Date: N/A	**Course:** Earth/Space Science	**Grade Level**: 12th grade or dual credit/dual enrollment; Can be used in advanced science classes or honors.	**Topic:** Solubility

Instructor: Hilary Roath & Amber Han

Instructional Method/Strategy:
Learning Cycle- 4E (2 Days)

NGSS Standards:

HS-ESS2-5. Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.

Objectives:
SWBAT:

- Explain Solubility
- Conduct student self-designed solubility lab
- Analyze data and discuss connection with limestone solubility

Core Idea:
ESS2.C: The Roles of Water in Earth's Surface Processes
The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks.

Science and Engineering practice: (Identify the practice and describe how you will explicitly address the practice in your teaching)
Planning and carrying out investigations: Students will use their understanding of solubility to plan and carry out an investigation of cave formations.

Materials (per group):
For the Engagement:

- Copy of each image
- Sheet of paper
- pens /pencils

For the Demo (teacher):

- Rock candy
- Hot water
- Container of some sort

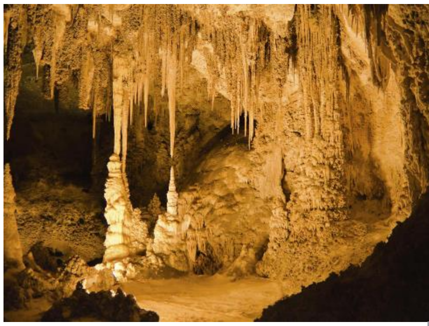
For the Lab (students):

- Clear plastic cup (with holes on bottom)
- Rock candy pieces (limestone)
- Hot water (rain)
- Sand (other rocks and dirt)
- Mesh
- Container of some sort
- KQHL worksheet

Resource:
Modified from:
http://www.rsc.org/education/teachers/resources/jesei/weather/teachers.pdf
http://www.wvgs.wvnet.edu/www/geoeduc/adaptiveactivities.PDF

Lesson Outline: (complete this section in a manner that aligns with the instructional method)
**The students will be grouped in four prior to coming to class

Engagement (10 minutes):
Each group will receive a copy of the following pictures and a sheet of paper. The students are to identify what the image is and construct similarities and differences between them on a sheet of paper. Scaffold the students to think of what makes us each of these objects (limestone).



(just the building) (just the white part of the rock)


(just the statue)

Once each group has written their responses, have them share their thoughts with the class. Scaffold each group to understand that each of these objects is made of calcium carbonate (limestone). Ask how each of these products have been formed, focus on the cave last. Scaffold the students to think how water has impacted its formation. How might temperature impact the formation?

Write the student responses on the board.

Explore (40 minutes):
Go on to the demonstration. Tell students that the rock candy will represent the limestone and the hot water will represent the rain. Ask students “What will happen if hot water is poured onto the rock candy?” Tell students to say their hypothesis to the person next to them.

Perform the demonstration (water should dissolve the rock candy).

Assign the self-design lab to students. Tell students that they will need to complete the KQHL worksheet and use all of the materials that are provided for them. Make sure students understand that the goal of the lab is to create a cave inside the cup. Have students map out their strategy and the materials that they will use on their lab sheet. Tell the students that before they retrieve materials, their strategy must be approved by the teacher. Have students keep a timer for how long it takes to dissolve all their rock candy.

A sample lab would be:

- Put soil in the plastic cup with holes on the bottom
- Add in rock candy pieces
- Put more sand on top,
- Compact the sand
- Put mesh on bottom of cup to prevent lots of sand falling out
- Pour hot water into cup slowly
- Rock candy will dissolve like limestone does in the rain
- Holes will be formed where the rock candy was and hopefully the sand will not cave in

After labs are completed, students will clean up and return to desks.

The teacher will then pass out analysis and discussion questions. (shown below)

If the students do not finish the questions the first day, have them complete it for homework.

End of Day One.

Explanation:

Review the procedure of the lab completed yesterday with the students. Allow the students to share their experiences with the lab with the class. Allow them to elaborate on what worked and what didn't and the results that they received.

Explain to the students that similar to how you created your cave, is similar to how our caves and other earth processes are formed in real life.

Students might ask "How long does this take in real life?" As students to look at their data sheets and the time that they recorded for dissolving the candy. Now tell them to multiply that by 10,000,000. The students will get a ridiculous number but emphasize that it is a possibility for caves as big as the Mammoth Caves in Kentucky to have taken that long. Tell students that scientists are still unclear and are looking for ways to calculate the exact rate and time it takes for caves to form.

This is due to the process of solubility (Have the students write on their sheet)

Solubility is a chemical property referring to the ability for a given substance, the solute, to dissolve in a solvent.

Ask the students:
What was our solute or substance? Rock candy - Limestone
What was our solvent? Water

Explain that A **solute** is a substance in which is dissolved in another substance, the **solvent.**

Can you think of any at home or everyday examples that would be a solute and a solvent?
Salt in water, skittles in water, alka seltzer in water etc. examples will vary

The reason this is important is because certain regions of the United States (student's own region if living in southeastern US) experience what is called a karst topography.

Karst Topography is a landscape formed from the dissolution of soluble rocks such as limestone, dolomite, and gypsum. It is characterized by underground drainage systems with sinkholes and caves.

Ask students: Are you familiar with this terminology?
Have you seen limestone before? where?

From here: pass out pieces of limestone to the students. Ask them to make physical observations about each with their groups and record them on their sheet. Scaffold the students to recognizing the pores in the rock. Ask them how the pores could play a role in the experiment that we did. (allow for water to flow through, can weather and erode the rock due to soluble properties and create karst topography)	
	Assessment: Exit Ticket: (individual) Show the cave picture to the students from the engagement Have the students explain how the cave could have formed based on their knowledge from the lab. (answers may not be exact what you want but starting the thought process will set a good tone for introducing solubility and earth processes in following lessons) (Bonus points: can answer question based on other images in the engagement as well?)

Pictures Are Talking

Directions: Look at each of the pictures that are given to your group (there should be 4). Observe the images and write a paragraph about your observations and descriptions. Use the following questions to help you get started.

Q: What do you think the objects in the pictures are made of? How do you think these were formed? Water natural forces do you think are needed to create these?

Picture 1

Picture 2

Picture 3

Picture 4

Let's Make A CAVE!

We now know that the rock candy, which represents the _____________ will dissolve in the hot water, which represents the ___________. This means that limestone can dissolve in the rain water over hundreds and thousands of years. These are important things to keep in mind.

Your goals for the today's lab:

1. Design a lab to show cave formation!

2. Complete the KQHL worksheet (you should know how to do these by now) before the start, during, and after the completion of your lab. This is on page 2.

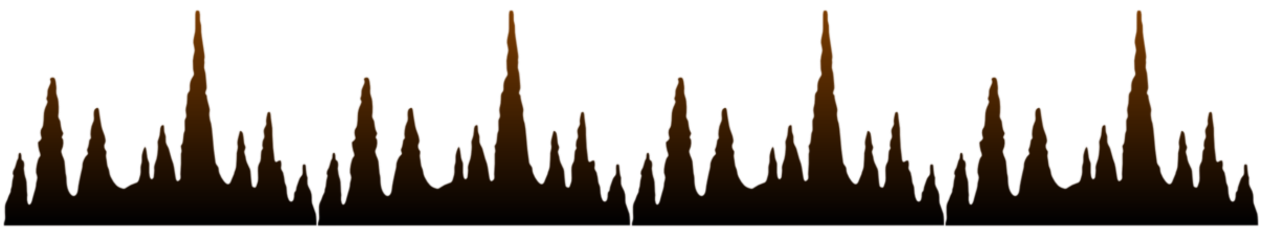
3. Map out your strategy and procedures of the lab. This is on page 3.

4. Complete the K, Q, H section of page 2 and page 3 and get a stamp of approval from me before starting the lab.

5. Complete the analysis and discussion questions. This is on page 4.

Important things to keep in mind!!

- ✓ Lab safety rules!
- ✓ Use all of the materials I have provided for you.
- ✓ Get your hypothesis approved before starting the lab!
- ✓ HAVE FUN!



Let's Make A CAVE!

KQHL

What do we already *know*?	Think of 3 research *questions*	What did you *learn*?
	1. 2.	

	3. *Hypothesis* "If_______, then_______."	

Let's Make A CAVE!

Procedures:

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Materials

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Let's Make A CAVE!

Analysis & Discussion

1. What did the rock candy represent? ______________________________
2. What did the hot water represent? ________________________________
3. Why did the cup sand represent? __________________________________
4. What happened in your model? Please explain in detail.

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5. How is your model different from what actually happens in the real world?

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6. How do you think you can better represent what actually happens in the real world?

7. What other things might impact the formation of caves in the real world?

Let’s Make A CAVE!

Notes

Pictures Are Talking (Key)

Directions: Look at each of the pictures that are given to your group (there should be 4). Observe the images and write a paragraph about your observations and descriptions. Use the following questions to help you get started.

Q: What do you think the objects in the pictures are made of? How do you think these were formed? Water natural forces do you think are needed to create these?

Picture 1

Student answers may vary.

Sample answer could be: Made from rock (limestone); Need time to make it, humans, water.

Answers will vary for all pictures.

Picture 2

Picture 3

Picture 4

Let's Make A CAVE!

We now know that the rock candy, which represents the Limestone will dissolve in the hot water, which represents the Rain. This means that limestone can dissolve in the rain water over hundreds and thousands of years. These are important things to keep in mind.

Your goals for the today's lab:

1. Design a lab to show cave formation!

2. Complete the KQHL worksheet (you should know how to do these by now) before the start, during, and after the completion of your lab. This is on page 2.

3. Map out your strategy and procedures of the lab. This is on page 3.

4. Complete the K, Q, H section of page 2 and page 3 and get a stamp of approval from me before starting the lab.

5. Complete the analysis and discussion questions. This is on page 4.

Important things to keep in mind!!

- ✓ Lab safety rules!
- ✓ Use all of the materials I have provided for you.
- ✓ Get your hypothesis approved before starting the lab!
- ✓ HAVE FUN!

Let's Make A CAVE!

KQHL

What do we already *know*?	Think of 3 research *questions*	What did you *learn*?
Sample answers: - Limestone gets dissolved in rain. - Caves can be made of limestone. - Rock candy will dissolve quickly in the hot water.	Sample answers: 1. Will sand stay in place to make a cave if rock candy gets dissolved? 2. How can we represent caves? 3. What happens to the dissolved limestone? *Hypothesis* "If_______, then_______." *Sample hypothesis:* *If we compact sand and put rock candy in in, then the candy would dissolve when hot water is poured into the cup and form caves where the candy was.*	Student answers will vary.

Let's Make A CAVE!

Procedures:

- Put soil in the plastic cup with holes on the bottom
- Add in rock candy pieces
- Put more sand on top,
- Compact the sand
- Put mesh on bottom of cup to prevent lots of sand falling out
- Pour hot water into cup slowly
- Rock candy will dissolve like limestone does in the rain
- Holes will be formed where the rock candy was and hopefully the sand will not cave in

Materials

- Clear plastic cup (with holes on bottom)
- Rock candy pieces
- Hot water
- Sand
- Mesh
- Container of some sort

Let's Make A CAVE!

Analysis & Discussion

8. What did the rock candy represent? Limestone
9. What did the hot water represent? Rain

10. Why did the cup sand represent? Cup represented the earth; Sand represented the soil and other rocks around the limestone.

11. What happened in your model? Please explain in detail.

    Student experiments will vary.

12. How is your model different from what actually happens in the real world?
    Model in classroom goes through much faster than in real life. There are no other environmental disturbances you find in the real world in the classroom. Etc,

13. How do you think you can better represent what actually happens in the real world?
    Get a larger cup with other rocks and soil within it; Different amounts of water; Add wind; etc.

14. What other things might impact the formation of caves in the real world?
    The amount of rain the location gets; Animals; Humans; etc.

Let's Make A CAVE!

Notes

Students can take note from the Explanation section from the second day here.

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Date:	Course:	Grade Level:	Topic:
N/A	Earth/Space Science	12 or Dual Credit/ Enrollment	Solubility of Limestone
Instructor: Hilary Roath & Amber Han		**Instructional Method/Strategy** PEOE	
NGSS Standards: **HS-ESS2-5.** Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.		**Objectives:** SWBAT: • Explain the Chemical reactions involved in limestone Dissolution	
Core Idea: **ESS2.C: The Roles of Water in Earth's Surface Processes** The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks.			

Science and Engineering practice: (Identify the practice and describe how you will explicitly address the practice in your teaching)

I can add these later if it is necessary.

Materials:

• Lab Sheet (Attached below)

• Safety goggles (one pair for instructor) • Chemical-resistant protective gloves (one pair for instructor) • Large sample of limestone with karst dissolution features (holes) • 10% hydrochloric acid (or other weak acid) with dropper • Bromethyl blue (BTB) (or other pH indicator solution) • Several small pieces of limestone (<2 inches) • Small clear cup or container (just large enough to submerse the small pieces of limestone in 50 ml of water) • pH water test kits (optional)

Resource: http://www.austintexas.gov/sites/default/files/files/Watershed/youth_education/karst_lesson_high_school.pdf

Lesson Outline: (complete this section in a manner that aligns with the instructional method)

**The students will be grouped in four prior to coming to class

Engagement:

Review previous lesson with students.

What is solubility? What happens when limestone is exposed to water? What is karst topography?

(Answers: **Solubility** is a chemical property referring to the ability for a given substance, the solute, to dissolve in a solvent.

Ask the students:

What was our solute or substance? Rock candy - Limestone

What was our solvent? Water

Explain that A **solute** is a substance in which is dissolved in another substance, the **solvent.**

Can you think of any at home or everyday examples that would be a solute and a solvent?

Salt in water, skittles in water, alka seltzer in water etc. examples will vary

The reason this is important is because certain regions of the United States (student's own region if living in southeastern US) experience what is called a karst topography.

Karst Topography is a landscape formed from the dissolution of soluble rocks such as limestone, dolomite, and gypsum. It is characterized by underground drainage systems with sinkholes and caves.)

Exploration:

Review what limestone is with the students and the pore activity they did the day before.

Hold up a piece of karst limestone. Ask students “what type of rock is this?” (limestone)

Why does it have holes and why does it form caves? Students may answer that water dissolved holes in the rock by physical weathering. (**Physical weathering** is a term used in science that refers to the geological process of rocks breaking apart without changing their chemical composition, by water, wind or freezing of pores eventually leading to cracks and breaking of rock)

Try to scaffold students to thinking about chemical weathering. How does this process occur? Allow student to think pair share.

Explain **Chemical Weathering** is: the erosion or disintegration of rocks, building materials, etc., caused by chemical reactions (chiefly with water and substances dissolved in it) rather than by mechanical processes

Conduct a PEOE (Predict Explain Observe Explain)

Part I: What happens to limestone when it meets hydrochloric acid?

Conduct the PEOE for putting a few drops of hydrochloric acid on the rock.

Have students record everything on a provided lab sheet.

Predict: What you think will happen

***Explain*:** Why you think it will happen

While wearing safety goggles and protective gloves, tell students you will now add a few drops of hydrochloric acid to the rock.

Observe: What actually happened

Explain: Why did it happen?

Write on the board and have students write on their lab sheet under the last explain.

Why does it fizz? Limestone is a calcium carbonate rock. The carbonate reacts with the H ion and creates a chemical reaction. Limestone is not very soluble so the rocks don't dissolve very quickly. If you add an acid however you add Hydrogen Ions (H+) which will react with the carbonate to form hydrogen carbonate HCO3 - ions which are very soluble in water, and the limestone will dissolve.

The chemical reactions that occur to cause dissolution of karst: CaCO3 + H2O + CO2 Æ Ca2+ + 2 HCO3 -

PART II:

After discussing the elements found within limestone, allow the students to think pair share the following question: “how they think limestone affects the pH of water?” and record the answer on their lab sheets. There answers will vary. Do not tell the students the answer.

Conduct the following experiment to figure it out. (demonstration will show how slightly acidic water can become basic when it interacts with limestone).

*****This process may take around 30 minutes so you should start the demonstration before the Explore activity so students can see how the solution starts as the color yellow (when the water is slightly acidic), then after their Explore activity, they can see how the solution turned blue (indicating the water became basic when it interacted with limestone. If you want to speed up the process, you can crush up the limestone or add pulverized chalk (which was originally made from limestone).

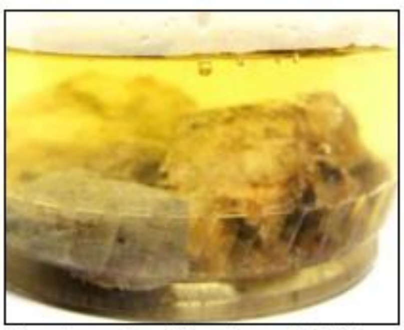
- Pour 50 mL of slightly acidic water in a clear plastic cup or container.
- Add 10 drops of Bromethyl blue (BTB) indicator solution to show that the water is slightly acidic (if the water is slightly acidic it should become yellow). If the water is not acidic, you can add a drop or two of hydrochloric acid or vinegar to make the water slightly acidic.
- Submerse several small pieces of limestone in the slightly acidic water. The solution should become green when the water is neutral and blue when the water becomes basic.

After the experiment:

Write on the board and have students record on their lab sheets.

Explain to the students how slightly basic rainwater becomes slightly acidic as it interacts with Carbon in the atmosphere and soil, forming carbonic acid, which Limestone in acidic water with BTB starts out yellow The water will eventually turn blue to indicate basic pH 8/16/2011 5 causes the limestone to dissolve. As the limestone dissolves it causes the solution to become basic.

Note: Universal indicator (or another pH indicator solution) can be used instead of BTB, but you should try the demonstration in advance to determine how long it takes the limestone to change the color of the solution from yellow to blue so you can plan your lesson accordingly. Optional: you can use pH kits to measure the pH of the water before and after it interacted with the limestone.



Limestone in acidic water with BTB starts out yellow

The water will eventually turn blue to indicate basic pH

Wrap up:

Review Part I and Part II with the students.

[redacted]	**Assessment:** *Exit Ticket:* Explain the Chemical reactions involved in limestone Dissolution

Name: Date:

PEOE Lab Sheet

Directions: Fill out the chart according to the teacher's instruction.

Part I: *What happens to limestone when it meets hydrochloric acid?*

Predict	
Explain	
Observe	
Explain	

Part II: *How do you think limestone affects the pH of water?*

Predict	
Explain	
Observe	
Explain	

Name: Key Date:

PEOE Lab Sheet

Directions: Fill out the chart according to the teacher's instruction.

Part I: *What happens to limestone when it meets hydrochloric acid?*

Predict	Student predictions with Vary.
Explain	Student explanations with Vary.
Observe	Possible observations: limestone begins to form white bubbles or fiz
Explain	Student explanations will vary, but have students record in this section the explanation that is written on the board. Some sort of summation will be as follows: Limestone is a calcium carbonate rock. The carbonate reacts with the H ion and creates a chemical reaction. Limestone is not very soluble so the rocks don't dissolve very quickly. If you add an acid however you add Hydrogen Ions (H+) which will react with the carbonate to form

	hydrogen carbonate HCO3 - ions which are very soluble in water, and the limestone will dissolve. The chemical reactions that occur to cause dissolution of karst: $CaCO_3 + H_2O + CO_2$ Æ $Ca^{2+} + 2\ HCO_3^-$

Part II: *How do you think limestone affects the pH of water?*

Predict	Student Predictions will vary.
Explain	Student Explanations will vary.
Observe	Possible student observations: The water changed from yellow to blue
Explain	Student explanation will vary, but have students copy in this section what teacher writes on the board. A summation of the explanation will look like something of the following: Slightly basic rainwater becomes slightly acidic as it interacts with Carbon in the atmosphere and soil, forming carbonic acid, which Limestone in acidic water with BTB starts out yellow. The water will eventually turn blue to indicate basic pH 8/16/2011 5 causes the limestone to dissolve. As the limestone dissolves it causes the solution to become basic. **The water is just changing color due to the indicator solution for the purpose of the demo. It does not happen like this in real life.

Date:	**Course:**	**Grade Level**:	**Topic:**
N/A	Earth/Space Science	12 or Dual Credit/ Enrollment	Karst Topography

Instructor: Hilary Roath & Amber Han

Instructional Method/Strategy:
Learning Cycle-5E

NGSS Standards:

HS-ESS2-5. Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.

Objectives:
SWBAT:

- Identify rainwater and limestone as the two necessary parts of dissolution cave formation.
- Understand recharge features and relationship to karst topography.

Core Idea:
ESS2.C: The Roles of Water in Earth's Surface Processes
The abundance of liquid water on Earth’s surface and its unique combination of physical and chemical properties are central to the planet’s dynamics. These properties include water’s exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks.

Science and Engineering practice: (Identify the practice and describe how you will explicitly address the practice in your teaching)
Planning and carrying out investigation: Students will not plan their own investigations in this lab, but they will be carrying out investigations to establish their understanding of the features within a karst topography
Developing and using models: Students will not develop own models, but will be using models within their investigations.

Materials (per group):

- 24-36 sugar cubes (24 sugar cubes are needed for modeling a fracture or sinkholes; 36 sugar cubes are needed for modeling a fault)
- 1” cube of clay-based modeling clay
- 5 ml pipette/dropper
- toothpick
- popsicle stick or butter knife (something to cut the clay with)
- 15 ml of water
- a couple of drops of food coloring
- Small rectangular container (21⁄2"L x 2"W x 15⁄8"H) - 0.14 L or 0.15 L

Resource:
http://www.austintexas.gov/sites/default/files/files/Watershed/youth_education/karst_lesson_high_school.pdf

Lesson Outline: (complete this section in a manner that aligns with the instructional method)
**The students will be grouped in four prior to coming to class

Engagement:

Review PEOE in previous lesson with students.

The Chemical Reaction: $CaCO_3 + H_2O + CO_2$ Æ $Ca^{2+} + 2\ HCO_3^-$

Ask students how they think limestone affects the pH of water. Review what was shown. (teacher may have it prepared prior to class so that they can compare it to the lab conducted today)

Answer any student questions before moving on.

Explore

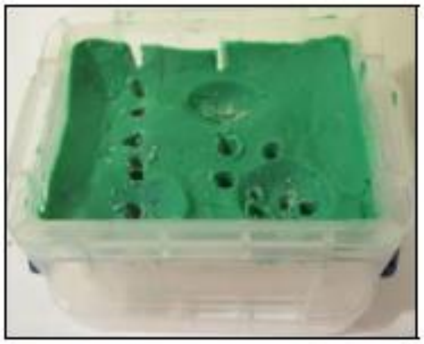
Students work in teams (of 4-5 students) to build sugar karst models to observe karst formation. Designate students into groups and instruct them to build a feature of the recharge zone to model and observe how fractures, faults, and sinkholes affect groundwater transport. Students will answer questions before and after the experiment. Vocabulary words such as recharge zone, fractures, faults, and sinkholes will not be covered until after the students have completed the experiment.

Circulate from group to group and ask students questions to assess understanding. Have students present their models and key findings to the other groups.

*Students will use data sheet (attached below) to write observations and answer questions. Experiments should look like this:

Sugar karst model of a fracture.

Sugar karst model of fault



Sugar karst model of sinkholes

End of First day

Explain

Review the explore activity as an engagement on day two.

For the Explore activity: Students will have the opportunity to see all of the models and share their results with the class in a discussion about how karst aquifers form in limestone, how the recharge feature they modeled (fracture, fault, or sinkholes) affects cave development, and how manipulating variables affected their results

Probing questions: What do the sugar cubes represent? What does the clay represent? What happened inside of the model? How is limestone similar to and different from the sugar cubes? Discuss connections between the Engage activity and Explore activity and strengths and limitations of the models. Go over these questions with the class during discussion.

Tell students to compete the notes page before showing lecture. Students should write their own definitions of the features of a recharge zone, in addition be able to identify where in the US Karst areas and aquifers are located. .Probing questions to asked the students are located in the notes section of each slide.Show the students the lecture:

https://docs.google.com/presentation/d/1sQdG_xQapFXz6EF4rUz_t_kUQAoV67xe66NrZtCQiDU/edit?usp=sharing

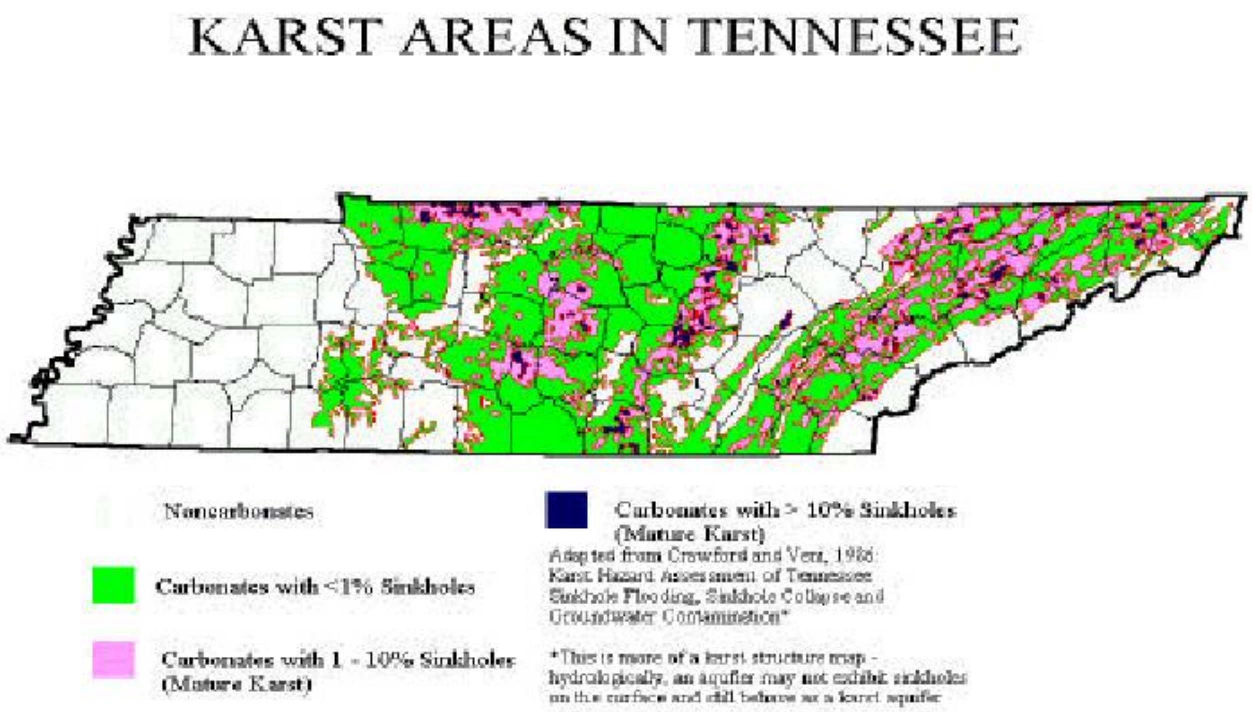
Have students take note of actual definition and discuss similarities and differences from their own definitions.

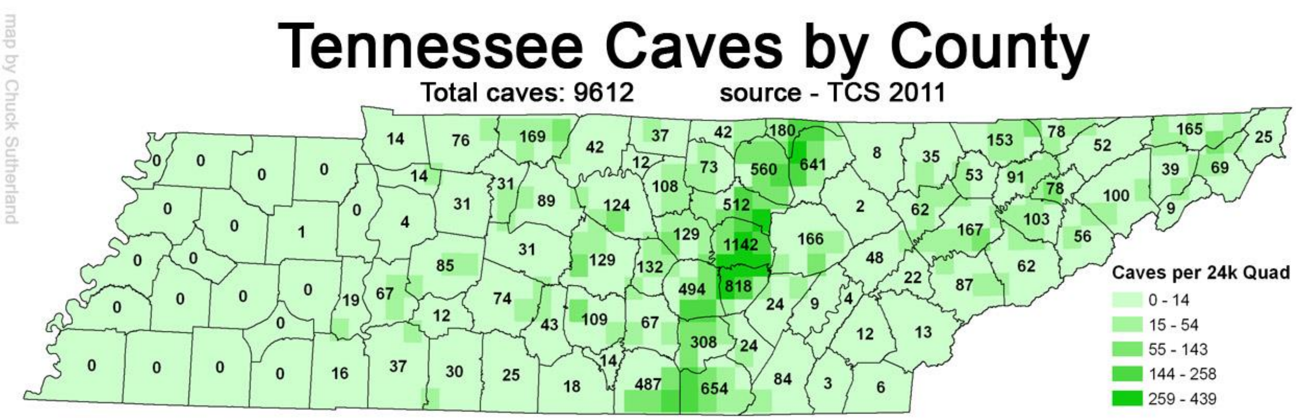
Elaboration:

Questions will also be asked in class discussion:

How does this lab relate to Tennessee? Where do we have karst topography?

Can relate question back to the map of the USA...Show to students from the Powerpoint





How Might pollution enter the topography? What will happen if there was a flood in the region?

Answer: Pollution and water percolates into the ground through the fractures and faults and sinkholes. Flood waters could cause more sinkholes in the area etc.

Assessment:
Exit Ticket:

[redacted]	What are two necessary parts of recharge features? How do recharge features relate to aquifers?

Name: Date:

A Look Inside the Holes

Intro: Understanding Karst is important since 10% of the Earth's surface is occupied by karst landscape and much of the world's population depends upon water supplied from karst aquifers. In Tennessee, our karst landscape is covered in recharge features like caves, faults, fractures and sinkholes.

Consider the following before you begin:

A. In your own words, what is Karst topography?

B. What do you think a recharge feature does?

C. How does limestone dissolve to form these recharge features?

D. What is the chemical reaction of karst limestone dissolution?

Building your own karst model:

Your group will build a sugar karst model to observe how sinkholes and caves are formed in limestone. Your group will be assigned to model one of the following features of the recharge zone to see how fractures, faults and sinkholes affect cave development.

<u>Groups 1&2: Model a fracture (a break or crack in rock):</u>

1. Fill the small rectangular container with two layers of sugar cubes (tightly packed).
2. Flatten a layer of clay on top of the sugar cubes. Seal the clay to the edges of the container creates an impermeable layer). Create a fracture by cutting through the clay with a Popsicle stick (make sure fractures is wide enough for water to flow through).

<u>Group 3&4: Model a fault (a fracture in rocks where one rock body slides past another):</u>

1. Fill the small rectangular container with two layers of sugar cubes (tightly packed) and add a layer of clay over half of the model.
2. Flatten a layer of clay on the half of the model that has two layers of sugar cubes and seal the clay to the edges of the container (make sure the clay is level. Do not use any clay where there are three layers of sugar cubes. In this model, the layer without clay moved relative to the layer with clay. Both sides of the fault originally had a clay-rich layer of soil, but the uplifted layer was more exposed to erosive forces so the clay-rich soil eroded away leaving the limestone (sugar) exposed to the surface.

Group 5&6: Model Sinkholes (depressions in the surface):

1. Fill the small rectangular container with two layers of sugar cubes (tightly packed).

2. Flatten a layer of clay on top of the sugar cubes and seal the clay to the edges of the container (this creates an impermeable layer). Press down on the clay with a finger to form a depression. Next poke a toothpick through the depression and wiggle it around to make a sinkhole large enough for water to flow through. You may make a few large sinkholes or many small sinkholes (make sure some are near the edge of the container so you can see how they affect cave development and recharge to the aquifer).

All Groups: Show the model to your teacher to see if any modifications need to be made before proceeding with the following steps.

1. Add a couple of drops of food coloring (representing contamination) to the model then "rain" across the entire surface of your model by slowly adding 5 ml of water with a pipette. Observe and document observations for trial 1 on the next page. Add another 5 ml water. Observe and document observations for trial

2. Add another 5 ml water. Observe and record observations for trial 3. 2. Present your model and key findings to the other groups.

Data Sheet

Which recharge feature (fracture, fault, or sinkholes) did your group model?

Type of Recharge Feature: ___________________________________

Draw your model and record observations after each trial:

Trial 1	Trial 2	Trial 3
Observations:		

Answer the following questions:

1. What do the sugar cubes represent? ______________________________
2. What does the clay represent? ___________________________________
3. What happened inside of the model?

   ____
   ____
   ____
   ____
   ____

4. How is limestone similar to and different from the sugar cubes?

Similar:____
____
____

Different:____
____
____

Notes

Directions: To the best of your ability and using what you learned in the lab, write down a 1-2 sentence definition of the features of a recharge zone.

Fault:

____
____
____

Fracture:

____
____
____

Sinkhole:

____
____
____

Now let's look at the slides that have the actual definition. Write the definition on the screen down for each feature. Was yours correct? Close?

Fault:

____
____
____

Fracture:

Sinkhole:

Additional Notes:

Name: Key Date:

A Look Inside the Holes

Intro: Understanding Karst is important since 10% of the Earth's surface is occupied by karst landscape and much of the world's population depends upon water supplied from karst aquifers. In Tennessee, our karst landscape is covered in recharge features like caves, faults, fractures and sinkholes.

Consider the following before you begin:

C. In your own words, what is Karst topography?
Student answers will vary.

D. What do you think a recharge feature does?
Student answers will vary.

D. How does limestone dissolve to form these recharge features?

When acids meet limestone; Limestone is a calcium carbonate rock. The carbonate reacts with the H ion and creates a chemical reaction. Limestone is not very soluble so the rocks don't dissolve very quickly. If you add an acid however you add Hydrogen Ions (H^+) which will react with the carbonate to form hydrogen carbonate HCO_3^- ions which are very soluble in water, and the limestone will dissolve.

E. What is the chemical reaction of karst limestone dissolution?

The chemical reactions that occur to cause dissolution of karst:

$CaCO_3 + H_2O + CO_2$ Æ $Ca^{2+} + 2\ HCO_3^-$

Building your own karst model:

Your group will build a sugar karst model to observe how sinkholes and caves are formed in limestone. Your group will be assigned to model one of the following features of the recharge zone to see how fractures, faults and sinkholes affect cave development.

Groups 1&2: Model a fracture (a break or crack in rock):

3. Fill the small rectangular container with two layers of sugar cubes (tightly packed).
4. Flatten a layer of clay on top of the sugar cubes. Seal the clay to the edges of the container creates an impermeable layer). Create a fracture by cutting through the clay with a Popsicle stick (make sure fractures is wide enough for water to flow through).

Group 3&4: Model a fault (a fracture in rocks where one rock body slides past another):

3. Fill the small rectangular container with two layers of sugar cubes (tightly packed) and add a layer of clay over half of the model.
4. Flatten a layer of clay on the half of the model that has two layers of sugar cubes and seal the clay to the edges of the container (make sure the clay is level. Do not use any clay where there are three layers of sugar cubes. In this model, the layer without clay moved relative to the layer with clay. Both sides of the fault originally had a clay-rich layer of soil, but the uplifted layer was more exposed to erosive forces so the clay-rich soil eroded away leaving the limestone (sugar) exposed to the surface.

Group 5&6: Model Sinkholes (depressions in the surface):

3. Fill the small rectangular container with two layers of sugar cubes (tightly packed).
4. Flatten a layer of clay on top of the sugar cubes and seal the clay to the edges of the container (this creates an impermeable layer). Press down on the clay with a finger to form a depression. Next poke a toothpick through the depression and wiggle it around to make a sinkhole large enough for water to flow through. You may make a few large sinkholes or many small sinkholes (make sure some are near the edge of the container so you can see how they affect cave development and recharge to the aquifer).

All Groups: Show the model to your teacher to see if any modifications need to be made before proceeding with the following steps.

1. Add a couple of drops of food coloring (representing contamination) to the model then "rain" across the entire surface of your model by slowly adding 5 ml of water with a pipette. Observe and document observations for trial 1 on the next page. Add another 5 ml water. Observe and document observations for trial

2. Add another 5 ml water. Observe and record observations for trial 3. 2. Present your model and key findings to the other groups.

Data Sheet

Which recharge feature (fracture, fault, or sinkholes) did your group model?

Type of Recharge Feature: Depends on Group

Draw your model and record observations after each trial: Models/ Observations will vary

Trial 1	Trial 2	Trial 3
Observations:		

Answer the following questions:

5. What do the sugar cubes represent? Limestone
6. What does the clay represent? Impermeable Layer
7. What happened inside of the model?
   Answers will vary depending on model

____

____

____

8. How is limestone similar to and different from the sugar cubes?

Similar: Have pores, soluble, colors are similar, coarse texture etc.

Different: One is food, one is not, one is always a cube, limestone can vary in shape etc.

Notes

Directions: To the best of your ability and using what you learned in the lab, write down a 1-2 sentence definition of the features of a recharge zone. Student answers will vary.

Fault:

Fracture:

Sinkhole:

Now let's look at the slides that have the actual definition. Write the definition on the screen down for each feature. Was yours correct? Close? Notes will be taken from the powerpoint

Fault:

Fracture:

Sinkhole:

Additional Notes:

Students can write notes about Aquifers, recharge zones, Karst Topography here if needed from the powerpoint.