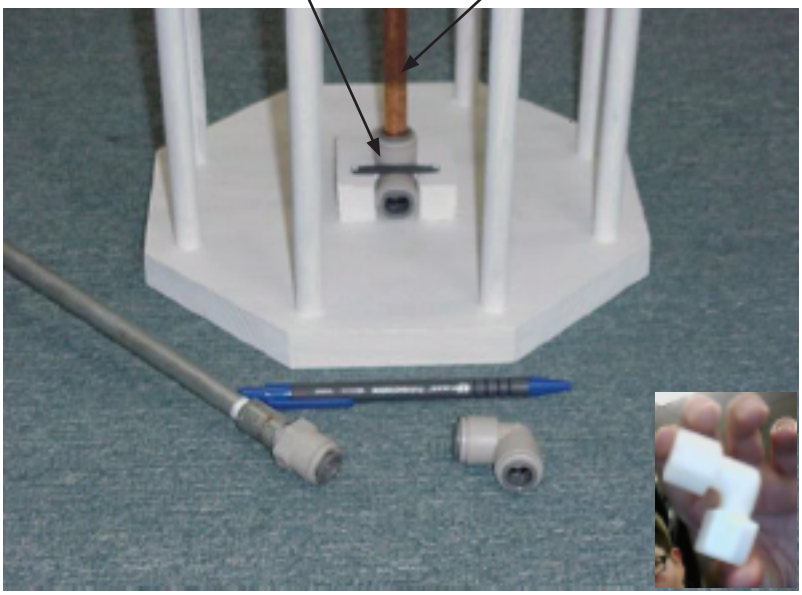
* Use additional sheets if necessary, to list all materials. A penalty will be given for not bringing this form or receipts.

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Model Water Tower Connector

Connector must be installed at the base of the model. Use the ⅜" diameter connector	Vertical tube may be any diameter - use a reducer or increaser as necessary to change tube size

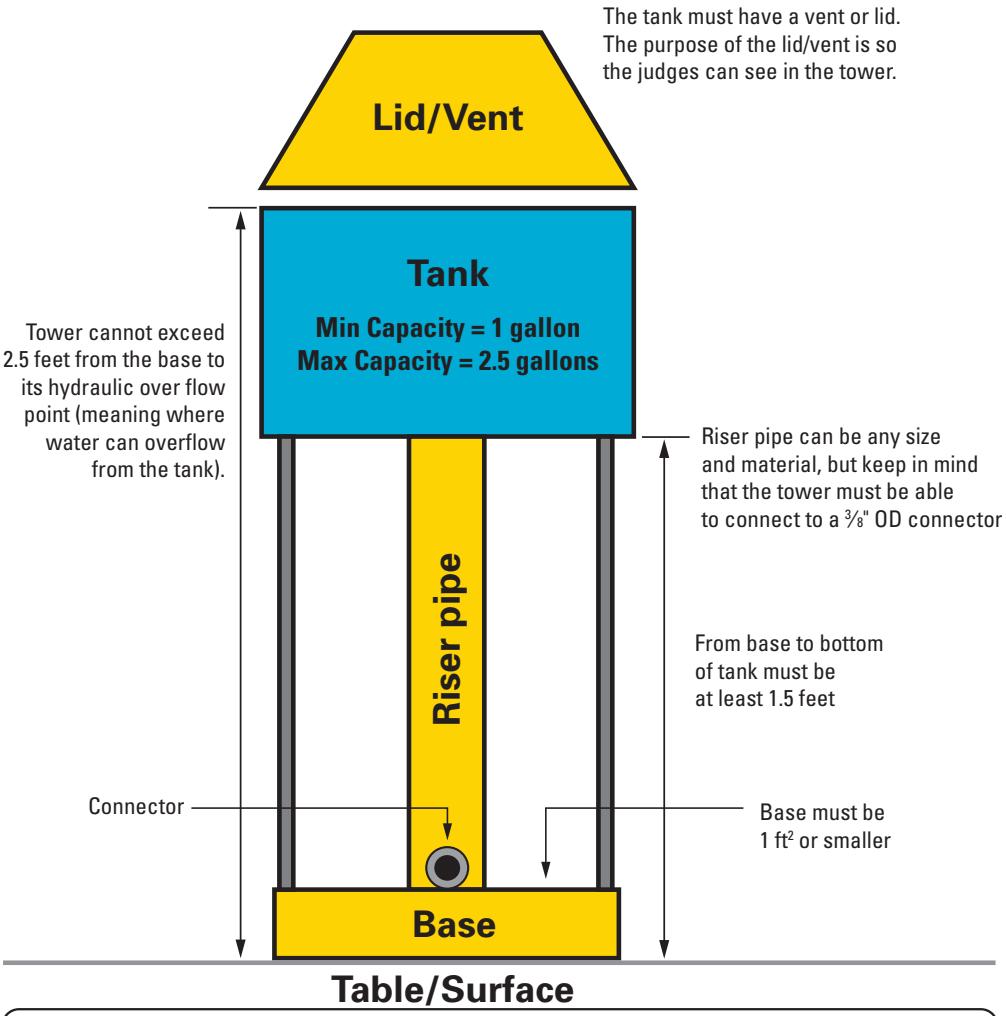


The proper ⅜" diameter push-on connector will be provided to all registered contestants. You must use the connector given to you to avoid a penalty.

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MWTC Requirements



Additional notes:

Your Model must be an elevated tank design including a riser pipe, a tank, a supporting structure to hold the tank and a base.

The maximum and minimum volume requirements INCLUDE the storage in you riser pipe.

The maximum 2.5 feet height refers to the length from the base to the hydraulic height (i.e. the overflow height).

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Accommodations:

ELL – Use strategies for analyzing charts and graphs (ELL – Immediate fluency), more complex problem solving and evaluating processes, and continue with how and why questions—research and support. Ask open ended questions to expand and stimulate language production (ELL – Speech Emergent) student pairing for fluency support.

ESE - Work with fewer items per page or line and/or materials in a larger print size (ESE – ADHD), have a designated reader, hear instructions orally (ESE – LD), take more time to complete a task or a test (ESE – LD and ADHD), and have extra time to process oral information and directions.

Extensions:

Reading

- Water Towers (ISBN: 978-0262022774)
- Design for Water: Rainwater Harvesting, Stormwater Catchment, and Alternate Water Reuse (ISBN: 978-0865715806)

Writing

Write an essay or a paragraph about environmental challenges to a water tower design. Consider how the weather, topography, the population of an area, or other factors might impact the design of a new water tower.

Design

Have students test their designs to see if they are scalable by doubling and tripling the distance from the water source to the cup.

Reference:

https://tryengineering.org/teacher/water-tower-challenge/#materials-preparation
https://www.hkywater.org/education/i-didnt-know-that/why-water-towers
https://instrumentationtools.com/hydrostatic-pressure-measurement-questions/
https://www.watercalculator.org/footprint/water-conservation-efficiency/
https://www.gettingsmart.com/2017/10/integrating-edp-and-cbl-in-stem/
https://www.collegetransitions.com/blog/so-you-want-to-be-an-engineer/
https://www.raeng.org.uk/publications/reports/thinking-like-an-engineer-implications-full-report
https://www.tpomag.com/online_exclusives/2018/07/the-shape-of-water-towers-an-engineering-history
https://www.nap.edu/read/11728/chapter/3

Student Handout

Engineering Teamwork and Planning

You are part of a team of engineers given the challenge of developing your own water tower than can deliver water to a paper cup that is about 36 inches or 90 cm away in a controlled manner. This means you must be able to stop and start the flow while filling the cup up just half way. You'll be given a range of items to build with, but first design your system on paper, then build it and test it. You'll reflect on the experience and present your designs to your class.

Research Phase

Read the materials provided to you by your teacher. If you have access to the internet, explore your town, city, or county's water system. See if you can find a water tower locally.

Planning and Design Phase

Engineers have built many different designs for water towers, but they all achieve the same goal of delivering water in a controlled manner to consumers (i.e. homes, schools, and businesses). Now it is your turn! On the back of this sheet or on a separate piece of paper, draw a detailed diagram showing the plan for your water tower.

American Water Works Association
FloridaSection

Materials you will need:

Presentation Phase

Present your plan and drawing to the class and consider the plans of other teams. You may wish to fine tune your own design.

Build it! Test it!

Next build your tower and test it. You may share unused building materials with other teams, and trade materials too. Be sure to watch what other teams are doing and consider the aspects of different designs that might be an improvement on your team's plan.

Reflection

Complete the reflection questions below:

1. How similar was your original design to the actual water tower your team built?

2. If you found you needed to make changes during the construction phase, describe why your team decided to make revisions.

3. Which water tower that another team made was the most interesting to you? Why?

4. Do you think that this activity was more rewarding to do as a team, or would you have preferred to work alone on it? Why?

5. If you could have used one additional material (tape, glue, wood sticks, foil — as examples) which would you choose and why?

6. Do you think your design is scalable? Would it work efficiently if the cup were 360 inches or 900 cm away from the water source? Why? Why not?