SPICE | Science Projects Integrating Computing and Engineering

Name:______________________________

Walker Water Runoff Challenge

Student Notebook

Class Discussion: What do engineers do?

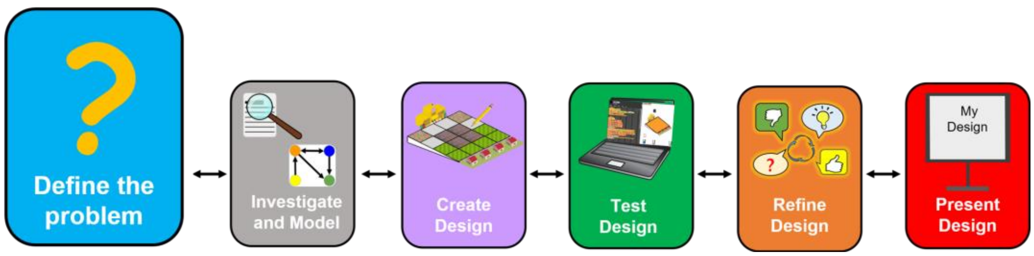
Talk to a partner about your ideas, and then share out with the class.

Example responses: They build things, design things. More sophisticated answers: They solve problems that address human needs or wants. These solutions often involve science.

You are going to be engineers and help Walker Upper Elementary school.

One of the first steps of engineering is to figure out the problem to solve.

Engineering Design Map



After watching the video as a class, help define the problem at Walker:

1.1. What problems are there at Walker Upper Elementary School?

(Examples)There is too much standing water when it rains. Areas of the school become unusable.

Runoff - sediment and pollution pass into the stream and the soccer field becomes unusable when it rains

1.2. How do you think Walker's problems affect the students and teachers?

(Examples) Students cannot use facilities when there is too much standing water.

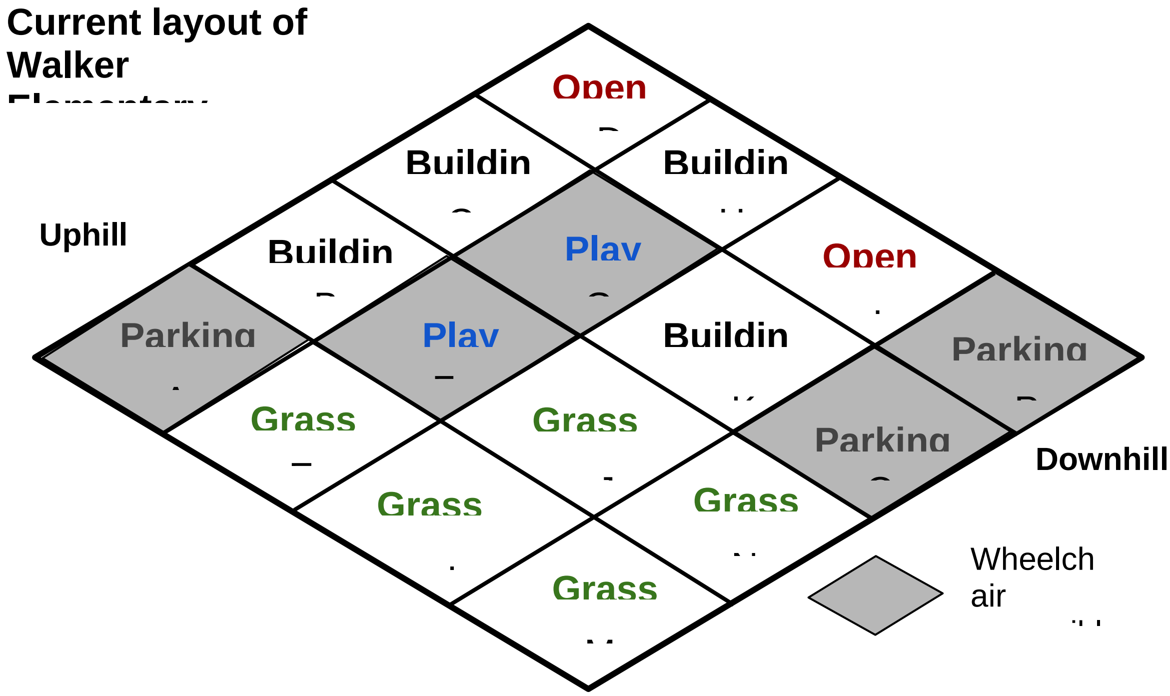
Teachers cannot park in parking lots.

Students and guests who use wheelchairs cannot access all of the buildings from the parking lot (Walker is not accessible)

1.3. How do you think Walker's problems affect the environment?

(Examples) Rainwater can collect pollution on the ground surface and carry it to the stream near the school. This water can carry pollution to other water sources, which can affect animal and plant life.

In this project, you will create designs for different spaces and uses at Walker. Use the following diagram to help you understand the current layout of Walker School.



1.4. For Walker School **now,** how many squares are for:

Building	Grassy field	Play area	Parking	Accessible

4	5	2	3	5

The students and teachers at Walker have the following needs:

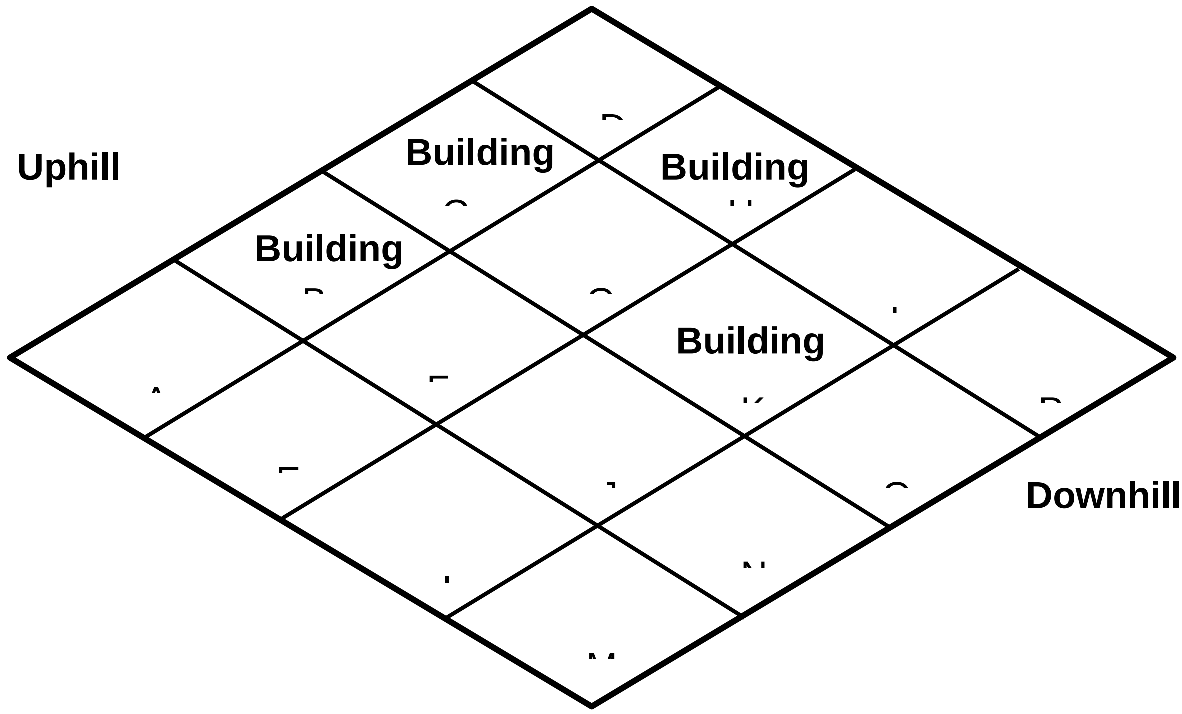
Building	Grassy field	Play area	Parking	Accessible
4 squares (B, C, H, K)	At least 4 squares	At least 2 squares	At least 3 squares	At least 6 accessible squares

1.5. Does the current design meet the needs of the students and teachers?

Yes **No**

Can you come up with a different plan that meets the needs of the students and teachers?

1.6. Use the blank grid below to make a plan by writing **grass**, **play**, and **parking** in the squares. Shade the squares you think should be wheelchair accessible:



1.7. For your new plan**,** how many squares are for:

Building	Grassy field	Play area	Parking	Accessible
Responses will vary. Ideally their solution meets the criteria.				

Remember, the students and teachers at Walker have the following needs:

Building	“Grassy” field	Play area	Parking	Accessible
4 squares (B, C, H, K)	At least 4 squares	At least 2 squares for hardcourt, 1 square for swings	At least 3 squares	At least 6 accessible squares

1.8. Does your design meet the needs of the students and teachers?

Yes   No (Responses will vary)

Project Criteria

We just explored the students' and teachers' needs for different areas. But there were other criteria mentioned in the video. Here is a complete list of project criteria:

A. The students and teachers at Walker have the following **needs:**

Building	Grassy field	Play area	Parking	Accessible
4 squares (B, C, H, K)	At least 4 squares	At least 2 squares for hardcourt, 1 square for swings	At least 3 squares	At least 6 accessible squares

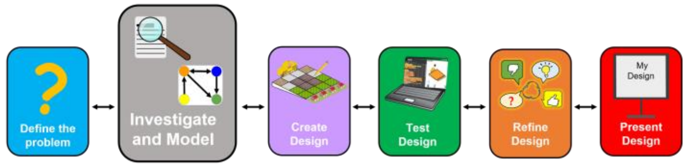
B. Your design needs to **minimize water runoff** after **heavy rains** (2 inches of rainfall).

C. Your design needs to stay **under budget of $750,000.**

Closing question: What is the problem we are trying to solve? Draw a picture of the problem below.

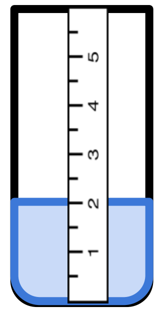
Drawings will vary. This prompts aims to elicit students' own ideas of the problem

Lesson 2: How much does it rain at Walker?



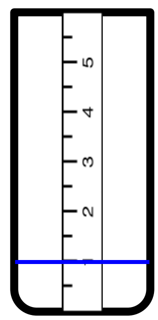
Discussion Question: How do we know how much water falls when it rains?

A rain gauge is used to measure the amount of rain that falls. Usually rain is measured in inches. For example, the rain gauge on the right shows **2 inches** of rain that fell in a heavy rainstorm:

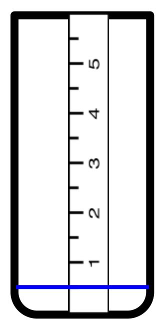


2.1. Fill in rain gauges

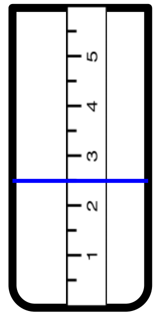
A. A moderate rain fell on Walker with a total of 1 inch of rain. Draw what the rain gauge would look like:



B. A moderate rain fell on Walker with a total of 0.5 inch of rain. Draw what the rain gauge would look like:

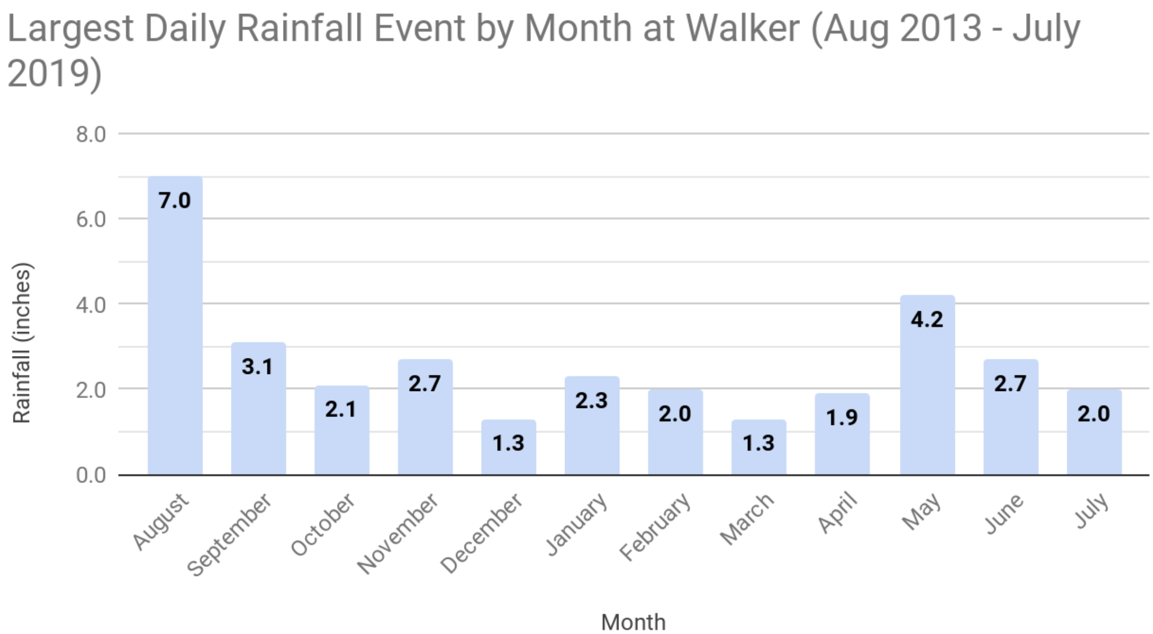


C. A heavy rain fell on Walker with a total of 2.5 inches of rain. Draw what the rain gauge would look like:



2.2. How much rain does Walker get?

Look at the rainfall chart below.



A. Looking at the graph:

Which month(s) had the largest one-day rainfall? _____August____________

Which month(s) had the smallest one-day rainfall? ___December, March_____

Your design must reduce water runoff after a heavy storm that rains **at least 2 inches**.

B. If your design is built for a heavy storm of 2 inches, how many months have rainfall events 2 inches or more?_______9_____________

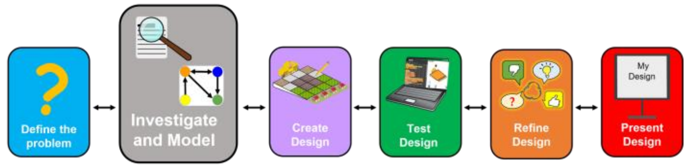
C. How many months have rainfall events under 2 inches?_________3___________

2.3. Closing question. Why do you think we need to design for at least 2 inches of rainfall?

In most months there is likely to be a storm that drops at least 2 inches of rain. We want to help make sure that every month does not have a storm that makes parts of the school unusable.

Lesson 3: Where does the rain go?

Discussion Question: When it rains, where does the rain go?



3.1. Draw your best ***prediction*** below of where rain goes. A **prediction** says what you *think* will happen based on observation.

Drawings will vary. This prompts aims to elicit students' own ideas of the problem. Student drawings will vary from drawings that aim to depict visually the path of rainfall, to those that represent the flow of water more abstractly (more like a scientific model), such as using arrows. It is not expected that students pictures here will be explanatory in a scientific sense.

3.2. Explain your drawing.

Responses will vary.

When it rains, some water runs off.

Students may represent absorption, drainage, or evaporation. They may have different ways of representing the volume of flow, for example by the size of the arrow or the number of arrows.

3.3 Investigation: Make it rain!

Go outside and pour water to make it rain. You will need:

- A large container of water
- A small container for pouring
- Your notebook

Record your observations:

Pick a ground surface.	Pour **a very small amount of water on the surface**. What happens to the water?	Pour **a lot of water on the surface**. Does anything different happen?
Surface #1: *will vary*	*I observe that the water…* *Students may observe that a small amount of water is absorbed into the ground*	*I observe that the water…* *Students may observe that some water is absorbed into the ground and some remains on the surface. Depending on the material, it may all be absorbed.* *(note any differences from the small amount)*
Surface #2: *will vary*	*I observe that the water…* *Students may observe that a small amount of water is absorbed into the ground*	*I observe that the water…* *Students may observe that some water is absorbed into the ground and some remains on the surface. Depending on the material, it may all be absorbed.* *(note any differences from the small amount)*

3.4. Look at observations from other students. List something that another student observed that you didn't observe.

A student may have tested 2 similar materials, such as concrete and asphalt, or grass and dirt. This would not enable students to contrast the materials. Consulting with another student enables them to see how a high-absorption material (e.g., grass) may behave differently from a low-absorption material (e.g., concrete)

3.5. Based on your observations, explain where rainwater goes after it hits the ground.

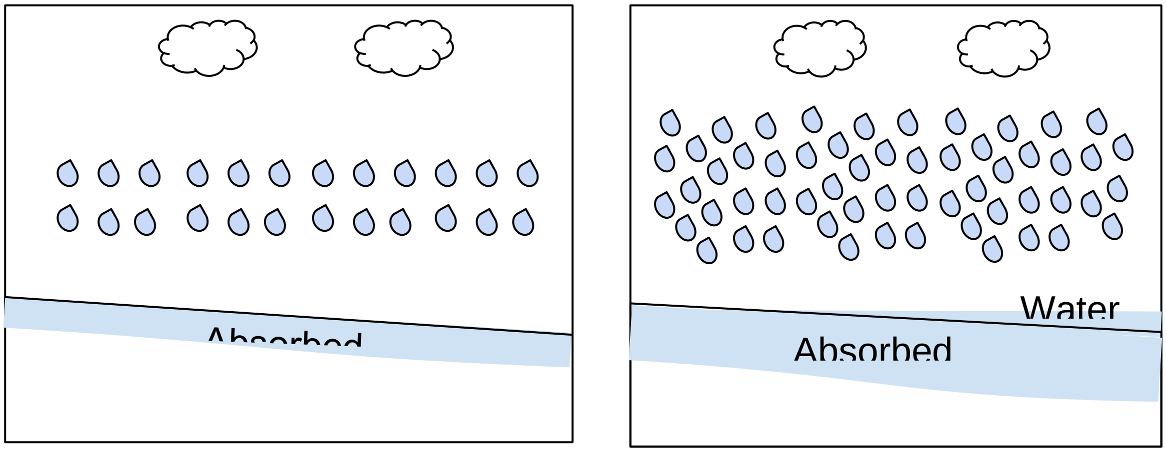
Ideally students are able to observe that, depending on the material, water can soak into the ground, or remain on the surface and flow downhill. Some students may not have opportunities to observe this from their own tests.

3.6. Based on your observations, explain how water flows differently on different surfaces.

Ideally, students are able to observe that less water is absorbed into some materials than others (or conversely more water remains on the surface of some materials than others).

3.7. What is water runoff?

You need to reduce ***water runoff*** at Walker. Every surface material can **absorb** different amounts of water. If the total rainfall is more than the surface can absorb, the rest of the water stays on the surface and runs off downhill. We call this **water runoff**.



(a) All rainfall is absorbed into

(b) The ground has absorbed

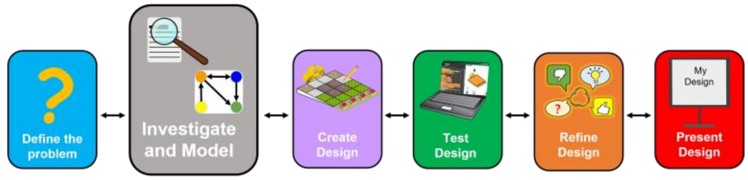
Using what you and your classmates observed, and what you have read above, revise what you drew in 3.1. Where does all the rainwater go?

Drawings will vary. Students will represent water flow in different ways. Ideally students are representing both the absorption of water into the surface as well as the water that is not absorbed and remains on top of the surface. Sophisticated students may attempt to contrast 2 types of materials in the drawings (more absorption vs. less absorption).

3.8. Closing question. How is this picture different from what you predicted in 3.1?

Responses will vary. Students should incorporate what they observed from the investigation as well as information from 3.7 above.

Lesson 4: How can we make a model of water runoff?



4.1. What is a model?

Give an example of a model from your daily life: Examples: model airplane or train, human body model, globe

What is it a model of? Examples: the real life things the models represents, such as airplane or train, a person, the Earth

Why is this model needed? Examples: It shows what things look like. It shows how things work.

Discussion: Share your example with the class. What makes something a model?

See teacher lessons for questioning and discussion approaches. Highlight especially how models include some things but leave other things out. Models usually aim to represent a particular aspect of the thing being represented, rather than everything about it

4.2. Models in science

A science model **explains how we think something happens** or **predicts what we think will happen.** When making models, **we choose to include things that are most important to explain** (and leave out other things).

Remember our engineering challenge:
To design the ground surface of Walker School to minimize water runoff.

- We will make models of the **ground surface of Walker School**.
- Your models will **explain and predict how water flows**. (All water has to go somewhere.)
- These models will help us **test how well different school ground designs reduce runoff**.

4.3. Draw a runoff model

Model requirements:

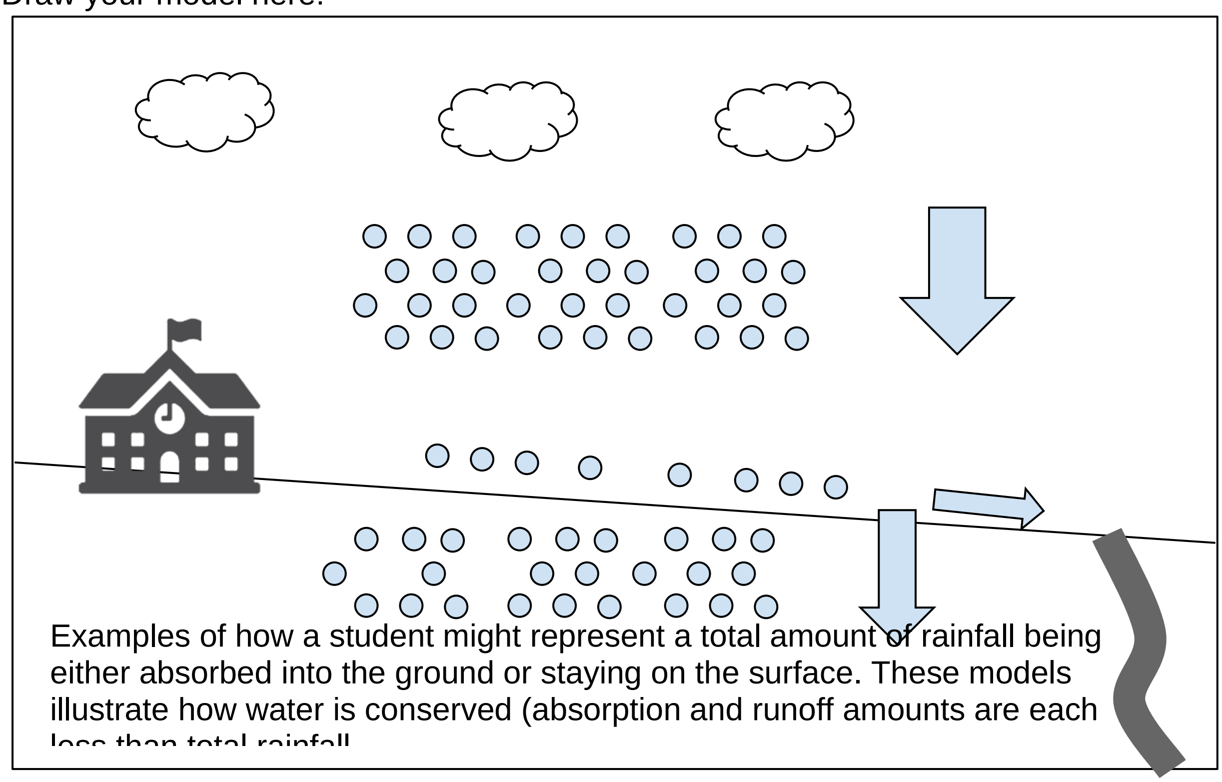
Your model should show **all 3 types of water flow** in and out of the ground surface:
- Rainfall
- Absorption to the ground (soaking in)
- Surface runoff (downhill)

Your model should also show **how much** of these types of water flow there is.

Here are some ways you could show water flow. Use one, more than one, or invent your own way!

arrows of different sizes and directions | water drops | rain gauge | words

Draw your model here:



4.4. Compare models. Find a partner and compare your model with another student.

How did they show different **types** of water flow? (arrow, rain gauge, words, etc.)

Responses will vary but should highlight ways that students use symbols differently to represent rainfall, absorption, and runoff, such as arrows or droplets.

How did they show different **amounts** of water flow? (bigger arrows, more arrows, etc.)

Responses will vary but should highlight ways that students use symbols differently to represent the amounts of rainfall, absorption, and runoff, such as bigger arrows, more droplets, etc..

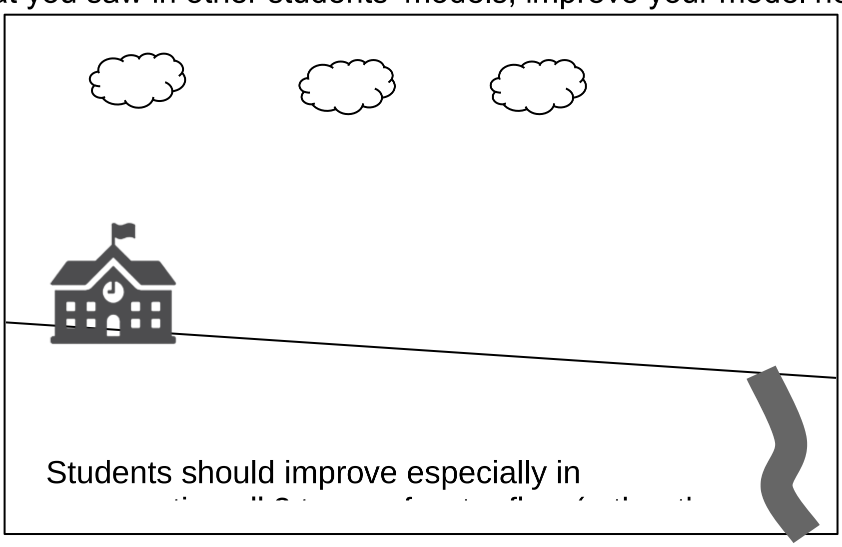
What is similar and different about your models?

Similarities: responses will vary

Differences: responses will vary

4.5. Improve your model.

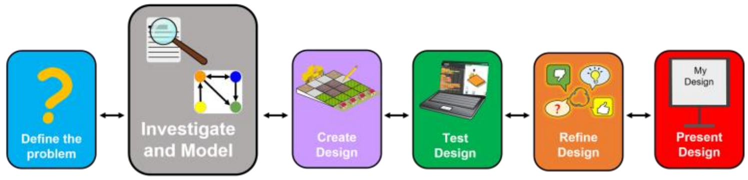
Based on what you saw in other students' models, improve your model here:



4.6. Closing discussion. What are the best ways to show how water flows? What are we including in our model? What are we leaving out?

The model includes rainfall, absorption and runoff. The model leaves out other things like evaporation or other methods of drainage. It leaves out the complexity of having different surfaces on the school.

Lesson 5: How can our model help us predict the amount of water runoff?



5.1. Imagine a rainstorm has just passed. The storm has dropped **3 inches of rainfall**!

But the ground surface can **absorb at most 1 inch** of water. Where does the water go?

A. How much rain will be **absorbed**? ____1 inch________ inches

Explain how you know:

The surface absorbs all it can, which is 1 inch.

B. How much rain will be **runoff**? _____2________ inches

Explain how you know:

Out a total of 3 inches of rainfall, just 1 was absorbed. The rest remained on top of the surface, which is runoff. 3 inches – 1 inch = 2 inches

The most amount of water a surface material can absorb is called the **absorption limit**.

If the rainfall is **more** than the absorption limit, the rest of the water stays on the surface and becomes runoff.

5.2. Predicting water runoff

Now you are going to use the model you built in 4.5 to ***predict*** how much runoff there will be after different amounts of rain. Remember, you need to show **total rainfall**, **water absorbed**, and **runoff** in your models.

A. How will you show different types of water flows? (arrows, raindrops, etc.)

responses will vary according to how students drew models in lesson 4.

B. How will you show different amounts of water flows? (bigger arrows, more, etc.)

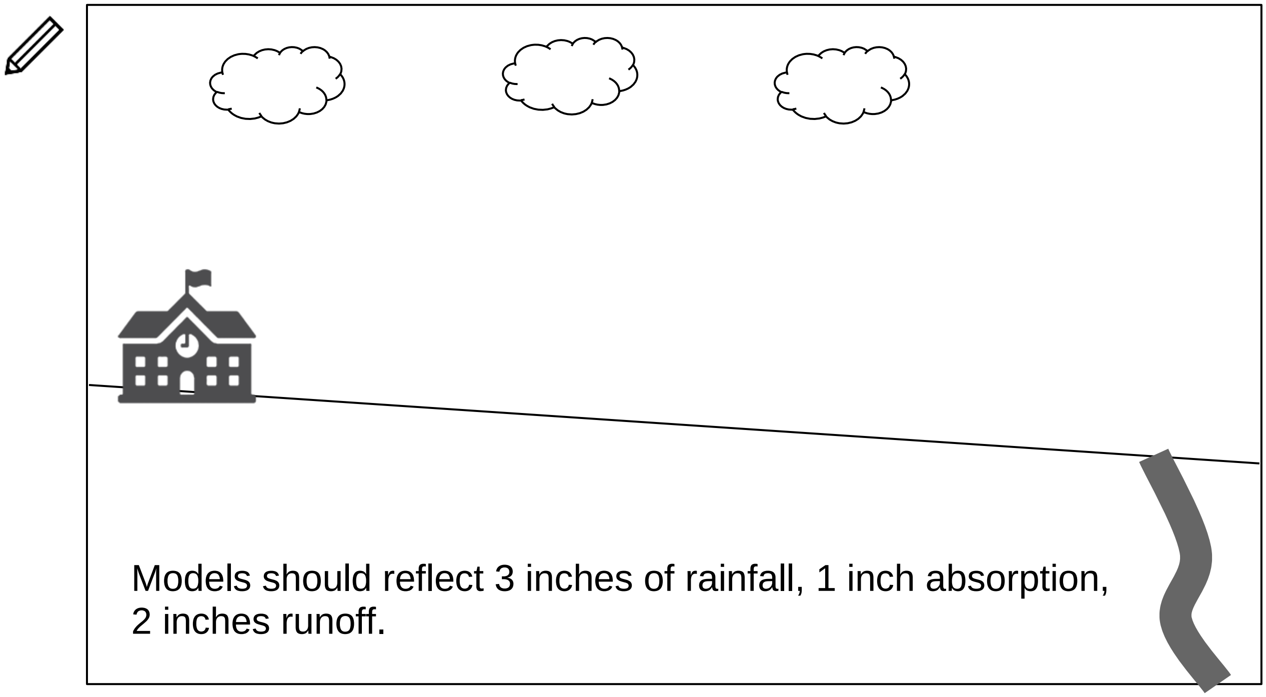
responses will vary according to how students drew models in lesson 4.

5.3. Predict the amount of absorption and runoff in each scenario using your model:

What if there are **3 inches of rainfall**, and the ground's **absorption limit is 1 inch**? Draw a model that shows the amount of rainfall, absorption, and predicts the amount of runoff.

Absorption limit: 1 inch

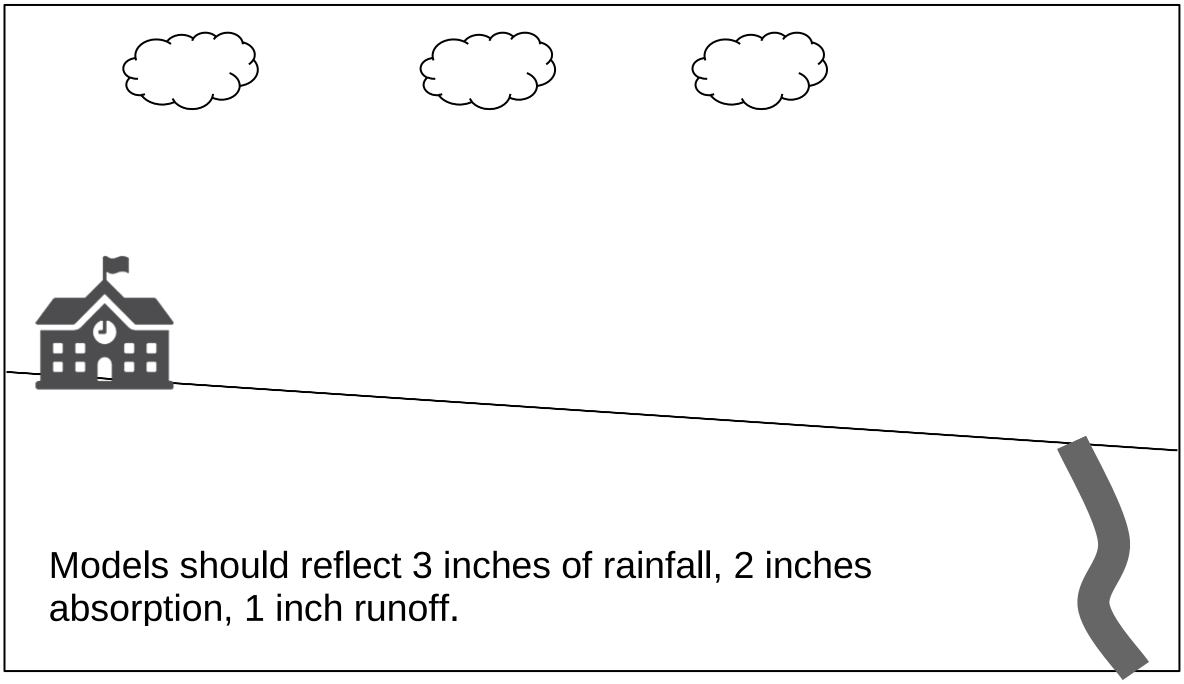
Total Rainfall: 3 inches **Total Absorption:**__1______ **Total Runoff**:___2_____



5.4**.** What if there are **3 inches of rainfall**, and the ground's **absorption limit is 2 inches**? Draw a model showing the amount of rainfall, absorption, and runoff.

Absorption limit: 2 in

Total Rainfall: 3 in **Total Absorption:**___2_____ **Total Runoff**:____1____

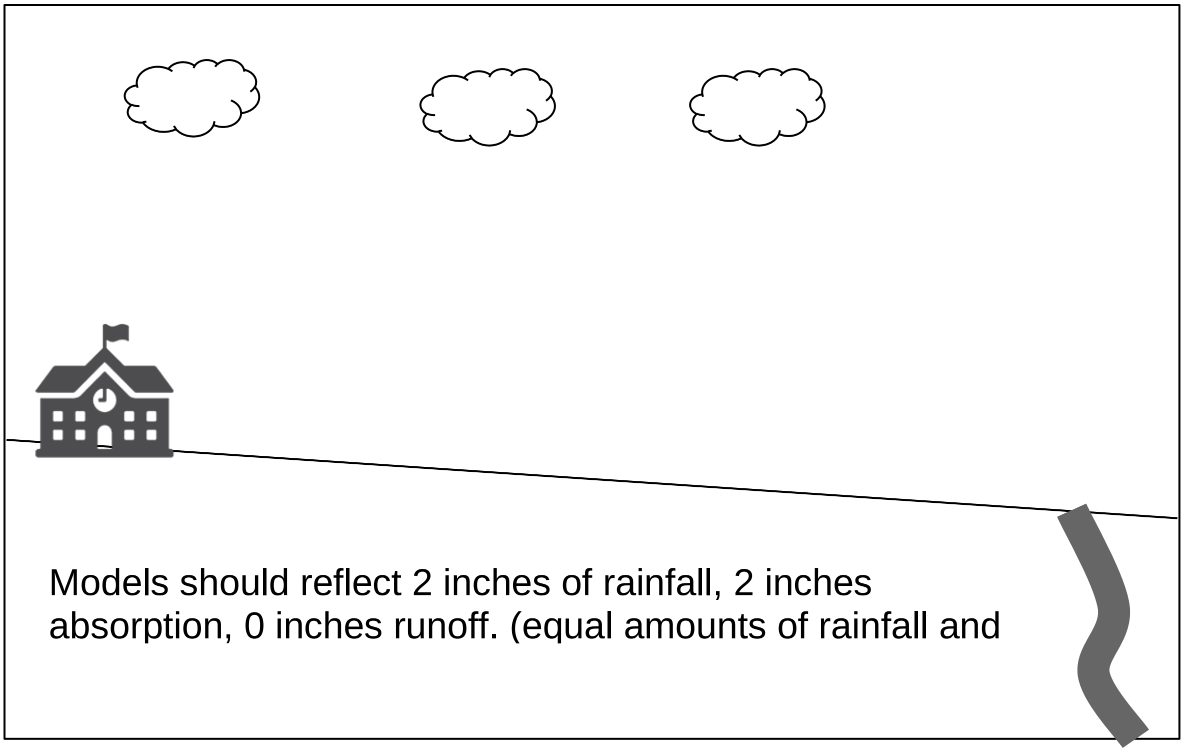


Models should reflect 3 inches of rainfall, 2 inches absorption, 1 inch runoff.

5.5. What if there are **2 inches of rainfall**, and the ground's **absorption limit is 2 inches**? Draw a model showing rainfall, absorption, and runoff (if there is any).

Absorption limit: 2 inches

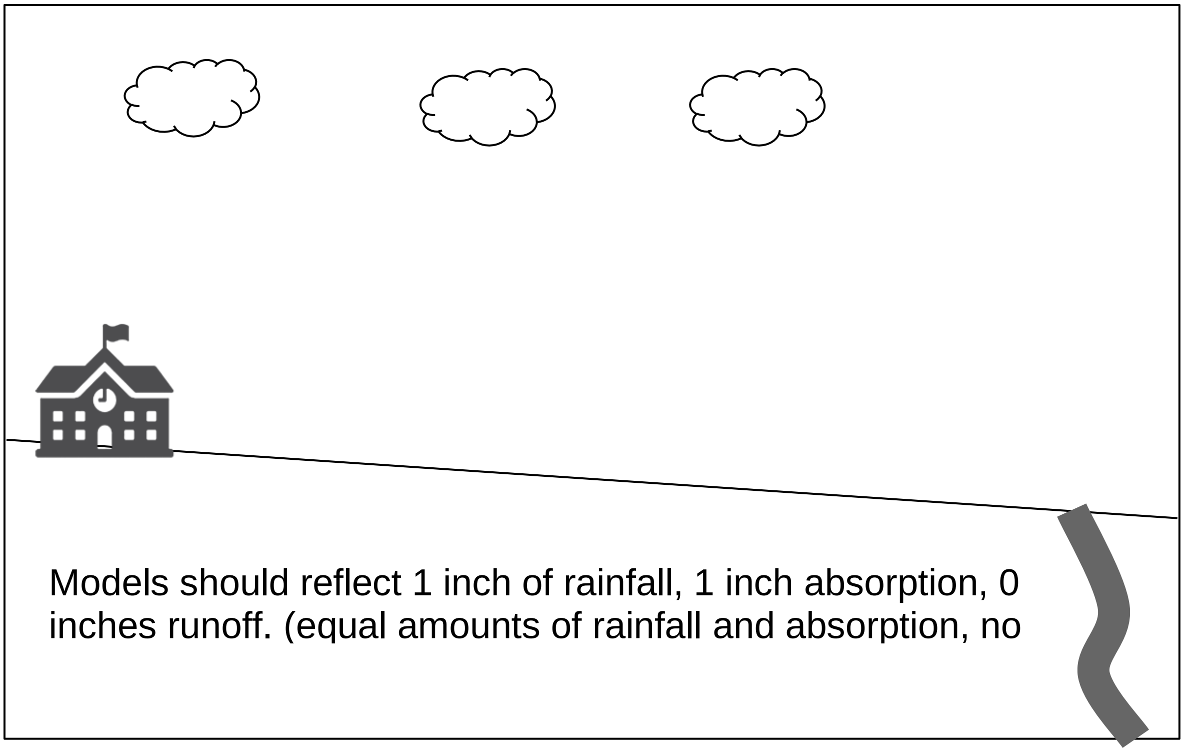
Total Rainfall: 2 inches **Total Absorption:**___2_____ **Total Runoff**:__0______



5.6. What if there is **1 inch of rainfall**, and the ground's **absorption limit is 2 inches**? Draw a model showing rainfall, absorption, and runoff (if there is any).

Absorption limit: 2 inches

Total Rainfall: 1 inch **Total Absorption:**____1____ **Total Runoff**:___0_____



5.7. Closing Question: How can you predict the total runoff if you know the total rainfall and the absorption limit?

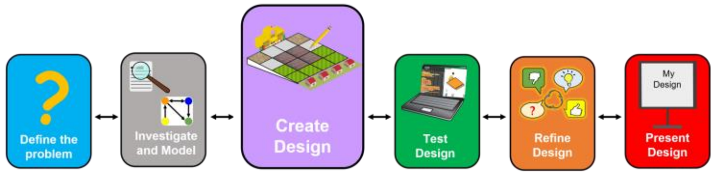
Students may articulate various aspects of the “rules” governing the relationships among rainfall, absorption, and runoff.

The ground will absorb an amount up to its absorption limit.

If it rains less than (or equal to) the absorption limit, all water will be absorbed.

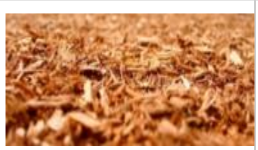
if it rains more than the absorption limit, the ground will absorb up to its absorption limit, and the remainder will be runoff.

Lesson 6: How can we design Walker to reduce water runoff?



Opening Discussion

The following table are the surface materials that you can choose to use for your designs. Which ones have you seen before, and where?

Material	Description	Picture	Absorption limit	Accessible ?	Cost
Standard Concrete	Poured material that hardens into a solid and seamless surface		Low	Yes (all students can use surface)	$37,500 per square
Permeable Concrete	Poured loosely packed material that looks and feels like concrete		High	Yes (all students can use surface)	$93,750 per square
Grass	Natural grass		High	No (not accessible to all students)	$18,750 per square
Artificial Turf	A carpet-like surface that looks and feels like grass		Medium	Yes (all students can use surface)	$112,500 per square
Wood Chips	Pieces of wood especially designed for playgrounds		High	No (not accessible to all students)	$37,500 per square

Poured Rubber	Rubber that can be poured into different shapes and colors.		High	Yes (all students can use surface)	$187,500 per square

Explore the materials:

6.1. What materials are best for parking lots?

Standard Concrete, Permeable Concrete

6.2. What materials are best for the “grassy” field?

Grass, artificial turf

6.3. What materials are best for the play area?

Grass, artificial turf, wood chips, poured rubber

6.4. What materials have high absorption limit (can absorb the most water)?

Grass, permeable concrete, wood chips, poured rubber

6.5. What materials have the lowest cost?

standard concrete, grass, wood chips

6.6. Are some materials good for absorption but not for cost? **<u>Yes</u>** **No**

Explain your answer: Permeable concrete and poured rubber are more expensive but have a high absorption limit.

6.7. Are some materials good for accessibility but not for cost? **<u>Yes</u>** **No**

Explain your answer:Permeable concrete, artificial turf, and poured rubber are more expensive but are wheelchair accessible.

6.8. Are some materials good for absorption, accessibility, AND cost? **Yes** **No**

Explain your answer: Materials that are good for both absorption AND accessibility tend to be the most expensive. (You have to pay for these features/properties.) Materials that are either absorbent OR accessible are less expensive.

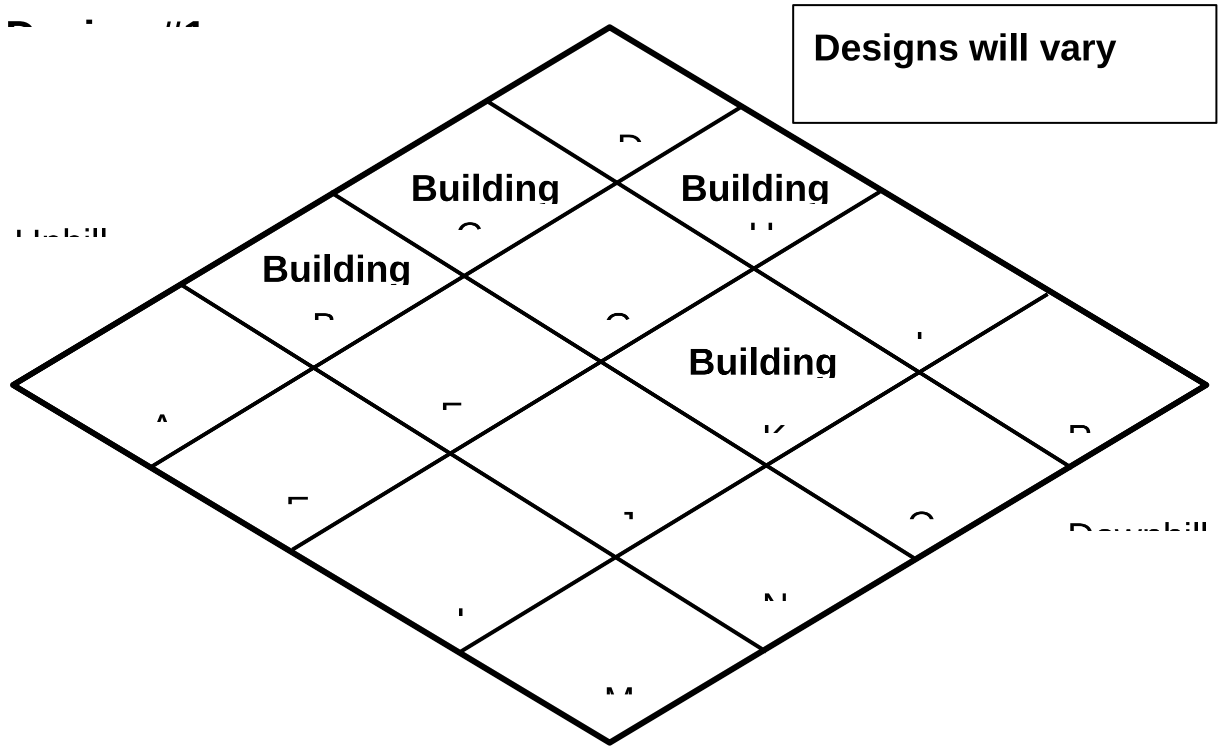
6.9. Make a design for Walker

Plan how you would like to redesign Walker. Remember the criteria on page 4:

- Minimize water runoff after heavy rains
- Stay under budget of $750,000.
- Meet criteria for “grassy” field, parking lot, play area, and accessible squares.

Label different materials in the following spaces to make **Design #1** for Walker.

Designs will vary



6.10. Check your design. How many squares does it have for each kind of area?

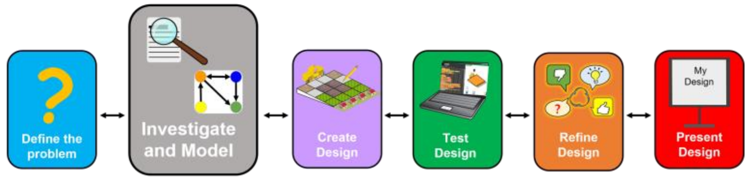
Building	“Grassy” field	Play area	Parking	Accessible
responses will vary				

Does your design meet the criteria? **Yes** **No** responses will vary

Closing Question: Why do we need a computer model to test our design?

Examples**:** We have a lot of things to calculate for a 16 square design--the cost, accessibility, and absorption limit of each material. We might also want to test many designs. Computers can help us test may designs more quickly.

Lesson 7: What language does the computer understand?



Opening discussion: What language does a computer understand?

7.1. TRUE/FALSE game (Whole class)

7.2. Play a dice game with your partner!

Instructions: We will play this game in pairs. Make sure you have a partner and start by deciding who will be PlayerA and who will be PlayerB in your group. Both players need to fill out the table in their notebooks.

For each game,

- Both partners roll dice and write down the values. PlayerA's dice is called DiceA and PlayerB's dice is called DiceB.
- Look at the instructions and decide whether each IF-THEN evaluates to TRUE or FALSE
- Based on which IF-THEN statement is TRUE, assign scores to PlayerA and PlayerB.

Game #1 Example

Instructions	DiceA value	DiceB value	TRUE/FALSE
Roll your dice			
IF DiceA is equal to 3, THEN (Set PlayerA_score to 1 Set PlayerB_score to 1)	5	3	FALSE
IF DiceA is less than 3, THEN (Set PlayerA_score to 3 Set PlayerB_score to 0)			FALSE
IF DiceA is greater than 3, THEN (Set PlayerA_score to 0 Set PlayerB_score to 2)			TRUE

PlayerA_score = ____0______ PlayerB_score = _____2_____

Game #2 Example

Instructions	DiceA value	DiceB value	TRUE/FALSE
Roll your dice			
IF DiceB is equal to 5, THEN (Set PlayerA_score to 2 Set PlayerB_score to 2)	2	4	FALSE
IF DiceB is less than 5, THEN (Set PlayerA_score to DiceB Set PlayerB_score to 3)			TRUE
IF DiceB is greater than 5, THEN (Set PlayerA_score to DiceB-DiceA Set PlayerB_score to DiceA)			FALSE

PlayerA_score = __4_______ PlayerB_score = ___3________

Game #3 Example

Instructions	DiceA value	DiceB value	TRUE/FALSE
Roll your dice			
IF DiceA is equal to DiceB, THEN (Set PlayerA_score to 3 Set PlayerB_score to 4)	2	2	TRUE
IF DiceA is less than DiceB, THEN (Set PlayerA_score to 1 Set PlayerB_score to 2)			FALSE
IF DiceA is greater than DiceB, THEN (Set PlayerA_score to 5 Set PlayerB_score to 3)			FALSE

PlayerA_score = ____3_____ PlayerB_score = ______4_____

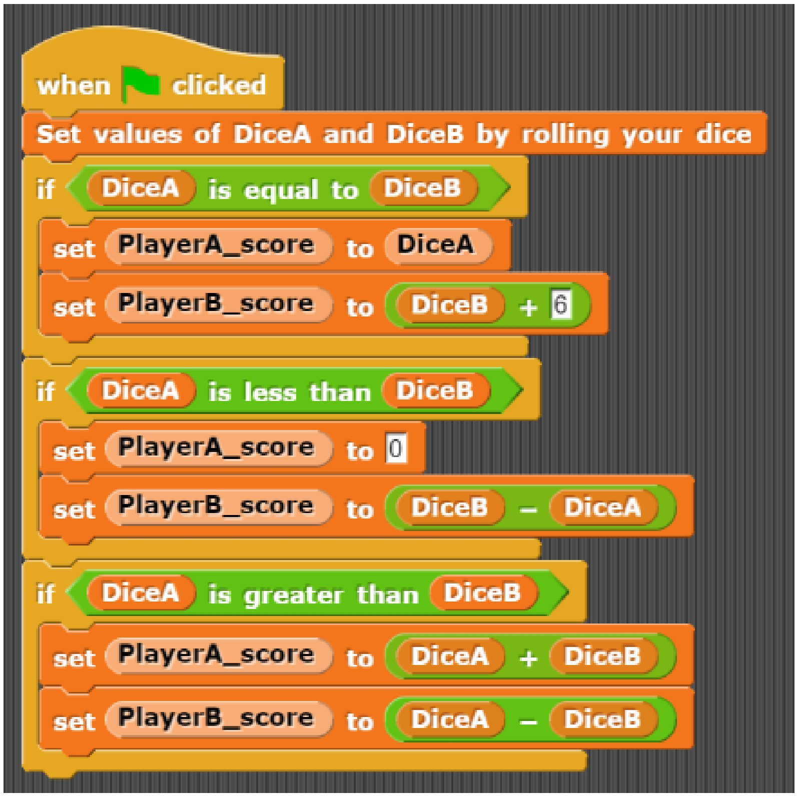
Game #4 Example

Instructions	DiceA value	DiceB value	TRUE/FALSE
Roll your dice			
IF DiceA is equal to DiceB, THEN (Set PlayerA_score to 3 Set PlayerB_score to DiceA-1)	5	1	FALSE
IF DiceA is less than DiceB, THEN (Set PlayerA_score to DiceA+3 Set PlayerB_score to DiceB+1)			FALSE
IF DiceA is greater than DiceB, THEN (Set PlayerA_score to 2 Set PlayerB_score to DiceA-DiceB)			TRUE

PlayerA_score = __2______ PlayerB_score = __4_________

7.3. Play a dice game by reading code (whole class activity)

This game is written in the language you will use to build your computer runoff model.

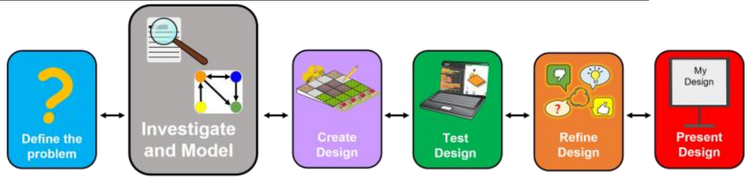


You will play the first 3 rounds as a class, then play 3 rounds with a partner. **Example**

	Dice variables		Score variables	
Round	**DiceA**	**DiceB**	**PlayerA_score**	**PlayerB_score**
1	4	5	0	1
2	5	1	6	4
3	3	3	3	9
4				

5				
6				

Lesson 8: Build a computer model to calculate runoff from different surfaces



8.1. Create test cases. In our model, wood chips have an absorption limit of 1 inch of rain. How much rain will be **absorbed** and will **run off** for different amounts of rainfall?

We will use these numbers as **test cases** for our computer model.

Rainfall	Absorption limit (wood chips)	Absorption and runoff
1 inch	1 inch	• Absorption: ___1_____ inches • Runoff: ___0____ inches
0.7 inches	1 inch	• Absorption: ___0.7_____ inches • Runoff: ___0____ inches
1.4 inches	1 inch	• Absorption: ___1_____ inches • Runoff: __0.4_____ inches

Test cases are numbers used to test whether a computer program is working correctly. You can use these values to test your computer model as you build it.

8.2. Make the rules for the model: Complete the 3 rules below that the computer can use to calculate total absorption and total runoff when it knows the total rainfall. **Circle a variable or value that makes each rule work.**

Rule #1. If the total rainfall **is equal to** the absorption limit:

- set total absorption to (circle one):

  total rainfall **absorption limit** 0 (zero) [both answers are correct]

- set total runoff to (circle one):

  total rainfall absorption limit **0 (zero)**

Rule #2. If the total rainfall **is less than** the absorption limit:

- set total absorption to (circle one):

  total rainfall absorption limit 0 (zero)

- set total runoff to (circle one):

  total rainfall absorption limit **0 (zero)**

Rule #3. If the total rainfall **is greater than** the absorption limit:

- set total absorption to (circle one):

  total rainfall **absorption limit** 0 (zero)

- set total runoff to: __**total rainfall – absorption limit**____ (write an expression)

8.3. Start building your computer model:

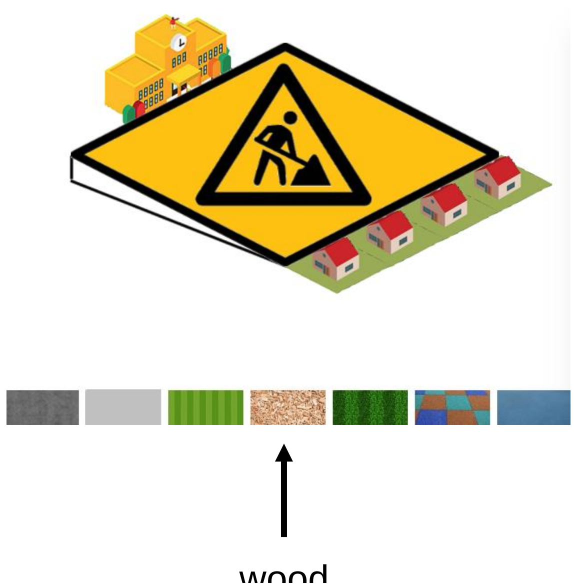
1. Login to the C2STEM system as instructed by your teacher.
2. Start building your model by adding the **when clicked** block
3. Set the amount of rainfall using the **set to** block. Drag a variable block or type in a value in each empty space.
4. Use the **Set absorption limit of the selected material** block to get the absorption limit of the material you are selecting.
5. Program **Rule #1** by dragging blocks from the left column. Use **set to** to assign variable values. Drag a variable block or type in a value in each empty space. Here are SOME of the other blocks you will need to use:

absorption limit   **if**   **is equal to**

When you have completed Rule #1, be sure to SAVE YOUR WORK!!!

8.4. Now <u>test</u> whether your program is working using the test case:

- Choose **wood chips**, which have an absorption limit of 1 inch



<u>Test rule #1:</u>

- Run your program with 1 inch of rainfall: 

.
- Move your mouse over the rain gauges to see the absorption and runoff. Record the results below.

Total absorption: ___1____ inches   Total runoff: ____0____ inches

- Does your model give the same result as your test case? **<u>Yes</u>**   No
- Explain why or why not: If the student has a correct model, the rain gauge for Total absorption will show 1 inch and the rain gauge for Total runoff will show 0 inch, the same result as the test case.

<u>Test rule #2:</u>

- Run your program with 0.7 inches of rainfall: 

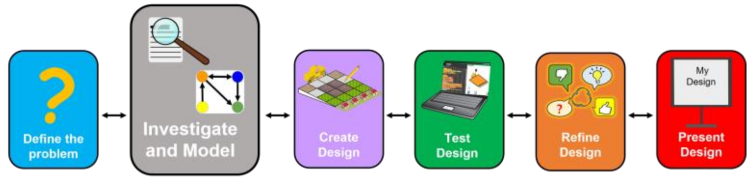
.
- Record results: Total absorption: _vary__ inches   Total runoff: _vary_ inches
- Does your model give the same result as your test case?   Yes   **<u>No</u>**
- Explain why or why not: If the student has a correct model, the rain gauges for Total absorption and Total runoff will NOT show the same result as the test case. Students have not yet programmed the code for this rule.

<u>Test rule #3:</u>

- Run your program with 1.4 inches of rainfall: 

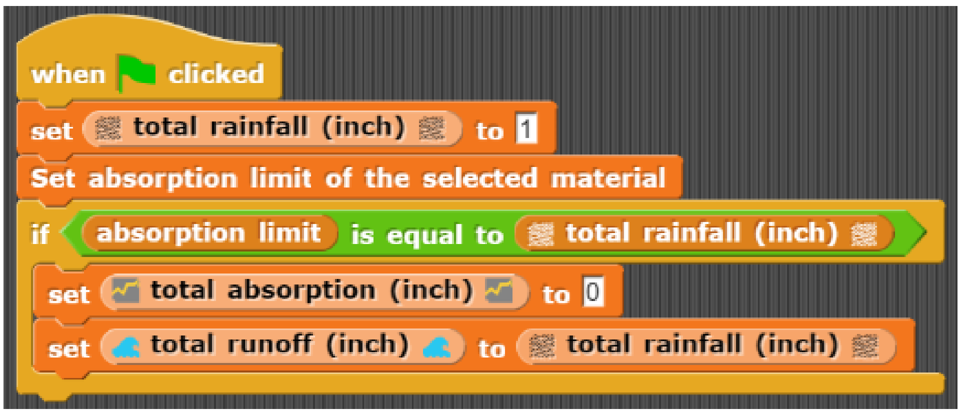
.
- Record results: Total absorption: _vary__ inches   Total runoff: _vary__ inches
- Does your model give the same result as your test case?   Yes   **<u>No</u>**
- Explain why or why not: If the student has a correct model, the rain gauges for Total absorption and Total runoff will NOT show the same result as the test case. Students have not yet programmed the code for this rule.

Lesson 9: Build a computer model to calculate runoff from different surfaces



Opening activity: Debug another student's program

Here is a program a student wrote for Rule #1 from yesterday, but **it does not give the correct results.**



Mistakes in a program are called **bugs**. Fixing a program so that it works correctly is called **debugging**. Explain what is wrong with this program and how to fix it.

There are two errors in the given program. First, when the absorption limit and the total rainfall are equal, the total absorption should be equal to either the total rainfall or the absorption limit. Second, the runoff should be 0.

9.1. Continue building your computer model:

- Login to the C2STEM system as instructed by your teacher. You programmed Rule #1 yesterday.
- Drag blocks into the program to make Rule #2, **if total rainfall is LESS than the absorption limit**.
- Here are SOME of the blocks you will need to use:

When you have completed Rule #2, be sure to SAVE YOUR WORK!!!

9.2. When you finish making Rule #2, test whether Rule #2 is working.

- Choose wood chips that have an absorption limit of 1 inch.
- Run your program using the **test cases** from yesterday. Record the absorption and runoff from your model below.
- **Your model should give you the same result as your <u>test case</u>.**

<u>Rule #1:</u>

- Run your program with 1 inch of rainfall: `set total rainfall (inch) to 1`.
- Record results: Total absorption: __1___ inches Total runoff: __0___ inches
- Does your model give the same result as your test case? **<u>Yes</u>** No

<u>Rule #2:</u>

- Run your program with 0.7 inches of rainfall: `set total rainfall (inch) to 0.7`.
- Record results: Total absorption: ___0.7_ inches Total runoff: _0___ inches
- Does your model give the same result as your test case? **<u>Yes</u>** No

<u>Rule #3:</u>

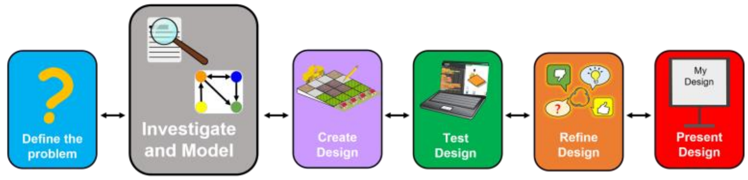
- Run your program with 1.4 inches of rainfall: `set total rainfall (inch) to 1.4`.
- Record results: Total absorption: __vary_ inches Total runoff: _vary__ inches
- Does your model give the same result as your test case? Yes **<u>No</u>**

9.3. Which rules work and which don't? Explain why.

Rules 1 and 2 should work because the code is completed for these rules. Rule 3 has not been completed, so it should not work.

If Rule #1 or #2 do not work, try to fix them. **Remember to SAVE YOUR WORK!!**

Lesson 10: Build a computer model to calculate runoff from different surfaces



10.1. Continue building your computer model:

- Login to the C2STEM system as instructed by your teacher. You programmed Rule #2 yesterday.
- Drag blocks into the program to make Rule #3 (rainfall is GREATER than the absorption limit).

10.2. Now test whether all the rules are working in your computer model.

- Choose wood chips that have an absorption limit of 1 inch.
- Run your program using the test cases, then record the absorption and runoff from your model below.
- **Your model should give you the same results as the test cases.**

<u>Rule #1:</u> For 1 inch of rainfall:

- Run your program with the following input: 

.
- Record the results below.

Total absorption: ___1____ inches Total runoff: ____0____ inches

- Does your model give the same result as your test case? **<u>Yes</u>** No

<u>Rule #2:</u> For 0.7 inches of rainfall:

- Run your program with the following input: 

.
- Move your mouse over the rain gauges to see the absorption and runoff. Record the results below.

Total absorption: ___0.7_____ inches Total runoff: ____0____ inches

- Does your model give the same result as your test case? **<u>Yes</u>** No

Rule #3: For 1.4 inches of rainfall:

- Run your program with the following input: `set total rainfall (inch) to 1.4`.
- Move your mouse over the rain gauges to see the absorption and runoff. Record the results below.

Total absorption: __1_____ inches Total runoff: ____0.4____ inches

- Does your model give the same result as your test case? **Yes** No

When you have completed Rule #3, be sure to SAVE YOUR WORK!!!

10.3. Bonus Challenge! Create a new test case.

- Your model should work with **any surface material**.
- Create test cases for artificial turf, which has an absorption limit of 0.6 inches. How much rainfall will you use to make sure all 3 rules in your model are working?

Test cases: Artificial turf **RESPONSES WILL VARY, EXAMPLES SHOWN**

Rule	Rainfall	Absorption limit (artificial turf)	Absorption and runoff
#1	0.6 inches	0.6 inches	• Absorption: __0.6____ inches • Runoff: ___0_____ inches
#2	0.3 inches	0.6 inches	• Absorption: ___0.3____ inches • Runoff: ___0_____ inches
#3	1 inch	0.6 inches	• Absorption: ___0.6__ inches • Runoff: __0.4____ inches

10.4. Now use your new test cases to test whether all the rules are still working.

Responses will vary. If students have done the model correctly, all the rules should work.

Rule #1: For _______ inches of rainfall:

- Total absorption: __________ inches Total runoff: __________ inches
- Does your model give the correct result? Yes No

Rule #2: For _______ inches of rainfall:

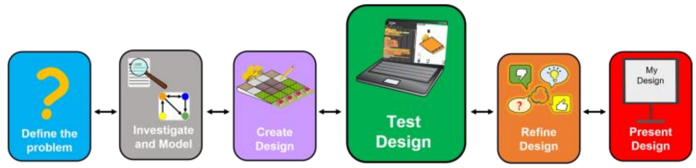
- Total absorption: __________ inches Total runoff: __________ inches
- Does your model give the correct result? Yes No

Rule #3: For _______ inches of rainfall:

- Total absorption: __________ inches Total runoff: __________ inches
- Does your model give the correct result? Yes No

Be sure to SAVE YOUR WORK!!!

Lesson 11: How can we test and improve our designs?



Discussion Question: How can we use our computer model to improve our designs?

The students and teachers at Walker have the following **criteria:**

Design criteria					
Building	**"Grassy" field**	**Play area**	**Parking**	**Accessible**	**Cost ($)**
4 squares (B, C, H, K)	At least 4 squares	At least 2 squares for hardcourt, 1 square for swings	At least 3 squares	At least 6 squares	No more than $750,000

Water flow performance	
Total rainfall	**Total runoff (inches)**
At least 2 inches	As low as possible

11.1. Find Design #1 on page 23. Test your design with your computer model to see how well it meets project criteria. Fill in the tables below.

Design criteria					
# Building squares	**# "Grassy" squares**	**# Play squares**	**# Parking squares**	**# Accessible squares**	**Cost ($)**
responses will vary					

Water flow performance		
Total rainfall (inches)	Total absorption (inches)	Total runoff (inches)

responses will vary		

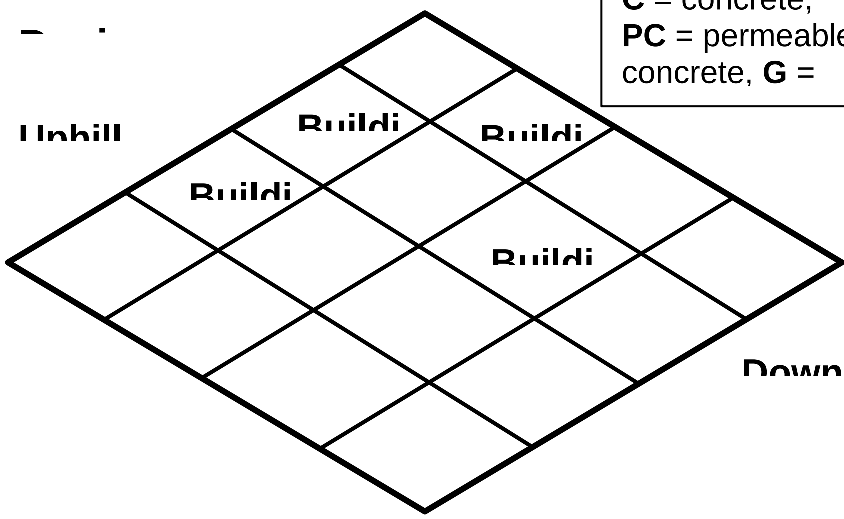
11.2. Does your design meet the criteria for **numbers of squares**? Yes No

11.3. Does your design meet the criterion for **cost**? Yes No

Create more designs. Engineers create many designs before making a decision. Can you improve your design by reducing runoff? Reducing cost? Improving accessibility?

11.4. Create Design #2 that **improves Design #1.**

C = concrete, **PC** = permeable concrete, **G** =



Use the computer model to test Design #2:

Design criteria					
# Building squares	**# "Grassy" squares**	**# Play squares**	**# Parking squares**	**# Accessible squares**	**Cost ($)**
responses will vary					

Water flow performance		
Total rainfall (inches)	Total absorption (inches)	Total runoff (inches)
responses will vary		

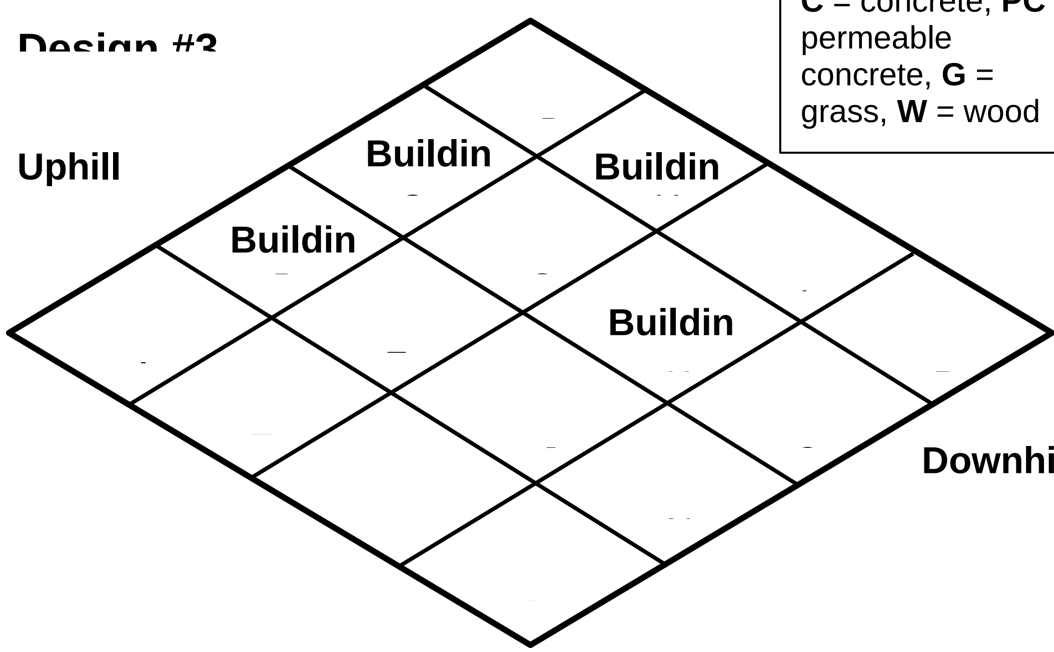
11.5. How does Design #2 improve Design #1?

Examples: Sophisticated students may attend to multiple criteria at once, for example: It has less runoff without increasing the cost. Other students may attend only to 1 criterion: It meets more criteria for squares used, it is more accessible, it is cheaper, it has less water runoff. Some students may say it looks better, but students should be attentive to engineering criteria more than aesthetic ones.

11.6. Create Design #3 that improves Design #1 or #2.

C = concrete, **PC** = permeable concrete, **G** = grass, **W** = wood

Design #3



Use the computer model to test Design #3:

Design criteria					
# Building squares	# "Grassy" squares	# Play squares	# Parking squares	# Accessible squares	Cost ($)
responses will vary					

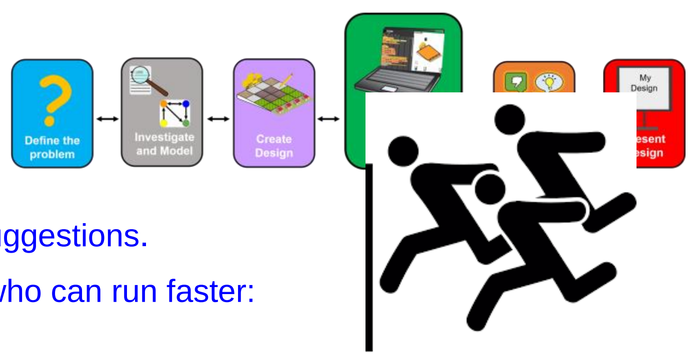
Water flow performance		
Total rainfall (inches)	Total absorption (inches)	Total runoff (inches)
responses will vary		

11.7. How does Design #3 improve Design #1 or #2?

Examples: Sophisticated students may attend to multiple criteria at once, for example: It has less runoff without increasing the cost. Other students may attend only to 1 criterion: It meets more criteria for squares used, it is more accessible, it is cheaper, it has less water runoff. Some students may say it looks better, but students should be attentive to engineering criteria more than aesthetic ones.

Lesson 12: How do you know what design will be the best?

Discussion Question: How can you design a fair race?



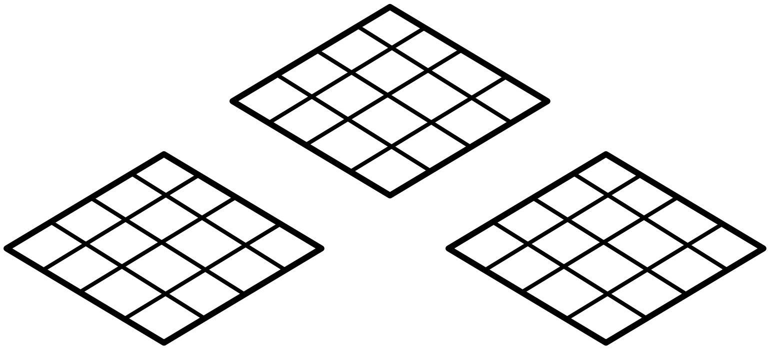
See teacher lesson book for discussion suggestions.

Example responses: if you want to know who can run faster:

- make sure distances are the same
- make sure starting times are the same
- one person doesn't run downhill while the other runs uphill
- racers should run on the same surface

12.1. When you test 2 designs to compare them, how can you be sure the test is **fair**?

Write down your ideas below.



Designs need to be tested under fair, equal conditions. Each design should be tested with the same amount of rainfall. This is the only way that the amount of runoff between two designs can be compared, and to know which design works better.

12.2. Conduct a fair test of your designs by filling in the table below with your 3 designs from your computer model.

	Design 1 (p. 37)	Design 2 (p. 38)	Design 3 (p. 39)
Total grassy field squares			
Total play area squares			
Total parking squares			
Total accessible squares			
Cost ($)			
Test your design			
Total rainfall (inches)	**same value**	**same value**	**same value**
Total absorption (inches)			
Total runoff (inches)			

12.3. Circle the part of the table above that makes your test a FAIR TEST. **Rainfall values are all the same**

12.4. What design(s) had the **most** accessible squares? **1 2 3**

12.5. What design(s) had the **lowest** cost? **1 2 3**

12.6. What design(s) had the **lowest** runoff? **1 2 3**

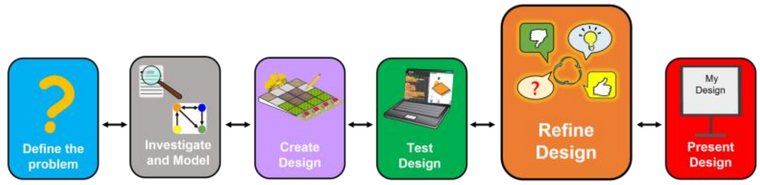
12.7. Is the design with the lowest runoff also the cheapest and most accessible design?

Yes **No (likely)** Explain why or why not: materials that are cheaper tend to be EITHER absorbent OR accessible, but not both. There is a trade off among cost, runoff performance, and wheelchair accessibility.

12.8. What design do you think is best? (circle one) **1 2 3**

12.9. Why did you choose that design? Students may choose designs because they meet a single criterion, like cost, or lowest runoff. A more sophisticated answer would acknowledge that ALL criteria need to be met for a design to be acceptable. A solution that meets all criteria may be preferable to one that meets only some criteria, even if the total runoff is not the lowest. Sophisticated answers will acknowledge multiple criteria at once rather than just referring to a single criterion.

Lesson 13: How can you use the model to improve your design?



13.1. Improve your best design from yesterday

- Login to the C2STEM environment as instructed by your teacher
- What was your best design from yesterday? Design # _will vary__
- Put this design into the computer model.

Now try to improve on this design by changing it, testing it, and comparing the results to a previous design.

Each time you find a design you like, record it on your **"New and Improved" design data sheet**. Use as many sheets as you like.

13.2. Work with your team to make the best design

- Compare different students' designs. (Are you conducting a fair test?)
- Can you combine parts of 2 different designs into a single design?
- Test the design to make sure it meets all the criteria:

Design criteria					
Building	**"Grassy" field**	**Play area**	**Parking**	**Accessible**	**Cost ($)**
4 squares (B, C, H, K)	At least 4 squares	At least 2 squares for hardcourt, 1 square for swings	At least 3 squares	At least 6 squares	No more than $750,000

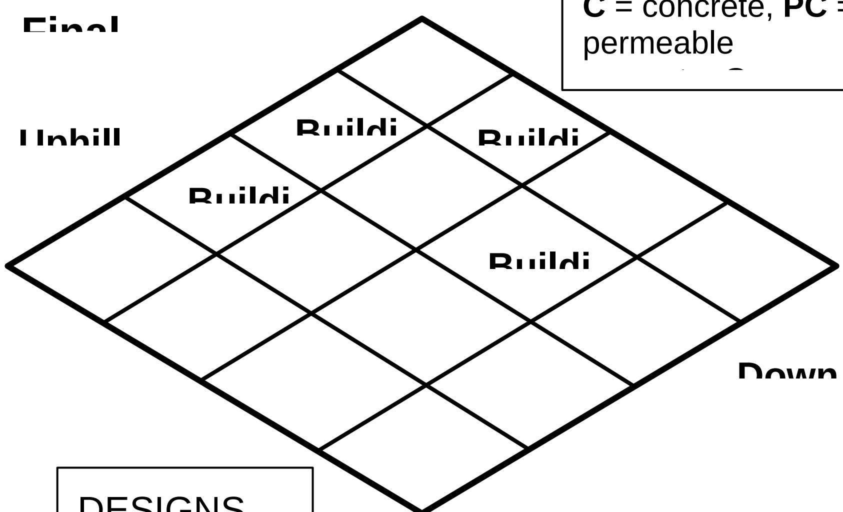
Water flow performance	
Total rainfall	**Total runoff (inches)**

At least 2 inches	As low as possible

13.3. Finalize your group's design

- Below, make your final sketch of your design that you will present to the class.
- Complete the table to show that your design meets the criteria.

C = concrete, **PC** = permeable



DESIGNS

Use the computer model to test your Final Design:

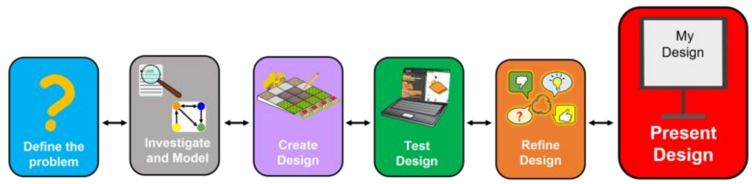
Design criteria					
# Building squares	**# "Grassy" squares**	**# Play squares**	**# Parking squares**	**# Accessible squares**	**Cost ($)**
responses will vary					

Water flow performance		
Total rainfall (inches)	Total absorption (inches)	Total runoff (inches)

responses will vary		

Why did you decide on this final design over other ones?
Students may choose designs because they meet a single criterion, like cost, or lowest runoff. A more sophisticated answer would acknowledge that ALL criteria need to be met for a design to be acceptable. A solution that meets all criteria may be preferable to one that meets only some criteria, even if the total runoff is not the lowest. Sophisticated answers will acknowledge multiple criteria at once rather than just referring to a single criterion.

Lesson 14: How can you convince the Principal at Walker to use your design?



Discussion Question: What makes a good presentation?

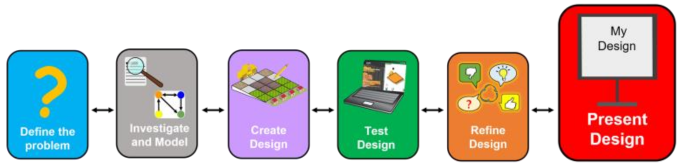
14.1. Create a presentation to convince the Principal at Walker to use your design. Use the template given to you by your teacher. You will want to show:

- **The problem**
    - Your understanding of the problem. What is the problem at Walker School? (Hint: Look back at Lesson 1).
    - What problem does this cause for the school and the environment? (Hint: Look back at Lesson 1).
    - What happens when it rains at Walker? (Hint: Look back at Lessons 2-5)
- **Our scientific model of the problem**
    - What is your scientific model of what happens when it rains? (Hint: Put your models from Lessons 4-5)
- **Our design and evidence**
    - Put in a picture of your 16-square design (you can take a screenshot of your computer model)
    - Test data supporting your design (put numbers into the tables)
- **Why our design is better than others we tried**

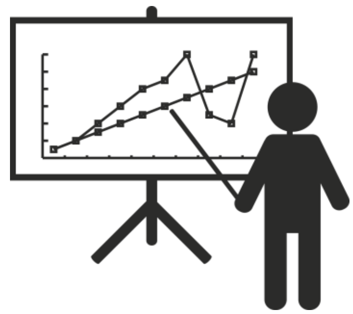
- Describe at least 2 designs, including your final design. Include a table or pictures of the designs you tried. Why did you choose your final design? What trade-offs did you have to consider? Was there another design you could have chosen?
- Why the principal should choose your design--Summarize how your design solves the problem at Walker School.

14.2. Once you have your presentation, practice your presentation to yourselves. Who in your group is going to say what parts? You can take notes below.

Lesson 15: Final Presentations



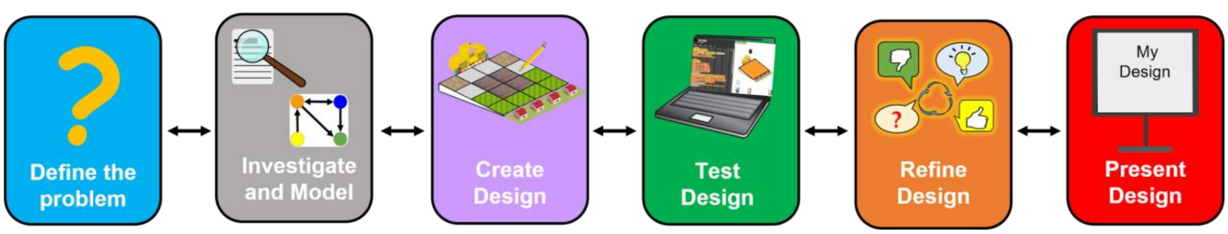
Be sure to be excellent audience members for your class and provide the same respect that you would like during your presentation!



Congratulations!

You have finished the project. You were engineers that helped design solutions that helped the students and teachers at Walker as well as helped the environment.

You have done so much during this project, including all of these design phases!



Be sure to keep thinking of how you can apply the science you learn in the future to solve engineering problems that benefit all of us!

Glossary of key terms

Science terms

Absorption	Rainwater that soaks into the ground surface
Absorption limit	The maximum amount of water that a surface material can absorb
Model	A scientific model explains how we think something happens or predicts what we think will happen. A model could be an object, drawing, mathematical expression, or computer program
Prediction	A statement about what you think will happen based on observation
Rainfall	Water that comes out of the sky as rain
Rain gauge	A device used to measure the amount of rain that falls (usually in inches)
Runoff	Rainwater that stays on top of the ground surface and flows downhill

Engineering terms

Design criteria	Requirements for how something should be designed
Engineering	A process of reaching a problem solution. A person who solves problems that address our wants and needs is an *engineer*.
Fair test	A way to test 2 or more solutions so that they can be compared to each other
Trade-off	Where designs must sacrifice one thing to improve on another

Computing terms

Bug	A mistake in a computer program. Fixing these mistakes is called *debugging*
Expression	A statement combining variables and operators, such as “Your_Age is equal to 10”
Operator	A word or symbol that acts on one or more numbers. Examples include plus, minus, equal to, and less than.
Test case	A set of values used to test whether a computer program is working correctly
Variable	An amount or quantity that can be changed