SPICE | Science Projects Integrating Computing and Engineering

Walker Water Runoff Challenge

Teacher's Guide

SRI Education

Digital Promise

VANDERBILT SCHOOL OF ENGINEERING

UNIVERSITY of VIRGINIA | SCHOOL of EDUCATION and HUMAN DEVELOPMENT

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Dear Colleague,

The SPICE team is delighted to be working with you and your students on the SPICE project! We are eager to see how your students' experiences with SPICE can help them develop knowledge and passion for science, computational modeling, and engineering.

An important part of SPICE is that it is strongly aligned with NGSS standards in earth science and engineering. Students investigate the causes of and develop solutions for urban water runoff through a combination of hands on activities, computer simulations, and systems modeling. Students will also be engaging with all three upper elementary NGSS engineering performance expectations. Students will participate in the engineering of school ground surface materials that minimize the impact of water runoff on the surrounding community. Students will define the problem, gather information, then develop, test, compare, and refine solutions. A rich simulation environment will enable students to predict water runoff from storms and test their engineering solutions.

In professional practice, the areas of science, engineering, and computing are highly intertwined. We hope you find the Water Runoff Curriculum helpful in providing your students the opportunity to participate in these three disciplines in a similarly integrated manner, to help prepare students for what lies ahead.

Sincerely,
The SPICE Research Team

SRI International
University of Virginia
Vanderbilt University
Digital Promise

Pacing Guide

Lesson (45 min)	Driving Question	Learning Objectives	Description
1	What problem are we trying to solve?	• Develop an understanding that engineers solve problems • Understand and define the problem at Walker Upper Elementary school	Discuss what engineers do and define problem at Walker.
2	How much does it rain at Walker?	• Understand that rain is measured in inches • Understand that a heavy rain at Walker is more than 2 inches • Understand the design criteria of 2 inches	Investigate rain gauge representation and rainfall data from Walker Hands-on investigations to explore where water goes when it rains
3	Where does the rain go?	• Observe and describe that some water is absorbed and some water stays on the surface • Different surface materials absorb different amounts of water	Hands-on investigations to explore where water goes when it rains
4	How can we make a model of water runoff?	• A science model is a representation that explains or predicts. In making models, we include things that are important and leave out other things. • To solve the Walker problem, we will make a model of how water flows in and out of the ground surface at Walker	Develop models of water flow, share, and revise with peers.
5	How can our model help us predict the amount of water runoff?	• The absorption limit of a material is the most amount of water it can absorb • Be able to predict the amount of water runoff given the amount of rainfall and the absorption limit of the surface	Develop simple models that predict runoff for various amounts of rainfall and absorption.
6	How can we design Walker to reduce water runoff?	• Become familiar with the available surface materials and their characteristics • Generate a design solution that meets some criteria • Recognize the need for a computer model to test their designs.	Investigate surface material chart and generate a design solution for Walker

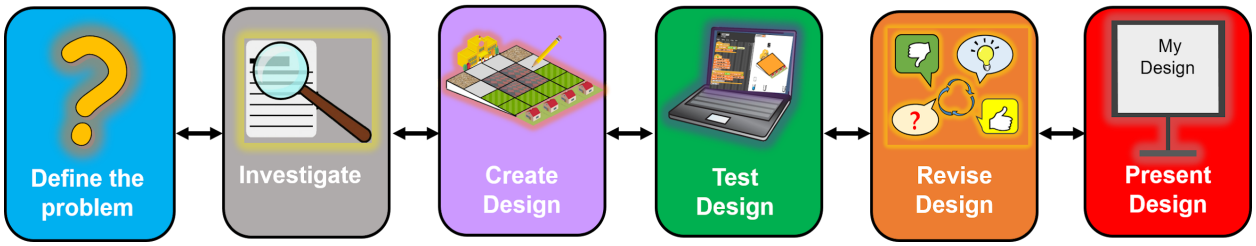
7	What language does a computer understand?	• Familiarize students with the language the computer uses (IF-THEN statements that are either TRUE or FALSE, variables, expressions, and Repeat-Until loops) through unplugged activities before programming the runoff model in Lessons 8, 9, 10.	Play a variety of dice games
8	Build a computer model to calculate runoff (part 1)	• Students will develop and test a simple runoff model that computes water runoff and water absorption based on rainfall and surface materials • Students will develop the part of the model for the case when the total rainfall is EQUAL TO the material absorption limit • Students will apply understanding of basic programming concepts such as if-then statements, variables, and expressions.	Students review the three model cases: total rainfall is either equal to, less than, or greater than the material absorption limit and articulate these cases as rules for computing absorption and runoff.
9	Build a computer model to calculate runoff (part 2)	• Students develop the part of the model for the case when the total rainfall is LESS THAN the material absorption limit • Students apply understanding of the basic system relationship ***total rainfall = total absorption + total runoff***	Students engage with a short debugging task and program the second rule (less than) into C2STEM and test whether it is working
10	Build a computer model to calculate runoff (part 3)	• Students develop the part of the model for the case when the total rainfall is GREATER THAN the material absorption limit	Students program the third rule (greater than) into C2STEM and test whether it is working, and test their model using a different material
11	How can we test and improve our designs?	• Students test designs with the computational model. • Use test results to evaluate design. • Generate multiple solutions to the problem.	Students test designs with their C2STEM model, evaluate their designs along all project criteria, and generate other designs in preparation for fair tests.
12	How do you know what design will be the best?	• Understand that fair tests hold variables constant to evaluate multiple designs. • Be able to conduct fair tests to compare different designs along specific design criteria.	Discuss what a fair test would be by making connections to fair races, conduct fair tests of their 3 designs and record their results, discuss what it

		• Understand that sometimes designers make trade-offs between design variables, and that there is more than one way to conceive of a “best” design	means to have a “good” design.
13	How can you use the model to improve your design?	• Designs can be improved through iterative testing and refinement • Documenting the results of design tests and comparing designs (using fair tests) can help to improve designs.	Individually refine their best design, then form groups and collectively come up with the best design they can.
14	How can you convince the Principal at Walker to use your design?	• Students synthesize what they have done into a presentation that argues for their design. • Students practice presenting their design.	Students create a presentation of their work and practice presenting to another group
15	Final presentations	• Students present their designs.	Students give their group presentations.

Engineering Design and Project Criteria

What is engineering design?
From the *NGSS Framework:* "**Engineering** is a systematic and often iterative approach to designing objects, processes, and systems to meet human needs and wants...."

Engineering relies heavily on science (and mathematics) understanding. The engineering design process generally involves multiple iterations of problem definition, research, designing, testing, and refining to meet some kind of criteria. We use the following representation for different phases of design throughout the project:



Criteria should reflect the needs of the expected end-user of the solution. The criteria used for this project are the following:

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	At least 3 squares	At least 6 accessible squares

B. Designs need to **minimize water runoff** after **heavy rains** (2 inches of rainfall).
C. Designs need to stay **under budget of $750,000.**

What isn't engineering design?
Developing solutions without testing their effectiveness is not a high quality representation of engineering design. Investigating why a phenomenon happens is considered more as science, whereas applying that understanding to design a solution to a human need is engineering.

How are we using engineering design in the curriculum?
In this project, students design different surfaces within the school grounds to decrease water runoff, cost, and increase accessibility according to the criteria above. During the unit, students develop conceptual models showing how water interacts with the landscape under different conditions. They develop computational models to help them test their designs.

C2STEM Quick Guide

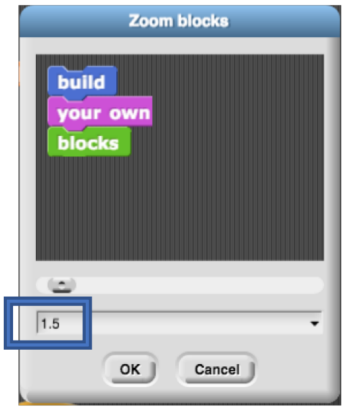
The **palette** contains all the blocks needed for the project.

In the **scripting area,** blocks can be dragged and snapped together to create a program.

The **stage** displays the behavior of the model. The green flag, pause, and red stop buttons play, pause, and stop the model.

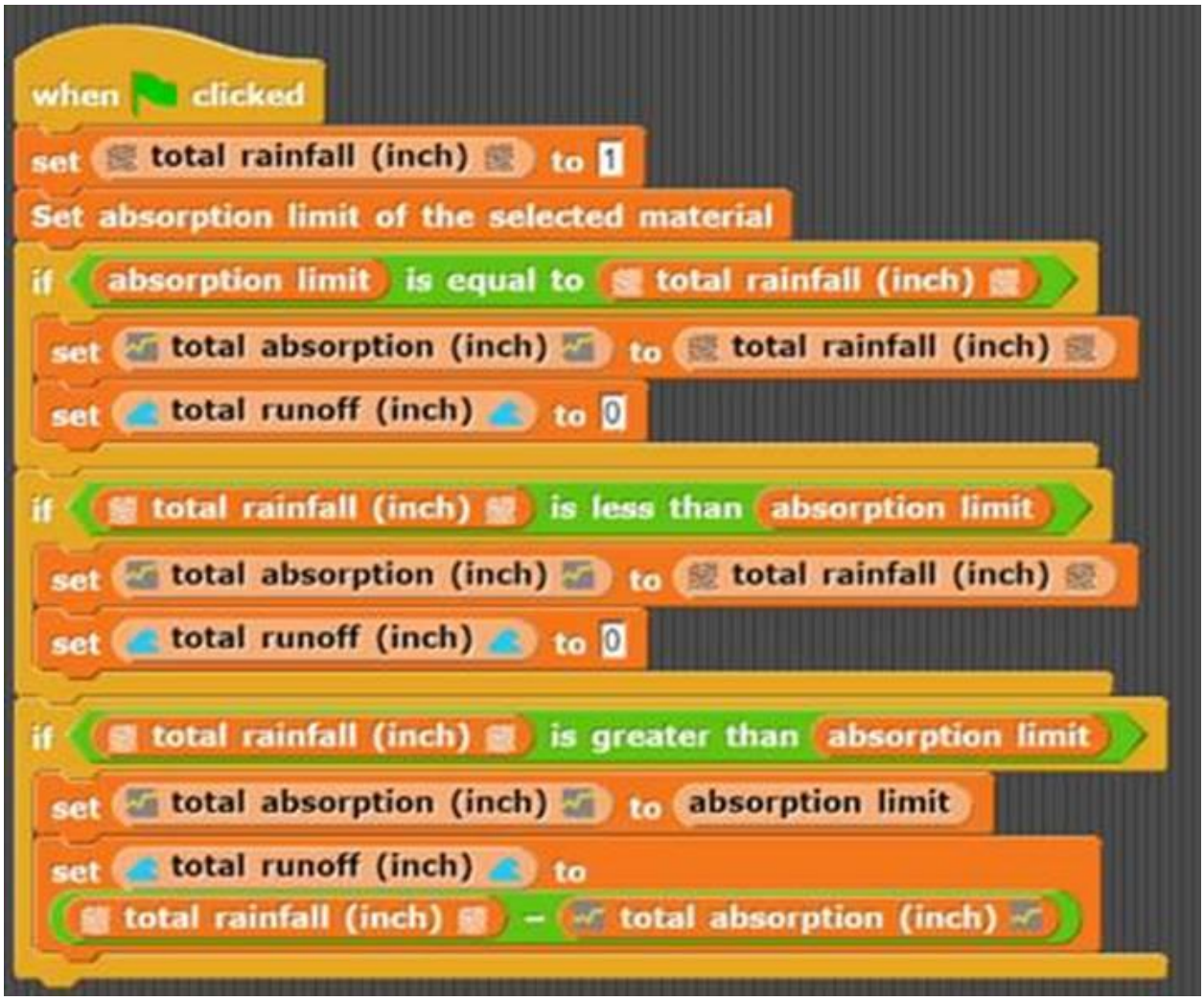
Making the box bigger

If it is hard to see the blocks because of the font size, click on the Gear button and then choose the "Zoom blocks..." option.



It is recommended to zoom the blocks to around 1.5 or larger.

Example of full code for computational model:



SPICE | Science Projects Integrating Computing and Engineering

Lesson Plans

Lesson 1: What problem are we trying to solve?

Learning goals:

- Develop an understanding that engineers solve problems that address human wants and needs
- Understand and define the problem at Walker Upper Elementary school

Materials: Walker Runoff Challenge Video and teacher slides 2-15

Preparation: N/A

Overview

- Students watch a video that describes the problem at Walker.
- Students start to understand specific needs of teachers and students at Walker.
- Students create an initial plan for how space can be used at Walker.

Relevant Vocabulary Words

- Engineering; engineers; conservation

Opening

(Teacher Slides 3-7)

What do engineers do?

5 min

Whole Class

Discussion Goal: Elicit student ideas about engineering and engineering design. Try to help students see that engineers design solutions to solve human problems and needs. Make sure to get a variety of students' participation. Encourage students to address one another and to ask each other questions.

Guiding questions for discussion: Record student ideas on the board.

Potential student responses are italicized in parentheses.

- Explain to students, "I am going to ask you some questions and, together, we are going to brainstorm some ideas about what it means to be an engineer. Make sure to raise your hand."

- Ask, "Has anyone heard of ***engineers*** or ***engineering***? What do you think they do?" *(engineers solve problems that address our wants and needs)*
- Ask, "Why is this work important?" *(Responses may vary)*
- Ask, "Where have you seen the work of engineers in your everyday life? Think of something you used today that someone had to create. Why did you need it?" (*example: water bottle)*
- Show engineering design map on slide 7 and/or have them refer to the ones in the lesson plans. Talk about each phase.

Activities

(Student Notebook p. 3-6)

(Teacher Slide #8)

1.1-1.3 Define the problem

10 min

Group

Purpose: Students define the problem at Walker

- Students will watch a video and then write down the problems at Walker School and how the problems impact the school and environment.
- For the next set of questions, allow for 2 or 3 students to volunteer sharing their observations. Validate and revoice (rephrase a student's idea to validate and highlight). Some ways to revoice are:
    - "So you are saying that..."
    - "So let me clarify..."
    - "I think I heard you say...."
    - "Is this what you are saying?"
- Ask students, "We just talked about what engineers do and you watched a video about some of the problems at Walker. How do you think those problems could hurt or help the environment?" *(Student responses may vary)*
- [Connect to NGSS crosscutting concepts - ***Conservation of Matter***] Say to students, "Engineers are focused on solving a problem by changing something about the environment where the problem occurs. With our problem, the rain that falls on Walker has to go somewhere,

and that means that often it is runoff and often it floods our fields and playground. Many times, the solution to a problem is just changing where things go. As engineers, we are going to focus on changing where the rain that falls at Walker goes."

> NGSS Crosscutting Concepts - Conservation of Matter
>
> Within this unit, we will focus on the conservation of matter as the main crosscutting concept. When engineering solutions to our problem, students will focus on increasing the amount of water that is absorbed in order to decrease the amount of runoff. Throughout the unit, we will come back to the idea that all the water has to go somewhere (it cannot just disappear), and check in as we build understanding of where the water is going a different points.

- Ask students, "Let's talk about that idea with the water that is coming into the playground. Where is it coming from? Where does the water go after it comes into the playground? All of the water that comes in has to go somewhere.
- Ask students, "What are some ways that an engineer might help prevent some of those issues? What could they do about it? For example, could they build something new? Or could they fix what is already there? How would they do that? Write down what you think." *(Student responses may vary)*

(Teacher Slides 9-15)

1.4-1.5 Explore the current Walker layout

15 min

Purpose: Students understand current layout of Walker School

- Students investigate the current layout of squares used for buildings, grassy areas, play, parking, and accessible squares at Walker and fill in the table with the number of squares.

- Using given criteria, students compare numbers of squares to see if the current design meets the needs of students and teachers.

1.6-1.8 Create a plan for Walker

10 min

Purpose: Familiarize students with the criteria for squares

- Students will create their own plan for buildings, grassy areas, play areas, parking, and accessible squares. **Note: buildings cannot be changed,** but everything else can.

Closing

What is the problem we are trying to solve?

5-10 min

Purpose: Review the purpose of the project and have students draw a picture of their understanding of the problem

Whole Class

1. Ask students, "Thinking back to everything we talked about this period, what are the important things that need to focus on to solve the problem?"
2. (Time permitting) Tell students, "Partner with the person next to you (or Teacher can create elbow partners) see what parts of the problem you remember and think are important."
3. (Time permitting) Ask students to share what they think the problem is. Encourage students to build on one another's responses, and state which part of someone else's response they "agree with, because…" or "disagree with, because…"
4. Have students draw a picture showing what they understand to be the problem they are solving.

Lesson 2: How much does it rain at Walker?

Learning goals:

- Understand that rain is measured in inches
- Understand that a heavy rain at Walker is more than 2 inches in a day.
- Understand why we have chosen 2 inches as a testing criterion for designs
- *Potential connections to other lessons during the year:* measurement (rulers, meniscus, etc.) and weather vs. climate.

Materials: Teacher slides 16-20

Preparation: N/A

Overview

- Students develop an understanding of rain gauge representation.
- Students explore graphs of precipitation at Walker.

Relevant Vocabulary Words

- rain gauge; rainfall

Opening

(Teacher Slide 17)

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

5 min

Whole Class

Discussion Goal: Rain is measured in inches that represents a volume of water.

1. Quickly review place in unit (review previous lesson).
   - Say to students, "In order to design for Walker, we need to have a better understanding of what **the problem** is that we are trying to solve. First, let's figure out how much rain falls there."
   - Ask students, "What are some ways we can measure rainfall? After there is a storm, how do we say how much rain has fallen?" *(Student responses may vary. Help students to talk about using tools, like rulers,*

to measure the amount of water that falls on the ground, or units like inches.)

- Allow 2 or 3 students to volunteer ideas. Validate and revoice (rephrase a student's idea to validate and highlight.) student responses. Some ways to revoice are:
    - "So you are saying that…"
    - "So let me clarify…"
    - "I think I heard you say…."
    - "Is this what you are saying?"
- Tell students, "Those are all good ideas. One way to measure the amount of water on the ground after it rains is to use a ruler."
- Hold up a ruler and say, "The ruler uses inches to determine how tall or long or deep things are." Show some examples by measuring nearby things."
- Tell students, "To measure water after it rains, we use something called a ***rain gauge***. The rain gauge also uses inches to measure how much water is on the ground after it rains. The water that comes out of the sky as rain is called ***rainfall.***"

  NOTE: Making the connection that a volume of water is measured in inches may be problematic for many students. You could tell students that an analogy would be a set of cups covering the area being rained on, and they are all 1 inch full. If students are still struggling, you could show them this video: https://youtu.be/9ipkEmwxT5k

Activities

(Student Notebook p. 7-8)

2.1 Fill in Rain Gauges

10 min

Group

Purpose: Students fill in a rain gauge to indicate different amounts of rain.

1. Circulate and help groups of students fill in their rain gauges for A-C.

NOTE: Students may need help representing a decimal on a linear scale. Remind students that 0.5 is the same as a half and ask them to locate that between 0 and 1.

(Teacher Slide 18)

2.2 How much rain does Walker get?

20 min

Group

Purpose: Students interpret bar graph of heavy rain amounts at Walker

1. Tell students: "We filled in the ***rain gauge***s for different ***rainfalls***. Now each bar in the graph represents the biggest rainfalls each month last year. Answer questions A, B, and C in your notebook."
2. For A, students can interpret the graph.
3. Ask students, "How much do you think is a lot of rain in one day? How much do you think is a little bit of rain in one day?" *(Students responses may vary. Make sure to have students reference the graph in their responses. Also, encourage students to use language "rainfall" and "rain gauge" in their responses.)*
4. Tell students, "You will need to reduce the amount of water that flows down from the ground into other areas that can cause those other areas to flood. This is called ***runoff***. You will need to reduce runoff for Walker for a storm of at least 2 inches of rain. You will test your designs using 2 inches of rain."

Closing

(Teacher Slide 20)

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

10 min

Whole Class

Purpose: Linking Discussion - Summarize what we learned in this lesson and revisit the problem definition at Walker.

1. Summarizing discussion: Determine the main take-aways from the activities. Encourage student language to include "rainfall", "rain gauge", "inches".

- Ask students, "What did we learn about rainfall?" *(Student responses may vary.)*

Engineering connection

This is a good time to revisit the engineering design process map. Help students understand that they are in the process of figuring out in more detail what the problem is that they are trying to solve. This is being done by investigating the different components of their conceptual models which will help them understand the problem they are trying to solve. Students have to understand how to measure the amount of rainfall in order to understand where water goes (absorption, runoff, etc).

2. Linking Discussion

- Ask students, "How does this help us understand the problem that we are trying to help Walker school solve?" *(Student responses may vary. Help students to talk about measuring rainfall.)*
- *Ask students,* "Why do you think we need to design for at least 2 inches of rainfall?" (*Help students base their response on the rain data graphs they inspected. 2 inches is an amount of rainfall that commonly falls during a storm at Walker.*)
- Ask students, "How does this relate to what an engineer might do?" *(Student responses may vary. Help students to talk about designing ways to reduce runoff.)*

Lesson 3: Where does the rain go?

Learning goals:

- Observe and describe that (1) some rainwater is absorbed into the surface and (2) water that is not absorbed stays on top the surface
- Different surface materials absorb different amounts of water

Materials:

- Teacher slides 21-28
- large container of water, like a 2-liter bottle
- small cup
- access to outdoor surface materials
- *Optional:* cut off the bottom of a plastic graduated cylinder, or put lines on straws so that students have more accurate measurements

Preparation:

- Students will need containers filled with water to take outside to pour different amounts of water over the same surface (ideally somewhat absorbent).

Overview

- Students explore surface materials at their school.
- Students start to develop a conceptual model by investigating where water goes.
- Students engage in hands-on activities to investigate what happens when water is poured on a surface.

Relevant Vocabulary Words

- Rainfall, absorption, water runoff

Opening

(Teacher Slide 22)

When it rains, where does the rain go?

5 min

Whole Class

Discussion Goal: Remind students that the design goal is to give rainwater a place to go, other than surface runoff. Remind students that **water is conserved**, it all has to go somewhere. Elicit student ideas about what happens to water when it rains. Make sure to get a variety of students' participation. Encourage students to address one another and to ask each other questions. Make sure to ask follow-up questions when students respond. Here are some example follow-up questions:

- How do you know that happened?
- Can you say more about that?
- Why did that happen?

Record some of the responses on the board. You can refer to their responses when they make their conceptual models in the next activity.

- Ask students, "When was the last time that it rained? What do you remember?" *(Student responses may vary)*
- Ask students, "Where did the water go when it last rained? Why do you think that happened? Can water just disappear?" *(Student responses may vary)*

Activities

(Student Notebook p. 9-12)

(Teacher Slide 23)

3.1-3.2 When it rains, where does the rain go?

10 min

Group

Purpose: Students make a prediction about where rain goes

- Students draw their ideas about where water goes when it rains.
- Students may use arrows to indicate water flow, or words or other pictures to describe the flow of water.

1. Have students draw a picture to show where they think the water goes when it rains. (We will describe what a model is in the next lesson.)
2. As students do this, encourage students to show where the water flows.

(Teacher Slides 24-27)

3.3-3.6 Investigation: Make it rain!

20 min

Group

Purpose: Students observe what happens to water hitting a surface.

1. Students should have access to water (either a hose or a container full of water).
2. Take students outside and have them pour water on a soft surface (if available, so that it absorbs) and record what happens when they pour a little water and when they pour a lot of water.
3. Have students record their observations in their notebook.

4. Students should observe that some water soaks into the ground, and some water remains on the surface.

NGSS Crosscutting Concepts in this Lesson

In this lesson, we are focusing on conservation of matter. Students explore where water comes from and goes when they pour water on different surfaces. The water must go somewhere--it cannot just disappear. Rainwater is either absorbed into the surface or it can stay on the surface as runoff. Students will represent these flows in the next lesson when they create their conceptual models.

3.7 What is water runoff?

Group

10 min

Purpose: Introduces runoff as water that is not absorbed.

1. Ask students "Your design needs to reduce ***water runoff*** around Walker. What is ***water runoff***?"
2. Say to students, "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**."
3. Say to students, "Now revise your previous picture. Show where the rainwater goes when it hits the ground."

Closing

3.8 How is this picture different from your prediction?

Whole Class

Purpose: Build consensus from students' work.

- Sense-making questions:
  1. Ask students, "Does your prediction match with what you observed in your observations outside? What differences did you find? Why were there differences?" *(Student responses may vary.*

Make sure to have them talk about the differences between what they observed and their predictions. This will link to the designs they will generate.)

2. Ask students, "Who would like to share their picture that shows where water goes after it rains?" *(Students share their responses. Make sure to have them talk about where the water comes from and goes.)*
3. Ask students, "Who has a different idea?" *(Student responses may vary)*

- Eliciting questions: Ask, "Can rainfall appear or disappear after it hits the ground?" *(Student responses may vary. Try to get students thinking about conservation of matter.)*
    - Can connect to evaporation and the water cycle.
    - Can connect to students' models - how do you represent the amount of water?

Tell students, " Tomorrow, we will start to develop ways to predict the amount of water runoff."

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

Learning goals:

- A science model is a representation that explains or predicts. In making models, we include things that are important and leave out other things.
- To solve the Walker problem, we will make a model of how water flows in and out of the ground surface at Walker

Materials:

- Teacher slides 29-39

Preparation: N/A

Overview

- Students discuss their understanding of what a model is in everyday life and extend that to science models
- Students develop their own model of water flow, showing how much rainfall, absorption and runoff occurs
- Students get feedback from a peer on their models and revise based on the feedback

Relevant Vocabulary Words

- Scientific model; Absorption; Absorption limit; Runoff

Opening

(Teacher slide 41)

4.1 What is a model?

5-10 min

Discussion Goal: Students generate ideas about what a model is and what it is for.

Eliciting Discussion:

- Say to students, "In your notebook in Lesson 4, write down an example of a model from your daily life. Also write what it is a model of, and why that model is needed." Allow students to work for a couple of minutes.

Whole Class

- Elicit some examples from students. For each example, highlight the following aspects of the model, as appropriate
    - **Models must represent something else.** For example, a model airplane represents a real plane. A globe represents the earth.
    - **Models include some things, but do not include EVERYTHING about what is being modeled.** For example, a model airplane shows what a plane looks like, but does not have all the working parts that make it fly (like engines). A globe shows the land and oceans, but does not have real water or real dirt, or people. Some globes show mountains, others don't. Some globes show countries and cities, others don't.
    - **Models include only the things that are needed for the model to be useful.** A model airplane does not need working engines to show what an airplane looks like. A globe does not need real water for it to show where things are on the Earth.
    - **Models include how the parts relate to one another.** The model should explain how something works, how the parts relate to one another, or predict how something might happen. For example, a globe shows how different places are related geographically. A model plane might show how the location of different parts are related, or how the parts turn to make the airplane move.
    - **Models are for communicating.** The model that you create might initially be to clarify your own thinking, but your model will also be used to help you communicate how

you think something works to someone else. Therefore, your model should be clear, consistent, and labeled.

Activities

(Student notebook p. 13-15)

(Teacher slides 31-34)

4.2 Models in science

5 min

Purpose: Extend the everyday idea of models to their use in science.

Whole class

NGSS Crosscutting Concepts in this Lesson

Students' models will include information about the flow of water above and through the surface at Walker that is needed in order to test problem solutions. Students' models should reflect conservation relationships, that the amount of rainfall should be equal to the total amount of absorption and runoff combined. We are not including evaporation in our computational model, but students could include it in their conceptual model if they want to.

- Say to students, "In science, ***models*** are not just smaller versions of real life objects like airplanes or the Earth. Scientists use models to explain how they think something happens or to predict what they think will happen. "
- Say to students, "Just like everyday models, science models only include things that are important to explain. They do not include things that are unimportant to the problem."
- Say to students, "Remember we are trying to design the ground surface at Walker School to reduce water runoff. Today you will draw a model of the ground surface that explains where water goes when it rains. Later you will make a computer model that predicts how much water runs off of a surface so we can test our solutions."

(Teacher slides 35-36)

4.3 Draw a runoff model.

10-15 min

Purpose: Students draw an initial model of water flow.

Individual

- Say to students, "You will draw a model of water runoff. Your model needs to show 3 types of water flow: rainfall, absorption, and runoff. Your models also need to show how much of these types of flow there is."
- Say to students, "In your notebook, there are some ideas about how you can show water flow in your model, like with arrows, water drops, rain gauges, or words. You can also invent you own ways of showing water flow."
- Get students thinking about how these different representations of water flow can show how much water is flowing and where.
- Give students some time to draw a model

4.4 Discuss and get feedback

10 min

Purpose: Students share their modeling approaches and get peer feedback.

Group

- Have students share their models with each other or the class. Consider projecting some examples on the screen or doing a gallery walk of models.
- Have students give feedback on another students' model and write it in their notebook. The feedback should suggest how it could better show the types of water flow and how much water is flowing.
- In particular, highlight if models are showing that *the amount of absorption or runoff is GREATER than the amount of rainfall* shown. This would indicate that **water is not being conserved**

in the model. Have students suggest how their models could more accurately show how much water is flowing.

(Teacher slide 38)

4.5 Improve your model

5 min

Individual

Purpose: Students revise their model based on prior discussion and feedback

- Give students a few minutes to incorporate the ideas from the discussion and feedback.

Closing

(Teacher slide 39)

4.6 Closing discussion

5 min

Whole class

Purpose: Synthesize the nature and purpose of scientific models

Engineering connection

This is a good time to revisit the engineering design process map. Help students understand that the model is important for explaining the problem at Walker. Their models from today will help them build a computer model that they will use to test their problem solutions.

Summarizing Discussion:

- Ask students, "What did we find were the best ways to show the types and amounts of water flow?" (Students may talk about arrows, raindrops, or rain gauges as showing flow)
- Ask students, "Was there a point today where you had trouble understanding what someone was showing in their model?" and "What can we do to solve that problem?"
- Ask students "What are important things that the model needs to include?" (Rainfall, absorption, runoff, the ground surface.)
- Ask students, "What are less important things that our model can leave out?" (Students might mention what type of surface it is--they will do that later with the computer model. Students might mention evaporation--you could say that evaporation happens too slowly for us to include it here.)

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

Learning goals:

- The absorption limit of a material is the most amount of water it can absorb
- Be able to predict the amount of water runoff given the amount of rainfall and the absorption limit of the surface

Materials:

- Teacher slides 40-45

Preparation: N/A

Overview

- Students do a thought experiment where they determine runoff based on rainfall and absorption
- Students are introduced to the idea of an absorption limit
- Students develop simple models that show different rainfall and absorption limits, and calculate the total runoff in each case

Relevant Vocabulary Words

- Absorption limit; total rainfall; total absorption; total runoff; scientific model

Opening

(Teacher slides 41-42)

5.1 Absorption limit

5 min

Goal: Students understand the idea of an ***absorption limit.*** This limit varies for different materials and determines how much rainfall is absorbed and how much is runoff.

Whole Class

Eliciting Discussion:

- Say to students, "Our investigation and modeling lessons showed us that when water falls on the ground, that water is either absorbed into the ground or stays on the surface."
- Allow students to work on the example, reading it aloud to them if needed
- Ask students, "What does a limit mean?" (*the most possible. Suggest speed limit as an example if students are stuck.*)
- Ask students to volunteer their answers, and guide them toward the correct response (3 inches rainfall, 1 inch absorbed, 2 inches runoff)
- Help them think through the example of 3 inches of rainfall and a 1 inch absorption limit. Ask students, "How much of the 3 inches are absorbed and how much will run off?"

Activities

(Student notebook p. 16-20)

(Teachers slides 43-44)

5.2-5.3 Modeling and predicting water runoff

10 min

Purpose: Students decide how they will draw their runoff models based on Lesson 4. Students make a model to illustrate the prediction students make in 5.1.

Individual

NGSS Crosscutting Concepts in this Lesson

Students continue to apply the concept of water conservation to developing models of water flow. All rainfall must be accounted for after it hits the ground surface. This enables students to use their model to make a prediction about how much water runs off based on the absorption limit of each surface material. Any rainfall that exceeds the absorption limit must remain on the surface as runoff.

- Say to students, "Think back to yesterday when we drew models of water flow. Some people used arrows, or rain gauges, or water drops, or other ways of showing how much rainfall, absorption, and runoff there

was. Decide how you will show these things in the models you will draw today."

- Give students time to complete 5.2.
- Say to students, "Complete the first model. Your model should show how much water is absorbed and how much runs off when there are 3 inches of rainfall and the absorption limit is 1 inch."
- If needed, remind students that any rainfall that is not absorbed becomes runoff.

5.4 - 5.6 Draw your own models

20 min

Individual

Purpose: Students draw models of 3 additional scenarios to predict how much absorption and runoff there is for each scenario.

- In 5.4, students represent 3 inches rainfall and a 2 inch absorption limit *(2 inches of rainfall are absorbed, leaving 1 inch as runoff)*
- In 5.5, students represent 2 inches of rainfall and a 2 inch absorption limit *(all 2 inches of rain is absorbed, leaving zero runoff)*.
- In 5.6, students represent 1 inch of rainfall and a 2 inch absorption limit *(all 1 inch of rainfall is absorbed, leaving zero runoff)*.

Engineering connection

Since water is conserved, in order to reduce runoff, we need to find somewhere else for the water to go (absorption). To solve the engineering design problem, students are working on engineering a surface that absorbs the most water possible while still meeting the needs of the school community.

Closing

5.7 How can you predict the total runoff if you know the total rainfall and the absorption limit?

5 min

Whole class

Purpose: Summarize the relationships among rainfall, absorption limit, absorption, and runoff. Link to the computer model that will be able to make predictions.

Summarizing Discussion:

- Ask students, "How were you able to predict the amount of runoff in each case?"
- Highlight the different scenarios they modeled. Sometimes rainfall was greater than the absorption limit, sometimes it was equal, and sometimes it was less.
- Have students articulate how they determined the absorption and runoff in each case. (In general, water is absorbed until the absorption limit is reached. If there is any additional rainfall left, it is runoff.)
- Mention that students will program a computer model that will be able to make these predictions for us.

Engineering connection

This is an opportunity to look ahead to the computer model. Soon, students will program a computer model that will be able to make these predictions for us. We need to know how to make these predictions so that we can tell the computer what instructions to follow. Having the computer make the predictions will allow us to test more complex designs more quickly rather than having to calculate by hand.

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

Learning goals:

- Become familiar with the available surface materials and their characteristics
- Generate a design solution that meets some criteria
- Recognize the need for a computer model to test their designs

Materials:

- Teacher slides 46-53

Preparation: N/A

Overview

- Students explore the list of surface materials and characteristics.
- Students identify best materials to meet various project criteria.
- Students generate and test design against some project criteria.

Relevant Vocabulary Words

- Absorption limit; models; design criteria

Opening

(Teacher slides 47-49)

Which materials have you seen before?

5 min

Whole Class

Discussion Goal: Students identify which of the available surface materials they have seen before, and where they saw them.

Eliciting Discussion:

- Ask students, "Can anyone remind me where we are in our engineering design process? What do we know so far? What do you think we need to do next? Why?" *(Allow students to build on one another's ideas to develop a more complete answer. We have learned about what happens to rain when it falls, and learned that some surfaces are more absorbent than others. We need to develop a solution that involves absorbent surfaces to reduce runoff.)*

- Ask students, "Why do we need all these kinds of materials?" *(possible responses: different uses require different materials)*
- Ask students, "Can we just use concrete for all surfaces at a school? Why not?" *(No. Concrete does not absorb water well. We wouldn't have a soccer field anymore. It is not very safe to play on.)*
- Some follow up questions to further student responses include,
    - "What would that mean for water runoff?"
    - "How would falling from a swingset on concrete feel?"

Activities

6.1-6.8 What materials are best? 15 min

(Student Notebook p. 21-23)

(Teacher slides 50-51)

Purpose: Students understand benefits and tradeoffs of different materials

Group

> Engineering Connection
>
> In this lesson, students start to need the computer model to calculate runoff based on a range of absorption limits in the school design.

- Students may need help understanding values of absorption limit.
- Multiple materials will fit under multiple answers.
- NOTE: Question 6.8 is particularly important because it is at the center of the main design trade-off students need to make. Materials that have high absorption limits AND have good accessibility tend also to be the most expensive (e.g., permeable concrete, artificial turf, poured rubber). If you go with lower cost materials, you sacrifice either accessibility or water absorption. Have a discussion about question 6.8 to elicit these ideas from students.

6.9 Make a design 20-25 min

Purpose: Students generate a plan for different materials in different areas of Walker

- Students are to write the different surface materials in the squares.
- Students will need to keep track of different purposes of squares (parking, grass, etc.)
- Students will check to make sure they meet project criteria, and then realize they can't check water runoff (and cost will be difficult to keep calculating), highlighting the need to build a computer model.

Closing

(Teacher slide 53)

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

5 min

Purpose: Highlight need for computer model to test designs

Whole Class

Summarizing Discussion:

- Ask students, "How would you calculate the cost of your design?" (*add up the cost of all the squares*)
- Ask students, "How would you calculate the runoff from your design?" (*need to know the absorption limits of each square of the design*)
- Ask students, "What if you wanted to test many designs?" (*we would have to add up costs and water runoff for every square for every design we wanted to test*)
- Ask students, "What would make this easier?" (*give the computer the instructions to do the calculations for us)*
- Say to students, "Tomorrow we will start building a computer program that will calculate cost and runoff for our designs."

Lesson 7: What language does the computer understand?

Learning goals:

- Familiarize with the language the computer uses (IF-THEN statements that are either TRUE or FALSE, input and output variables, and expressions) through unplugged activities before programming the runoff model in Lessons 8, 9, 10.

Materials:

- Teacher slides 54-67
- Dice (one per student, or computers to roll virtual dice)
- Projector/Elmo
- Whiteboard

Overview

- Students do a simple whole-class TRUE/FALSE activity based on teacher instructions.
- Students play 4 rounds of a dice game in groups of two where they evaluate IF-THEN statements as TRUE or FALSE and assign points to one or both players accordingly.
- Students view a computer program (projected in front of the classroom) describing rules for playing a dice game, and interpret the code to play a dice game as part of a whole class activity.

Relevant Vocabulary Words

- If-Then statements, variables, expressions, operators

Opening

(Teacher Slide 55)

What language does a computer understand?

3 min

Discussion Goal: Computers do not understand human languages like English, Spanish, Chinese, etc. Computers have their own language. We need to learn that language if we want to tell computers how to help us solve problems.

Whole Class

Eliciting Discussion:

1. Say to students, "Remember in the last lesson, we decided we needed a computer to help us calculate things like cost and runoff. To make the computer help us with this, we need to learn its language."
2. Guiding questions for discussion:

- "Have you ever written a computer program? In what language?" (*Scratch, App Inventor, etc*)
- "What kinds of commands or language do you think a computer understands?" (*Say, If <something> then do <something>, etc.*)

Activities

(Student Notebook p. 24-27)

(Teacher slides 56-57)

7.1 Let's play a simple TRUE/FALSE game! — 3 min

Whole Class

Purpose: Students practice True/False and follow a conditional (IF-THEN) statement

Open the activity with the following set of prompts

Say to students in the following order,

- "In order to create a computer model, let's first try to understand the language the computer uses. Let's start by playing a simple game."
- Let's all stand up. I'm going to make a statement. If the statement is true for you, say TRUE and follow the instruction."
- "If I am wearing blue, raise my right hand" (need to say true and also raise hand)
- "If I am wearing socks, raise my left hand."
- "If I have dark hair, stand on one leg."
- Use other examples as desired.
- "Thank-you all for playing. Let's all sit down now."

Closing the activity

Say to students, "True and False are very important to computers. Computers decide what to do based on whether statements are TRUE or FALSE, like you just did."

(Teacher slides 58-64)

7.2 Play a dice game with your partner — 20 min

Purpose: Students learn to evaluate IF-THEN statements (a) using variables and operators as part of the condition and (b) assigning variable values to constants or other variable values or values of expressions

Work in pairs

1. Say to students, "Now, we are going to determine whether statements are TRUE or FALSE based on whether values are equal to, less than, or greater than. To practice we are going to play a few dice games."
2. Say to students, "First, open your notebooks to Lesson 7. We will play Game #1 together."
3. Demonstrate how the games work as a class. Invite two students to be PlayerA and PlayerB. Have them roll dice. Tell the class what values were rolled. Show students how to complete the table for Game #1 by filling in the values of DiceA and DiceB, then determining whether each of the 3 statements is TRUE or FALSE. Based on which one is true, assign the scores of PlayerA and PlayerB accordingly. Play the game a few times if necessary, until students are ready to try it with their partner.
4. [Instructional note: You can roll the dice virtually by typing "roll dice" into google search]
5. Have students Play Games #2, 3, and 4 on their own.

Activity Debrief

When students are finished, ask if students have any questions

Instruction prompt: In this dice game, DiceA, DiceB, PlayerA_score, and PlayerB_score are called **variables**. A variable can have different values depending on what the instructions tell the computer to do.

Words like plus, minus, or less than are called operators. When you combine variables using **operators**, we call it an **expression**. Here are some examples of expressions: Dice1 + Dice2, Dice1 is less than Dice2, Dice1 – 5.

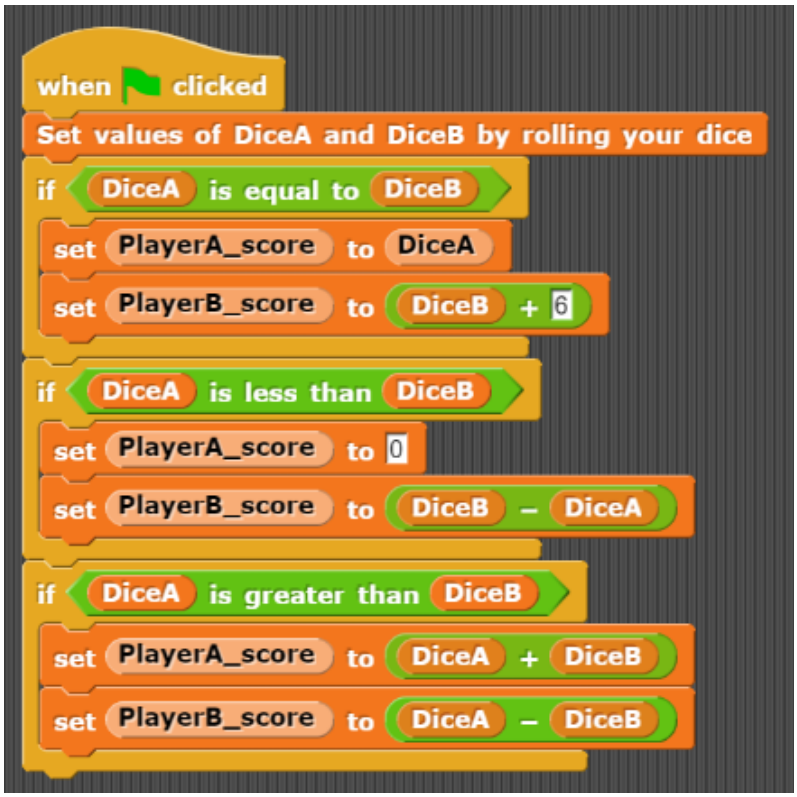
(Teacher slide 65)

7.3 Play a dice game by reading code

15 min

Purpose: Familiarize students with the block-based programming language they will use to build their runoff simulation.

Whole class



- Project the code. Say "This is what the computer language you will be using tomorrow looks like."
    - Note: This is not a fair game, but it has been designed this way to have the same program structure as that of the runoff model that students will work on in Lessons 8-10.

- Walk the students through the code and show them that the instructions are just like the ones they used to play the previous dice games. Just like before, depending on the role of the dice, we will set PlayerA_score and PlayerB_score to certain values.

- Ask pairs of student volunteers to come up to the board and roll dice. Have the class reach consensus on the appropriate scores and record them on the white board in a table like this:

	Dice variables		Score variables	
Round	Dice1	Dice2	Player1_score	Player2_score
1				
2				
3				
4				
5				
6				

- Try to do an example where DiceA is greater, one where DiceB is greater, and one where they are equal, so that students can have practice evaluating each of the 3 cases.
- Do 3 rounds together as a class, then have students do 3 more with their partner.

Closing

(Teacher slides 66-67)

Foreshadow tomorrow's lesson

2 min

- Say to students, "Now that we understand how to use computer language, tomorrow we will start building a program to test our designs for Walker. Instead of rolling dice and calculating player scores, the program will use the rainfall and the absorption limit to calculate the runoff."

Whole Class

Lesson 8: Build a computer model to calculate runoff from different surfaces (part 1)

Learning goals:

- Develop and test a runoff model that computes total absorption and total runoff based on total rainfall and surface materials
- Develop the part of the model for the case when the total rainfall is EQUAL TO the material absorption limit
- Apply understanding of basic programming concepts: if-then statements, variables, and expressions.
- Apply understanding of the basic conservation relationship ***total runoff = total rainfall – total absorption***
- Develop and use a set of test cases to test and debug their models

Materials:

- Teacher slides 68-81
- Student computers with reliable internet
- Demonstration video to introduce the programming environment

Preparation

- Provide students with usernames and passwords to log into the C2STEM environment (tinyurl.com/spiceva). Have students write their usernames and passwords into their notebook.

Overview

- Students develop test cases for when total rainfall is either equal to, less than, or greater than the material absorption limit
- Students articulate these cases as rules for computing absorption and runoff
- Students program the first rule (equal to) into C2STEM and test whether it is working

Relevant Vocabulary Words

- If-Then statements, variables, absorption limit, total absorption, total rainfall, total runoff, test cases

NOTE: Timing of Lessons 8 - 10

Lessons 8 - 10 are where students develop the computational model used to test their design solutions. Lesson 8 is the longest, because students have to develop test cases, formulate the runoff rules, learn to use the programming environment, program the first rule, then test the rule. Lesson 8 therefore may take more than one day, depending on the length of your classes. Lessons 9 and 10 will take less time because students only have to continue to develop and test their model code. It is expected that part of lesson 8 could spill over into the following day, but as students become familiar with the programming environment and the testing process, they will become more adept. Lessons 8-10 are expected to require a total of 3 instructional days.

Opening

(Teacher slide 68)

Review basic ideas

5 min

Whole Class

Discussion Goal: Students understand that they will use the language they learned in the dice games yesterday to program the computer. Students understand that rainwater either soaks into the ground or stays on the surface.

Reviewing Discussion:

- Ask students, "Today we're going to continue in our engineering design process. Can anyone remind me about where we are? What we have done? And what we still need to do?" *(Allow students to build on one another to more completely answer the question. So far we have developed a clear definition of the problem, and considered some solutions to that problem. We need a tool to test the solutions.)*
- Ask students, "Yesterday we learned about the language computers use to do things for us. What are some parts of the language we learned about? For example, we learned about TRUE and FALSE, and if-then." *(Student responses may vary. Other things students might say include variables, operators (less than, greater than, plus, minus*)
- Say to students, "We are going to use those ideas today to program the computer to calculate water runoff."

- Ask students, "What are the two things that can happen to rainwater when it hits the surface?" *(elicit absorb into the ground and stay on the surface or runoff)*

Activities

(Student Notebook p. 28-31)

(Teacher slide 69)

8.1 Create test cases

10 min

Group

Purpose: Students apply the concept of absorption limit to create a set of test cases.

- Say to students, "We are going to create some test cases. Test cases are values we use to test whether our computer program is working. We test computer programs with numbers we know are correct, so if the computer gives the wrong answer, we know our program is not working correctly."
- Allow students to work on 8.1. Students explore the 3 cases, where rainfall is equal to, less than, or greater than material absorption limits.
- **Student challenge:** Students may struggle especially with rainfall is less than absorption limit. If there is only 0.7 inches of rainfall but the absorption limit is 1 inch, only 0.7 inches of rainfall will be absorbed (not 1 inch).
- Go over the table in 8.1 together. If possible, reproduce the table on the whiteboard to refer to over the course of the next 3 lessons. Students will return to these values each time they want to test their model.

(Teacher slides 70-71)

8.2 Make the rules for the model

10 min

Purpose: Students generalize their calculations in the previous exercise to create expressions for each of the 3 cases.

- When figuring out the expressions, ask students how they calculated it for the specific storm in 8.1.
- You can do the first case (equal to) together as a class.

NGSS Crosscutting Concepts in this Lesson

It will be helpful to continue to emphasize the idea of conservation in this lesson, especially around the test cases and the runoff rules. Students should understand the basic reason for these rules: we have to account for all the rainfall--it must go somewhere and cannot just disappear. This is why we can calculate runoff based on rainfall and absorption limit.

- Rule #1: If total rainfall is equal to the absorption limit:
    - Set Total Absorption to EITHER total rainfall or absorption limit (both are correct, because the two are equal)
    - Set Total Runoff to 0 (zero)
- Rule #2: If total rainfall is less than the absorption limit:
    - Set total absorption to total rainfall
    - Set total runoff to 0 (zero)
- Rule #3: If total rainfall is greater than the absorption limit:
    - Set total absorption to absorption limit;
    - Set total runoff to (total rainfall – absorption limit). Students must write their own expression for runoff in Rule #3--students may need help reasoning through this. Ask them how they figured out the runoff was 0.4 inches in the test case (1.4 – 1=0.4).

(Teacher slides 72-78)

8.3 Start building your computer model

20 min

Purpose: Students program Rule #1 into the C2STEM environment.

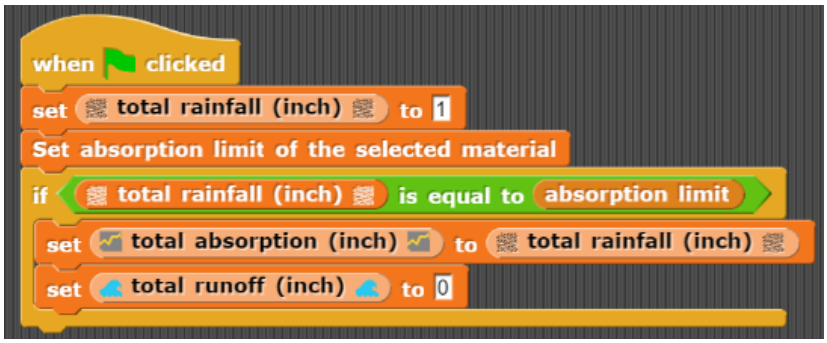
Individual (with elbow partners)

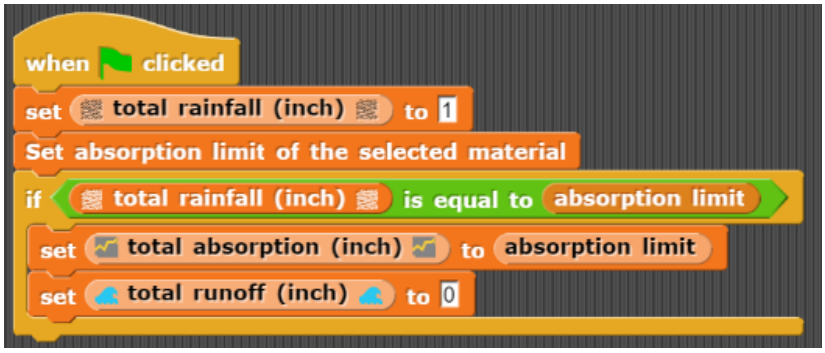
Check-in For Student Understanding in 8.3

Some students might find it helpful to write out the program themselves in English language ("pseudocode"). At the end of this lesson there is a sheet you can provide your students if you think it would be helpful. Otherwise, students can proceed directly to the programming environment.

- Have students use computers to log into the C2STEM system with their assigned usernames and passwords.
- Show the demonstration video that introduces students to the features of the programming environment.
- It would be helpful to do the first few blocks as a class. On the projector, show students how to assemble the first few blocks together:

- Then refer students to their expressions in 8.2. Students will need to drag blocks the left side of the screen to complete Rule #1 in one of the following ways:





- Encourage students to work with an elbow partner to help them craft the code.
- Remind students to save their work, so that they don't lose their progress.

(Teacher slides 80-81)

8.4 Testing the program

15 min

Purpose: Students test whether the Rule #1 they programmed gives the correct result calculated in part 8.1.

Individual (with elbow partner)

- Students will choose the material with an absorption limit of 1 inch (wood chips)
- Students will test their program using 1 inch (Rule #1), 0.7 inches (Rule #2), and 1.4 inches (Rule #3) of rain.
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- One way to quickly check the values produced by the model is to see if water is conserved. Does the amount of rainfall equal the amount of water absorbed plus the amount of water runoff? If not, water is not conserved and there is a problem.
- Students should mouse over the rain gauges to verify that Rule #1 is working. If it is not working, they should modify the code so that it does work.

- Students should realize that Rule #2 and #3 should not work because they haven't programmed them yet.
- Encourage students to work with a partner to help them make Rule #1 work correctly.

Closing — Foreshadow Lesson 9 — 2 min

Purpose: Inform students they will program and test Rule #2 next.

Whole Class

- Remind students to save their work.
- Say to students, "Today you programmed and tested Rule #1, when the total rainfall is equal to the materials' absorption limit. All the rainfall gets absorbed into the surface, leaving no water to run off. Tomorrow we will program rule #2, when the total rainfall is LESS than the materials' absorption limit."

(Optional Additional Practice)

Write instructions for your computer model

Before you program your computer model, complete (in English) these instructions for calculating the runoff based on your 3 rules.

When the green flag is clicked:

- Set the amount of rainfall

- Set the absorption limit of the material

- IF _____

  THEN

- IF _____

  THEN

- IF _____

  THEN

Lesson 9: Build a computer model to calculate runoff from different surfaces (part 2)

Learning goals:

- Develop and test a runoff model that computes water runoff and water absorption based on rainfall and surface materials
- Develop the part of the model for the case when the total rainfall is LESS THAN the material absorption limit
- Apply understanding of basic programming concepts such as if-then statements, variables, and expressions
- Apply understanding of the basic conservation relationship ***total runoff = total rainfall – total absorption***

Materials:

- Teacher slides 82-87
- Computers with browser; reliable internet

Preparation

- Students should already have assigned usernames and passwords to log into the C2STEM environment (tinyurl.com/spiceva)

Overview

- Students engage with a short debugging task
- Students program the second rule (less than) into C2STEM and test whether it is working

Relevant Vocabulary Words

- If-Then statements, variables, absorption limit, total absorption, total rainfall, total runoff, test cases, debugging

Opening

(Teacher slide 83)

Debug another students' program

5 min

Goal of Activity: Students get experience debugging (fixing errors in) an incorrect program, which will help them fix their own program or help another student.

Group

- Say to students, "Yesterday we programmed Rule #1, when the rainfall is equal to the material absorption limit. Before we program Rule #2, spend a few minutes figuring out what is wrong with the students' program at the start of Lesson 9."
- INSERT STRATEGIES TO USE TO HELP STRUGGLING STUDENTS?
- Answer: The example sets absorption to 0 and runoff to the total rainfall. The program should instead set runoff to 0, and total absorption to the absorption limit (or total rainfall). Go over this with the class. E

NGSS Crosscutting Concepts in this Lesson

In this lesson, students should continue to emphasize the conservation of water, especially around the test cases and the runoff rules. Students should understand the basic reason for these rules: we have to account for all the rainfall--it must go somewhere and cannot just disappear. This is why we can calculate runoff based on rainfall and absorption limit. It is also an easy way to do an initial check about whether or not an answer is reasonable, does rainfall=runoff+absorption? If not, there's definitely a problem!

(Student Notebook p. 32-33)

(Teacher slides 84-87)

9.1 Continue building your computer model

10-20 min

Purpose: Students program Rule #2 into the C2STEM environment.

- Have students use computers to log into the C2STEM system with their assigned usernames and passwords. Have students open their previous work. The code as they left it yesterday will appear.

- Students need to add code for Rule #2 and connect it below their existing code from the previous day. Guide them to complete the expressions for absorption and runoff in the following way:

(Teacher slide 87)

9.2 Testing Rule #2

5-10 min

Purpose: Students test whether the Rule #2 they programmed gives the same result as the test case (8.1).

Group

- Students will choose the material with an absorption limit of 1 inch (wood chips).
- Students will test their program using 1 inch (Rule #1), 0.7 inches (Rule #2), and 1.4 inches (Rule #3) of total rainfall.
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- Students should mouse over the rain gauges to verify that Rules #1 and #2 are working (will show correct amounts).
- Students should recognize that Rule #3 will not work because they haven't programmed it yet.
- Encourage students to work with a partner to help them make Rules #1 and #2 work correctly. When working with a partner, encourage students to take turns trying testing the rules. If a rule does not work, encourage students to help each other figure out what is wrong with the code, then remind students about the underlying meaning of the rules.
- For students who finish this quickly, they can be encouraged to continue to Lesson 10 on their own.

Closing — Foreshadow Lesson 10 — 2 min

Whole Class

Purpose: Inform students they will program and test Rule #3 tomorrow.

- Say to students, "Today you programmed and tested Rule #2, when the total rainfall is equal to the materials' absorption limit. All the rainfall gets absorbed into the surface, leaving no water to run off. Tomorrow we will program Rule #3, when the total rainfall is GREATER than the materials' absorption limit."

Lesson 10: Build a computer model to calculate runoff from different surfaces (part 3)

Learning goals:

- Develop and test a runoff model that computes water runoff and water absorption based on rainfall and surface materials
- Develop the part of the model for the case when the total rainfall is GREATER THAN the material absorption limit
- Apply understanding of basic programming concepts such as if-then statements, variables, and expressions
- Apply understanding of the basic conservation relationship ***total runoff = total rainfall – total absorption***

Materials:

- Teacher slides 88-89
- Computers with browser; reliable internet

Preparation

- Students already have assigned usernames and passwords to log into the C2STEM environment (tinyurl.com/spiceva)

Overview

- Students program the third rule (greater than) into C2STEM and test whether it is working
- Students test their completed model.
- Students having extra time can develop another set of test cases and test their model using the new test cases.

Relevant Vocabulary Words

- If-Then statements, variables, absorption limit, total absorption, total rainfall, total runoff, test cases

(Student Notebook p. 34-36)

(Teacher slide 89)

10.1 Continue building your computer model

10-20 min

Purpose: Students program Rule #3 into the C2STEM environment.

- Ask students, "Who can explain what Rule 1 and Rule 2 are?" *(Rule 1 is when the total rainfall is equal to the materials' absorption limit. All the rainfall gets absorbed into the surface, leaving no water to run off. Rule 2 is when the total rainfall is less than to the materials' absorption limit. All the rainfall gets absorbed into the surface, leaving no water to run off.)*
- Say to students, "Today, we are going to work on Rule 3, when the total rainfall is greater than the absorption limit."

NGSS Crosscutting Concepts in this Lesson

It will be helpful to continue to emphasize the idea of conservation in this lesson, especially around the test cases and the runoff rules. Students should understand the basic reason for these rules: we have to account for all the rainfall--it must go somewhere and cannot just disappear. This is why we can calculate runoff based on rainfall and absorption limit. It is also an easy way to do an initial check about whether or not an answer is reasonable, does rainfall = runoff + absorption? If not, there's definitely a problem!

- Have students use computers to log into the C2STEM system with their assigned usernames and passwords. Have students open their previous work. The code as they left it yesterday will appear.
- Students need to add code for Rule #3 and connect it below their existing code from the previous day. Guide them to complete the expressions for absorption and runoff in the following way:

- **Student challenge**: Students may not realize they can place the green subtraction operator in the set field and may need support with this.

10.2 Testing Rule #3 — 10 min

Purpose: Students test whether the Rule #3 they programmed gives the correct result calculated in part 8.1.

- Students will choose a material with an absorption limit of 1 inch.
- Students will test their program using 1 inch (Rule #1), 0.7 inches (Rule #2), and 1.4 inches (Rule #3) of rain.
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- Students should mouse over the rain gauges to verify that all 3 rules are working.
- Encourage students to work with a partner to help them make all 3 rules work. When working with a partner, encourage students to take turns trying testing the rules. If a rule does not work, encourage students to help each other figure out what is wrong with the code, then remind students about the underlying meaning of the rules.

10.3. Bonus Challenge! Create a new test case (optional activity) — 10-15 min

Purpose: Student create new test cases for a different material and test whether the program works for the new material

- Suggestion: If students progress through Rules 1-3 quickly and need another challenge, they can test whether the program works for another material that has a different absorption limit. The student notebook provides guidance for creating test cases for the material artificial turf (which has an absorption limit of 0.6 inches).
    - Doing this activity is not required in order for students to proceed to lesson 11, but could be enriching for students who are proficient with coding.
- Students will determine what values of rainfall are appropriate to test (these values should be equal to, less than, and greater than 0.6 inches)
- Students will test their program using these total rainfall values
- Students test if their program gives them the correct values.

Closing — Foreshadow Lesson 11 — 5 min

Whole Class

Purpose: Inform students how they will use the computer model they have developed to test and compare their designs in Lesson 11.

- Say to students, "Now that you have programmed all 3 rules into your computer model, we will use this model to test our 4 by 4 grid designs that we developed in Lesson 6. Tomorrow we will test our designs from Lesson 6 using the computer model to compare their total runoff, cost and accessibility. "

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

Learning goals:

- Computer models facilitate testing of numerous designs and complex designs
- Designs must be tested to determine how well they perform
- Engineers generate multiple designs before making a final decision

Materials:

- Teacher slides 90-94
- Computers with browser; reliable internet;
- Demonstration video for using C2STEM to test designs (optional)

Preparation: Students already have assigned usernames and passwords to log into the C2STEM environment (tinyurl.com/spiceva)

Overview

- Students test a previous design using their computational model.
- Students evaluate this design against design criteria.
- Students generate 2 additional designs that improve on their previous design

Relevant Vocabulary Words (students have seen these words in previous lessons. Help reinforce them by using them during discussions)

- Criteria, total absorption, total rainfall, total runoff, absorption limit

Opening

(Teacher Slide 91)

What can our computer model do?

5 min

Whole Class

Discussion Goal: Our computational model can help us test our designs for water runoff and cost. Our computational model also has limitations.

Review Discussion:

1. Quickly review place in unit - Ask students, "Today we're going to continue in our engineering design process. Can anyone remind me about where we are? What we have done? And what we still need to do?" *(Allow students to build on one another to more completely answer the question. So far we have developed a clear definition of the problem, considered some solutions to that problem, and coded a tool that will test various solutions to compare how effective they are. We still need to decide which solution will best solve the problem (and why?).)*

> **Engineering connection**
> This is a good time to revisit the engineering design process map. Help students to remember that the purpose of developing the model was to test their design solutions. In this lesson, they will use their designs from Lesson 6. Engineers must create multiple solutions to a problem before deciding on the best solution, making the use of computers necessary to determine which solution is more effective for solving the problem.

2. Guiding questions for discussion:

- Ask students, "What can our computer model do? How is it going to help us test our solutions?" (*It can calculate runoff for us based on what material has been chosen. It will make testing solutions with many surface materials much easier. It will make testing many solutions much easier.*)
- Ask students, "What doesn't our model include?" (evaporation, drainage systems. It only includes a handful of available materials)

NGSS Crosscutting Concepts in this Lesson

Each time students test a design, they must record the total rainfall used for the test, the total absorption for the test, and the total runoff for the test. These values are available by mousing over the rain gauges in the C2STEM model. These 3 values emphasize the conservation of water that the total runoff is equal to the total rainfall – total absorption. The focus of the engineering problem is to minimize runoff. This is accomplished by maximizing the amount of water absorbed. Good design solutions do not make the water disappear--rather, they create a place for more water to be absorbed, resulting in less runoff.

Activities

(Student Notebook p. 37-39)

(Teacher Slide 92-93)

11.1-11.3 Test your design

15 min

Group

Purpose: Students test their lesson 6 design solutions using the computer model.

- Show students the demonstration video about how to use the computer model to test a design.
- Students will need to refer to their design from Lesson 6 (page XX) or create a new one.
- Students will input their Lesson 6 design into the computer model, test it (by clicking the green flag), and recording the outcome of their test. The will also reevaluate their design according to the design criteria.

11.4 - 11.7 Create more designs

15-20 min

Purpose: Students generate at least two other solutions.

1. Say to students, "Engineers generate multiple solutions for a project to be able to pick from the best ones."
2. Students may find this difficult if they especially like their solution. You can prompt to be creative in their designs, such as using combinations of materials for a single purpose (e.g., combining artificial turf and grass for the grassy field). Prompt students to try to improve a specific aspect of their design, like improving accessibility, reducing runoff, or decreasing cost.

   (Caution: students often think that moving the same materials in the same proportions around in the grid is a new design, within the model it is the same design. Students must choose different materials or different proportions of the same materials.)
3. Students test and document the outcomes of each design. Students describe how each new design constitutes an improvement over a previous design.

Closing — How do we know what design will be best? — 5-10 min

(Teacher Slide 94)

Whole Class

Purpose: Elicit students' ideas about how to compare different solutions (to be built upon in the next lesson).

- Eliciting Discussion:
  1. Ask students, "You just generated three designs. How can you figure out which one is the best?" *(Student responses may vary. Have students explain why they chose their best solution. Encourage students to use language that includes design criteria, rainfall, absorption, and runoff.)*

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

Learning goals:

- Understand that fair tests hold variables constant to compare multiple designs.
- Be able to design and conduct fair tests to compare different designs along specific design criteria.
- Understand that sometimes designers make trade-offs between design variables, and that there is more than one way to conceive of a “best” design

Materials:

- Teacher slides 95-99
- Computers with browser; reliable internet

Preparation: Students already have assigned usernames and passwords to log into the C2STEM environment (tinyurl.com/spiceva)

Overview

- Students discuss what a fair test would be by making connections to a fair race
- Students conduct fair tests of their 3 designs and record their results.
- Students compare the designs and choose 1 to use as the starting point for the next lesson.

Relevant Vocabulary Words

- Fair tests; trade-off

Opening

(Teacher Slide 96)

How can you design a fair race?

5 min

Whole Class

Discussion Goal: Help students understand that certain variables need to be kept the same in order for tests to be fair. Students will need to understand that the total rainfall needs to be the same if they are to do fair tests of their designs.

Eliciting Discussion:

1. Ask students about where we are in the design process, "Today we're going to continue in our engineering design process. Can anyone remind me about where we are? What we have done? And what we still need to do?" *(Allow students to build on one another to more completely answer the question. So far we have developed a clear definition of the problem, considered some solutions to that problem, and coded a tool that will test various solutions to compare how effective they are. We still need to compare design solutions to determine which is most effective.)*
2. Guiding questions for discussion:
   - Ask students, "A running race is a way to find out who can run the fastest. How do we design a fair race?" *(Student responses may vary)*
   - Ask students, "Would it be fair if one student started way in front of the class, or if a student started way behind? Or if some students run on sand while others run on a track? Could some students run without shoes? Why or why not?" *(Student responses may vary)*
   - Ask students, "How can you make a race a fair test of students' running speed?" *(Student responses may vary. Help students understand that certain variables need to be kept the same in order for tests to be fair.)*

Activities

(Student Notebook p. 40-41)

(Teacher Slide 97)

12.1 How can you make a fair test of your designs?

5 min

Group

Purpose: Describe how to conduct a fair test of the Walker designs

- Ask students, "Right now you have created 3 different designs for Walker school and we have to test them. How can we test the designs to determine which one performs the best? How can we make sure the test is fair, like a running race?"

- Have students write their ideas in 12.1 of their notebook.
- If students struggle, ask students, "Would it be fair if one design was tested under really light rainfall and another under really heavy rainfall?" *(No. The rainfall needs to be the same in order to test how much gets* absorbed *and how much runoff there is.)*

(Teacher Slide 98)

12.2 Conduct fair tests

10-15 min

Purpose: Students compare their three designs by testing them all with the same total rainfall

1. Students will list the design criteria for all 3 of their designs side by side.
2. Students should choose an amount of rainfall that tests the design criteria (at least 2 inches of total rainfall, per the criteria). *(NOTE: If students test with too little rainfall, there may not be any runoff.)* Student should document the results of their test in the table.

12.3-12.9 Evaluate the designs

15 min

Purpose: Based on the results from the fair tests, students compare their designs along specific design criteria

1. Tell students to work in pairs to answer the questions in 12.3-12.8. Students should
    a. First, answer the questions on their own
    b. Then, share their answers with their elbow partners
    c. Ask each other questions if they disagree (eg., "I got a different answer. Can you show me how you got yours?")
    d. Then make a final decision on their design choices
    e. Explain their final design choice to their elbow partners

2. Students will need to justify their design choice, and will likely have to weigh trade-offs between cost, runoff, and accessibility.

   NOTE: **The prompt in 12.7 is particularly important because it synthesizes their answers to 12.4-12.6 by highlighting the nature of trade-offs in design.** It is likely that the design that has the best runoff performance will also NOT be the least expensive or most accessible. Recall from lesson 6 that materials that have high absorption limits AND have good accessibility tend also to be the most expensive (e.g., permeable concrete, artificial turf, poured rubber). If you go with lower cost materials, you sacrifice either accessibility or water absorption. Students will have to choose which of these is more important to them, or think hard about which design allows them to meet multiple criteria simultaneously. For instance, students may choose the cheapest design, even if it does not meet the accessibility criterion. **Students should try to achieve as many of the criteria as possible with a single design.**

Closing

(Teacher Slide 99)

What are different ways to have a good design?

5-10 min

Whole Class

Purpose: Summarize students' work and discuss trade-offs when choosing designs.

Summarizing Discussion:

1. Ask students, "How did you decide what design to choose?" *(Student responses may vary)*
2. Ask students, "Was it the best for every criterion?" *(Student responses may vary. Some students will be faced with a choice between a cheap design and a low runoff design.)*
3. Ask students, "Is there more than one way to have a good design?" *(Yes. Elicit ideas for choosing a good design. One way could be to pick the cheapest one--maybe the school could spend the extra money another*

way. Another way is to use the entire available budget of $750,000 and minimize runoff to the extent possible. There are multiple ways to conceive of the best design.)

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

Learning goals:

- Designs can be improved through iterative testing and refinement
- Documenting the results of design tests and comparing designs (using fair tests) can help to improve designs.

Materials:

- Teacher slides 100-103
- Computers with browser; reliable internet

Preparation:

- Students already have assigned usernames and passwords to log into the C2STEM environment (tinyurl.com/spiceva)
- Students will work in groups (of 3-4) that will create their final presentations to the class. Student can sit with their groups at the start of class.

Overview

- Individually, students iteratively refine their best design from the previous day, documenting important designs and test results along the way.
- Students form groups of 3-4 and collectively come up with the best design they can.
- Students document the final design that they will present as a group in Lesson 15.

Relevant Vocabulary Words (encourage the use of these terms in conversations)

- Fair tests; criteria; trade-off

Opening

(Teacher Slide 101)

Lesson overview

2-3 min

Whole Class

Overview Goal: Orient students to the lesson goal

- Provide an overview of the lesson
- Say to students, "Today we are going to continue to test and refine our designs. You will start with your best design from yesterday. Individually, each of you will work for the first part of class to improve your own design by testing it with the computer model."
- Say to students, "Then in your groups, you will come up with the best single design that you can based on your individual designs. You will present this design to the class in a couple of days."

Activities

(Student Notebook p. 42-43)

13.1 Improve your best design from yesterday

15-20 min

Individual

Purpose: Students individually iteratively refine designs using the simulation.

- Students should log in to C2STEM and put their best design from the previous day into the model.
- Students should separately try to decrease the runoff, cost, and increase accessibility while having to manage trade-offs (like choosing more expensive materials to reduce runoff).
- Students should document the best design(s) on a supplementary design sheet

13.2 Work with your team

20 min

Group

Purpose: Students discuss designs with members of a group and achieve consensus on the best design as a group.

- Students should be in the groups that they will be in for presentations (they will choose the design they will present at the end of the project).
- While students are in groups:
    - Each person should share their best design achieved through testing and revising
    - Other group members should listen and ask questions about the different designs
    - The group should decide on the design that they will present.
    - Students can also attempt to come up with a new design that combines the best parts of individual designs and test it
    - Provide an explanation for why they chose a specific design

- Students may need to be reminded to make sure they conduct fair comparisons of designs (total rainfall needs to be the same).

(Teacher Slide 103)

13.3 Finalize the design

10 min

Group

Purpose: Students choose and record the group's final design

- Each student in the group should make sure to record the group's decision.
- Students will need to test their final design using the computer model if they haven't already.
- Students should explain why they arrived at their final design over other options.

Closing — Foreshadow Lessons 14 & 15 — 1 min

Purpose: Inform students that in 2 days they will be presenting their group's best design. Tomorrow they will create the presentation and the next day give their presentations.

Whole Class

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

Learning goals:

- Students synthesize what they have done into a presentation that argues for their design.
- Students practice presenting their design.

Materials:

- Teacher slides 104-107
- Students already have assigned usernames and passwords to log into the C2STEM environment (tinyurl.com/spiceva)
- Presentation template (either Google Slides or Google Doc). Presentations can either be slide decks or a poster.

Preparation:

- You may want to create a google folder for everyone's google slides/doc in one place so that the presentations go smoothly in Lesson 15.
- Decide how many minutes each group will get to present based on the number of groups and time of your class.

Overview

- Students create a presentation of their work
- Students practice presenting to another group

Relevant Vocabulary Words

- None

Structuring Lesson 14 to Meet the Needs of YOUR Students

Lesson 14 allows students time to prepare a presentation on their design work. It is very open ended, and you should choose the activities that best align with your teaching style and classroom norms. You may develop your own criteria for the contents of students presentations. Presentations may be slide decks or posters. You may ask students to practice their presentations or not. The activities outlined here are suggestions on activities you could do to help students synthesize insights from the 3 week unit.

Depending on how many student groups you have and how long presentations are, you may need only half a class to do the presentations in Lesson 15. This would give students an additional half a class to prepare the presentations if you choose.

Included at the end of this lesson is a simple rubric for the presentations. You may choose to use this one, modify it, create your own, or have students co-create it with you.

Opening

(Teacher Slide 105-106)

What makes a good presentation?

5 min

Whole Class

Discussion Goal: Help students think about criteria for good presentations, and what the Principal might want to see for her/him to decide. If you normally use presentation rubrics/criteria this is a good place to remind students of your class norms. If you don't, you could use this opportunity to create class-generated rubrics.

Eliciting Discussion:

1. Guiding questions for discussion:

- Ask students, "What do you think the Principal wants to know in order to make his/her decision?" *(Encourage students to talk about their runoff models, criteria of their designs (squares used, cost, etc), runoff performance. What makes it a good design?)*

Activities

14.1 Create your presentation

35-40 min

(Student Notebook p. 44-45)

(Teacher Slide 107)

Group

Purpose: students create their presentation

- Students can either use the google doc or google slide template (would recommend you choosing one kind for everyone).
- They may need to go back and take pictures of their final designs in C2STEM and get test results if they haven't already.
- Make sure to tell students how much time they have for their presentations (5 minutes is usually plenty per group).

Below are some guidelines for structuring and organizing the student presentations:

- For **The Problem (page/panel/slide 1),**
    - Understanding of the problem: students can refer to Lesson 1.
    - How it affects the school and the environment: students may want to watch the opening video again to remember how the problem affects the school.
    - What happens when it rains at Walker: students can refer to lessons 2-5, and can include conceptual models or drawings of what happens when it rains. Students should include a description of what they intend to change (increase absorption) to decrease the amount of runoff.
- For **Our Scientific Model of the Problem (page/panel/slide 2)**
    - Students can use models created in Lessons 4-5
- For **Our Design and Evidence (page/panel/slide 3),**
    - Students can take a screenshot of their design in C2STEM and copy it into their document.

    - Students should have test data that show that it meets project criteria.

- For **Why our design is better than others (page/panel/slide 4),**
    - Students should describe the different kinds of designs they tested in activities 11-13 and how they came to choose their final design over all the others.
    - To argue for why the principal should choose their design, students can summarize the reasons why their design solves the problem at Walker.

14.2 Practice your presentation

5-10 min

Purpose: students practice what they are going to say.

Group

- Students may need help to figure out who is going to say what within their group. They can take notes in the notebook.
- Students can first practice among themselves, and then if there is extra time they can practice with another group.
- Each student should have a role in the presentation

Closing — Prepare for presentations

2 min

Purpose: summarize what students will do during presentations

Whole Class

- Give students guidance as to the procedures for presentations (each group will have 5 minutes, etc.).
- Suggestion: Ensure each member of each group has a role for the presentation
- Sample rubric on the following page.

Walker Water Runoff Presentation Sample Rubric

	4	3	2	1
Problem definition	Describes the problem, its effects on the school AND the environment	Describes the problem, and its effects on the school OR the environment	Describes the problem	Does not describe the problem
Runoff model	Shows a runoff model including amounts of rainfall, absorption, and runoff	Shows a runoff model including rainfall, absorption, and runoff, but not amounts	Shows a runoff model including rainfall, absorption, or runoff.	No runoff model
Design and evidence	Screenshot of 16 square design AND test data supporting design AND clear explanation of design	Screenshot of 16 square design AND test data supporting design and some explanation of design	Screenshot and/or test data and/or limited explanation	No clear design or evidence of effectiveness
Design Justification	Compares 2 designs, and describes tradeoffs between the designs	Compares 2 designs, but does not describe tradeoffs between designs	Shows 2 designs, but does not compare the designs	Only describes one design and does not discuss tradeoffs
Presentation	Student(s) involved contributed equally **AND** presentation delivery was clear and well-practiced	Student(s) involved contributed equally **OR** parts of presentation delivery were clear and well-practiced	Student(s) involved did not contribute equally **AND** presentation delivery was not clear	Student(s) involved did not present

Lesson 15: Final Presentations

Learning goal:

- Students communicate their understanding by presenting their designs.

Materials:

- Projector
- Optional: videocamera to record

Preparation:

- To make transitions go smoothly, have all the presentations in a single google folder.

Overview

- Students give their group presentations.

Relevant Vocabulary

- None

Opening	Presentation welcome **Goal**: Orient and remind students about presentation logistics. 1. Quickly remind students that they will be presenting in groups. 2. You may want to set up a reminder (hold up a piece of paper) if students are going over time.	5 min Whole Class
Activities (Student Notebook p. 46)	Student Presentations **Purpose: Students give presentations** - Students give their presentations in groups. - Depending on the presentation format, a gallery walk might be appropriate.	30-40 min Whole class

- Invite students to ask questions of their peers and contrast other designs with their own. Promote respectful discussion.
- Highlight ways that each group's design has merit. What did they deem most/least important (cost, runoff, accessibility) and why? Note the trade-offs students must make in achieving a final design.
- Suggestion: On the white board, consider tabulating the main design/performance criteria as follows:
-

Group #	Cost	# accessible squares	Inches of rainfall	Total runoff
Group 1				
Group 2				
Group 3				

- Then the class can look across all groups' designs to compare them. Keep in mind that not all students might have chosen to report runoff for 2 inches of rainfall, so runoff values might not be directly comparable. This is an opportunity to revisit the idea of fair tests.

Closing

Reflect on project

10 min

Purpose: Reflect on how science can be used to help people

Whole Class

- Possible questions:
  1. What did we learn in this project?
  2. How did we use what we learned to help Walker?
  3. What is engineering and how does it help improve people's lives? What other examples of engineering can you think of? (*Anything that is designed was engineered by somebody--look around the room or think of anything students enjoy, like video games or media*)

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