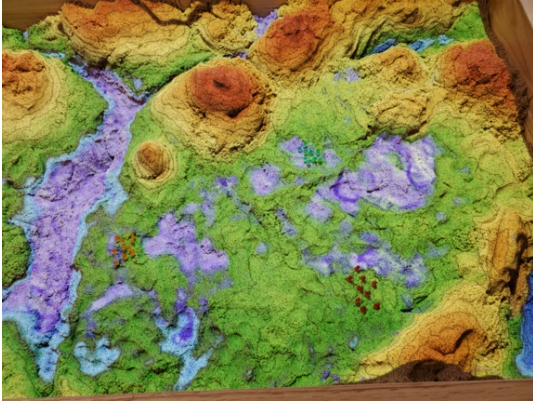# LESSON: City Planning (Grades 3, 5, 7)

+ OVERVIEW

In this design challenge, students will be presented with flooding as a problem that needs to be addressed by city planners. Students will get to look at an Augmented Reality (AR) Sandbox demo to demonstrate how rainfall can impact a city and will then be presented with the following problem. "The city of Teastem has hired you, a city planner, to assist in dealing with the city's problem of flooding. You have brought in an AR Sandbox to lay out the topography of the city, analyze the layout of the city, and design a solution for the flooding problem. Today, you will put on your engineering hat to prevent flooding in the town of Teastem."

Students will engage in a STEM challenge to design solutions for the city of Teastem that provide multiple methods to address flooding without causing further damage to the city. Teams will receive bonus points if their solutions hold up against slow earth changes from weathering and erosion occurring gradually over time and fast earth changes from weathering and erosion that cause sudden damage like a landslide.

+ 2021 Science TEKS covered in this design challenge

Grade 3 TEKS: 3.1.B, 3.1.E, 3.1.G, 3.2.D, 3.10.C

Grade 5 TEKS: 5.1.B, 5.1.E, 5.1.G, 5.2.D, 5.12.C

Grade 7 TEKS: 7.1.B, 7.1.E, 7.1.G, 7.2.D, 7.11.A

+ Math TEKS covered in this design challenge

Grade 5 TEKS: 5.10.F

Grade 7 TEKS: 7.3.A

+ 2022 Technology Applications TEKS covered in this design challenge

Grade 5 TEKS: 5.3.A, 5.3.B

Grade 7 TEKS: 7.3.A, 7.3.B, 7.3.C

+The students will be able to:

> Model and describe rapid changes in the Earth's surface
> Describe how human activities can be beneficial or harmful to an ecosystem
> Analyze the effects of human activity on groundwater and surface water in a watershed
> Add, subtract, and multiply rational numbers fluently
> Solve a problem using the engineering design process
> Work collaboratively with other to develop a plan of shared responsibilities

+ Students will use the following STEM fluency skills:

> Communication
> Collaboration
> Creativity
> Critical Thinking
> Resilience
> Time/Resource Management
> Innovation
> Adaptability

+ Materials needed for this design challenge:

> Dam Wall (4 gray LEGO® bricks)	$200,000
> Terraforming (per cm^2)	$5,000
> Aquafence Barrier (single 4x2 blue LEGO® brick, max stack: 2)	$10,000

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+ Materials needed by the facilitator:

> Projector and computer
  - Internet connection will be required to access SageModeler (free to use)
> Document camera
> Slide deck for the lesson
> Copies of the scorecard for each group
> AR Sandbox
> Plastic hand shovel
> Lego bricks
> Measuring tape
> Gloves
> LEDs

+ FACILITATION GUIDE

SECTION	PROCEDURE

INTRODUCTION	**Slide 1: City Planning**
	
	Slide 2: Flooding
	> Ask students what is happening in the picture.
	   ■ Explain that the picture shows the after math of Houston after Hurricane Harvey. Explain that the roadways were covered with feet of water hence the need for boats to save rescue people and belongings.
	> Ask students how did it happen.
	   ■ Explain that the hurricane brought so much rain that the ground couldn't absorb it and rivers and streams couldn't hold the water. Therefore, the water spilled into streets, highways, and homes.
	> Ask students where does flooding occur.
	   ■ Explain that flooding can occur due to slow moving thunderstorms (flash floods) or by a gradual increase in water level of a river or creek (river floods). Because of these different types of floods, different areas can be affected. Areas most susceptible to flash flooding are mountainous streams and rivers, urban areas, low-lying areas, storm drains, and culverts. River floods occur seasonally with general rains in areas near rivers or bodies of water.
	> Ask students what can we do to prevent this.
	   ■ Explain that levees and floodwalls are designed to prevent water from overflowing and flooding the adjacent land. Levees and floodwalls can protect urban and rural areas from moderate to high floods and can be combined with other structures such as gates, pumps, and drains.
	   ■ Explain that the implementation of these tools is determined by city planners.
	
	Slide 3: Engineering Design 1
	> Ask students the question: what is engineering?
	   ■ Explain to students that engineering is when engineers take what they know and apply it to solve problems by designing a product or process.

- For example, phones could only be used at home or in specific locations. Why is this a problem? (Needing to make a call outside the home). What solution did engineers design to fix that problem? (Cell phones).
  - *Teacher's Note: Any example can be used here, but focus on examples that students are familiar with.*

Slide 4: Engineering Design 2
> Ask students the question: What are some examples of engineering jobs?
- *Teacher's Note: If students have trouble giving examples, ask students who they think makes the things they use. Who makes refrigerators, cars, helmets, cell phones, and sneakers?*

Slide 5-6: Engineering Jobs 1-2
> Show students pictures related to engineering jobs connected to the challenge.
> City/Urban planners
- Ask students what they see in the pictures.
- The people who work to plan out where things go in the city are city and urban planners. They help plan out cities to address city concerns while also keeping in mind the environment and the people who live in the city.
> Civil Engineers
- Ask students what they see in the pictures.
- The people who work and build for the city are civil engineers. Civil engineers help get water and electricity to buildings but also build bridges and roads. In case of flooding, they are the people in charge of building dams and barriers to protect the city.

Slide 7: Engineering Design 3
> Ask students the question: Who can be an engineer?
- Anyone!

Slide 8: Demonstrations
> Demonstrate to students how the AR Sandbox works and how we can determine if flooding is occurring.
- *Teacher's Note: The AR Sandbox should be positioned such that a document camera can be placed above it and the teacher can use a keyboard and mouse. The teacher will set up the Sandbox to create a city layout. Putting the mouse pointer over the north side of the city, the teacher will make it*

precipitate by holding the "3" key on the keyboard for approximately 30 seconds. Upon completion of the demo of the flooding of the city, the teacher will press and hold the "2" key on the keyboard to dry the city.

- Rainfall Demo
- Design Testing Demo

▪ Explain to students that the AR Sandbox will be used for part of their engineering design challenge.

▪ During the demo, explain to students what the colors and lines projected onto the AR Sandbox mean. The lines represent contour lines and let scientists know that the area on the line is at the same elevation. The colors let scientists know if the area is higher or lower. Elevation colors follow a similar pattern to the rainbow. Red is the highest, then orange, yellow, green, and blue is the lowest.

▪ Explain that scientists simulate rainfall to see how the flow of water on land relates to the contour lines and elevation in the AR Sandbox.

▪ Explain to students the layout of the AR Sandbox that represents the city of Teastem. When rainfall occurs, we see areas collect water. As city planners, we do not want water to collect in the areas that have city development, which would indicate flooding. Teastem has a problem with flooding! When we change the landscape, we can see how the flow of water changes as well.

> Shift to SageModeler Demo
> Ask students what impacts water quality.

▪ Explain that the different chemicals and substances in the water will determine how clean it is for humans and animals.

> Ask students how does water quality affect people.

▪ Explain that poor water quality can result in illness if the water is ingested, but it's also common for water with poor quality to cause rashes and other irritations on the body. Poor water quality also Impacts the fish that live there and can affect human lives if they rely on fish for food.

> Open up SageModeler to show students the relationships between human actions and water quality.

▪ Ask students what they think the blue lines mean.

- Explain that the blue lines indicate a negative relationship. Reinforce that this doesn't always

something mean bad but it does mean that it will cause a decrease in the next variable.

- Ask students what they think the red lines mean.
  - Explain that the red lines indicate a positive relationship. Reinforce that this doesn't always mean something good but it does mean that it will cause an increase in the next variable.
- Demonstrate for students how moving the sliders on the variables up or down impacts the water quality slider up or down.
  - *Teacher's Note: The sliders for flood barrier and dam will appear when the "simulate" button at the top right of the screen is selected.*
- Demonstrate to students that if they want to build a dam wall, they will move the slider up to the top. The teacher will hit the record button and show how to access the values for water quality and stream wildlife.
- Repeat the process to demonstrate building an aquafence barrier.
- Explain to students that they will need to use the SageModeler to see how their decision to build things also impacts the environment.

Slide 9: Engineering Design Process
- > Ask students if they think all engineers solve their problems in one try. Explain to students that it takes many tries to get something correct in engineering. In engineering, there is no such thing as a mistake, only opportunities to learn. It is okay to fail. Just find the mistake and correct it. In engineering, there is never one correct solution. There are always many solutions to a problem and always improvements that can be made. The steps that engineers take to find these solutions are called the *engineering design process*.
- > Ask students to read the first big step (Identify).
  - What does identify mean? (To point out or find). Engineers design solutions: what do they need to know first before they can find the answer? (The problem)
  - How do people know when they have found the correct answer? In engineering, there are no correct answers, just better ones. Explain to students that there are expectations that engineers must meet called *criteria*. For example, when

engineering a football, what does a football need to do? (Bounce, look a certain way, have laces, have air inside, etc.). Those things are all called criteria. By comparing the design to the criteria, an engineer knows a solution will work. Is a child-sized football the same as an adult football? The criteria for both footballs include leather, the white laces for fingers, and the shape. However, the two footballs would have different criteria for the size. The footballs are similar but different because of different criteria.

- Once the criteria are understood for the design challenge, what could make it difficult for an engineer to design their solution? (Money, time, materials, etc.) Explain to students that these rules are called *constraints* or rules that engineers must follow. Engineers are given constraints they must follow when finding the solution to a problem. Think about football again. What are college and professional footballs made from? (Leather). What if instead, the rule (or constraint) was not to use leather, could another type of football be made instead? Many of the footballs for sale are made of rubber because the engineer had different constraints.

> Ask students to read the next step (Imagine).
  - Ask students what imagine, or imagination, means. Are these things real or tangible? They may not be real, but they help give us ideas about what things could be. In this step, see what materials are available, then brainstorm, or think about possible ideas/solutions to the problems.
  - Explain to students that there are no right answers in engineering. Start with as many ideas as possible.

> Ask students to read the next step (Plan).
  - The third big step of the engineering design process is to plan out the idea. Make sure that what is designed can be repeated. A plan will help an engineer identify where mistakes happen so they can be fixed.
  - When planning, begin with the brainstorming phase. Each team member will contribute their ideas, and then the team combines the different ideas!
  - Once ideas are combined into a single group idea, determine what materials will be used for the solution and make sure the design has met the criteria and constraints of the project.

> Ask students to read the next step (Create).

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	▪ The fourth step is to create! Since this is the very first creation, it is called a *prototype*. A prototype is a first or preliminary model of something from which other forms are developed or copied. A prototype is created to test the engineer's idea or concept. Engineers ask themselves, "Did the idea work the way we wanted it to?" After testing the idea, the engineer will make improvements to the prototype. > Ask students to read the last step (Improve). ▪ Finally, the last step is to improve. How does an engineer know if the prototype did well on the test? It must meet certain expectations and follow some rules. But how do engineers determine how well it met the expectations and how well it followed the rules? In school, how do you know if you mastered something? (Grades). The prototypes made today will be scored using a scorecard or rubric. By looking at the score, each team will determine if the design could be better. If improvements should be made, then the team will revisit the plan and decide what to do to improve the score. Remember, there are no correct answers in engineering, just better solutions.

IDENTIFY	**Slide 10-11: Identify –** Problem
	> Have students read the bolded section.
	   ▪ Ask students to *identify the problem*.
	> Explain to students that they will put on their engineering hats to help prevent flooding in the city of Teastem.
	
	Slide 12: Identify – Criteria (Desired Outcomes)
	> Ask students what criteria or desired outcomes mean.
	   ▪ Explain to students that criteria are what engineers use to determine if they have successfully solved the engineering problem.
	> Ask students what will determine if the solution is successful in helping Teastem today.
	   ▪ A successful design solution should include the following:
	     • No flooding in key locations
	       ○ *Teacher's Note: The clusters of LEDs will represent the three key locations.*
	     • Use at least three different methods and methods in multiple locations

- Not cause more flooding or damage to other parts of Teastem
- Limit environmental impact

Bonus points will be awarded if the team's flood prevention system works after erosion occurs outside Teastem.

- *Teacher Note: Erosion will be defined by the widening of the river as it leads into Teastem.*

Slide 13-14: Identify – Constraints (Limitations)

> Explain to students that constraints are rules the engineers must follow.
> Explain the constraints for this engineering design activity:
  - <u>Time Limit</u>: Students will have 30 minutes to build their flood barriers.
    - *<u>Teacher's Note: The teacher will time the design challenge and give the students time checks periodically to assist the teams with their time management.</u>*
  - <u>Materials</u>: Students can only use the materials available.
  - <u>Budget</u>: Students will have $1,000,000 to complete this challenge.
    - *Teacher's Note: Fake money can be given to each group to represent their budget. Students will then go to the supply table and hand the teacher the money to "buy" their materials.*
  - <u>Collaboration</u>: One design element from each team member must be used in the final design. Explain to students that a design element is taking one part of someone's idea and adding it to another.
  - <u>Redesign</u>: Each team can test their prototype as many times as needed during the 30-minute design phase. Remind students what a prototype is. It is the first creation of our design.
    - *Teacher Note: When a team is ready to test their design, they should raise their hand. The teacher will then ask them to come to the testing station and test their design. If a team received a low score on any part of the design, the team should redesign if they still have time.*

IMAGINE	**Slide 15: Imagine –** Explore Materials
	
	> Explain the role of the LEGO bricks® for this challenge and what each piece represents.
	    ▪ *Teacher's Note: Be sure to mention any restrictions on the LEGO® bricks. The dam piece is four grey LEGO® bricks high with unlimited length. The aquafence barriers are blue LEGO® bricks that cannot be more than two bricks high with unlimited length.*
	> Explain to students that they may also terraform the land.
	    ▪ *Teacher's Note: Students will use a shovel or gloved hands to carve out any terraforming.*
	> Explain to students that the map space they will be working with is 28 cm x 82 cm and that the length of a single LEGO® brick is 1 cm x 3 cm.
	> Explain to students they will use the SageModeler and need to record the values for water quality and stream wildlife based on what they build.
	
	Slide 16: Imagine – Brainstorm
	
	> Give students one minute to individually design and draw a plan of how they think they can address the flooding in Teastem. Emphasize that students should not talk during this minute or share ideas. Remind students their ideas will be used as design elements for the final design.
	> After a minute, give students five minutes to present and share their ideas with the group. Let students know that they should focus on key aspects of their ideas that they like and want to be used as design elements for the final design when sharing.
	    ▪ *Teacher's Note: If students are struggling with an idea for their design, provide ideas without giving the solution. For example, "This is a design that I tried earlier, but it failed. What could I do to improve it?" Emphasize that the design failed to reinforce that it is okay to fail and to let students know they cannot copy the design and expect success.*

PLAN	**Slide 17: Plan –** Gather Materials
	
	> Hand out the scorecard that will be used during the design challenge. Review the testing criteria with the class and answer questions. The testing criteria will inform their design decisions.
	> Have students collaborate to come up with a final design. Let students know they must include at least one element from each team member for their final design.
	> Review the design criteria:
	    ▪ A successful design solution should include the following:
	        • No flooding in key locations

- Use at least three different methods and methods in multiple locations
- Not cause more flooding or damage to other parts of Teastem
- Limit environmental impact.

Bonus points will be awarded if the team's flood prevention system works after erosion occurs outside Teastem.

> Students will need to select the materials to be used for the design and develop a budget for the project. Students will have $1,000,000 to "purchase" materials for their design at the classroom supply table. The prices used in this challenge can be found in the materials list. Students will raise their hands when they are ready to purchase materials. The teacher will make sure the appropriate amount of money is spent to purchase each material but will not guide students on following their budget. Students can go over budget if they want to, but remind them that they will lose points on their scorecard.

Slide 18: Plan – Team Member Responsibilities
> Each team member must be given responsibility, such as materials manager, banker, head engineer, and quality control manager.

CREATE

Slide 19: Create – Design Your Solution
> Remind students to have fun, be creative with their designs, and work together.
> Remind students that being an engineer is not about getting the solution on the first try. There is no right answer, just better solutions.

Slide 20: Identify – Criteria
> Display the reminder slide for students to look at while working.

Slide 21-22: Create – Test
> When students wish to test their design, they will come up to the AR Sandbox. The teacher must be present. Students will use the tools to modify the city. The tools will be made available at the AR Sandbox and students will be required to put on gloves before making changes to the city. The teacher will oversee producing precipitation to test the success of the design. It will rain for approximately 30 seconds. The bonus test for erosion will be done by drying up the AR Sandbox with the "2" key, and then widening the water channel by two finger widths (one finger width on

	each side of the channel). It will rain for approximately 30 seconds with the wider channels. ■ Teacher Note: The teacher will need to reset the AR Sandbox after each test run. > Students will calculate their scores when testing in front of the teacher. The teacher will go through each of the categories on the scorecard with the students. The students will mark their scores and calculate the total. > The teacher will recap the point total with the students and how many points the team received for each category to make sure it matches with what the students recorded.

IMPROVE	**Slide 23: Improve** – Redesign: Discussion
	> Students will reflect on their score and discuss the following:
	    ■ What worked?
	        • *Teachers Note: Focus on the materials being used and ask why they think those materials were helpful. Ask how placement of their tools affected the path of travel of the water.*
	    ■ What did not work?
	        • *Teacher's Note: Focus on the materials being used and ask why they think those materials did not work as well. Ask how the placement of their tools negatively affected the path of travel of the water.*
	    ■ What do you want to improve?
	        • *Teacher's Note: Focus on engineering aspects with students. Ask students why they were city planning for Teastem. Ask students if they found a solution or just part of one. Reinforce that it is okay to not succeed on the first try and that engineering is about making improvements over time. Ask students if they would design their city differently if they had no rules, how? Ask students if working together was difficult. Learning to work together is very important and it is easier to find a solution with many ideas rather than just one idea.*