How to Build a Forest

Mathematics & science lesson, grade 6

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Lesson overview

In this lesson, students will use ratios in calculations, measure tree heights using a clinometer, practice making observations in the world around them, and engage in a role-playing exercise making decisions about use of natural resources and ecosystem services.

Learning objectives & "I can" statements

Learning objectives

Students will be able to

- use geometry to measure the height of a tree.
- apply the concept of a ratio to compare elements of fabricated trees to real trees.
- describe and identify biotic and abiotic factors.
- describe how biotic and abiotic factors affect the functioning of a forest ecosystem.
- explain the flow of energy through a forest ecosystem.
- engage in a simulation of real-world decision-making regarding environmental resources and ecosystem services.

"I can" statements

"I can use geometry to measure the height of a tree."
"I can apply the concept of a ratio to compare elements of fabricated trees to real trees."
"I can describe and identify biotic and abiotic factors."

"I can describe how biotic and abiotic factors affect the functioning of a forest ecosystem."
"I can explain the flow of energy through a forest ecosystem."
"I can engage in a simulation of real-world decision-making regarding environmental resources and ecosystem services."

Common Core State Standards & North Carolina Essential Standards

CCSS Language Arts

6.W.7. Conduct short research projects to answer a question, drawing on several sources and refocusing the inquiry when appropriate.

6.SL.4. Present claims and findings, sequencing ideas logically and using pertinent descriptions, facts, and details to accentuate main ideas or themes; use appropriate eye contact, adequate volume, and clear pronunciation.

6.RLSTS.3. Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

6.RLSTS.8. Distinguish among facts, reasoned judgment based on research findings, and speculation in a text.

CCSS Mathematics

6.RP.1. Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities.

6.RP.2. Understand the concept of a unit rate a/b associated with a ratio a:b with b ≠ 0, and use rate language in the context of a ratio relationship.

NCES Science

6.L.2.1 Summarize how energy derived from the sun is used by plants to produce sugars (photosynthesis) and is transferred within food chains and food webs (terrestrial and aquatic) from producers to consumers to decomposers.

6.L.2.3 Summarize how the abiotic factors (such as temperature, water, sunlight, and soil quality) of biomes (freshwater, marine, forest, grasslands, desert, tundra) affect the ability of organisms to grow, survive and/or create their own food through photosynthesis.

Materials

Measure Tree Height

- Thick, heavyweight paper
- Straight drinking straw
- String
- Washer or fishing weight
- Measuring tape
- Recording paper
- Trees

What's invisible?

- Forest, slides of a forest, or a printed forest photo

Watershed Obstacle Course

- Sturdy plastic or Styrofoam cups (they need to have some kind of lip)
- String
- Duct tape
- Permanent marker
- Water
- Timers

Vocabulary

Biotic, abiotic, ecosystem, ecosystem services, ratio, percent, diameter, circumference, clinometer, stakeholder, watershed

Before the performance

Tree Time Math

It may seem like it takes a very long time for the Builders to complete the forest on stage. However, it really is a very short time in the life of a tree. Let's figure out how many years are represented in the short amount of time it takes for each tree to gain maturity on stage.

1. The first trees to go up on stage are the slowest growing fabricated trees. They take on average 25 minutes to reach a height of approximately 21 feet. Slow growing trees add on average 1 foot of height per year. How many minutes would it take a

real tree with a slow growth rate to achieve a height of 21 feet? (Hint: You need to calculate how many years it will take the tree to grow that tall. You need to calculate how many minutes are in a year. Then you need to multiply the two numbers together!)

2. Most trees on stage have medium growth rates of 5 minutes. They also reach 21 feet in height. Real trees with medium growth rates add on average 1.5 feet of height per year. How many minutes would it take these trees with medium growth rates to reach heights of 21 feet?
3. A few fabricated trees have very fast growth rates of 15 seconds. These trees reach 20 feet in height. Real trees with fast growth rates add on average more than 2 feet per year. How many minutes would it take these real trees to reach a height of 20 feet? (Hint: You need to first convert the seconds into a fraction of a minute and express it as a decimal.)
4. How much slower do real trees grow than the fabricated trees?
    a. What is the ratio of the number of minutes it takes the real tree with a slow growth rate to achieve full height to the number of minutes it takes the fabricated tree with a slow growth rate to achieve the same height? Simplify the ratio!
    b. What is the ratio of the number of minutes it takes the real tree with a medium growth rate to achieve full height to the number of minutes it takes the fabricated tree with a medium growth rate to achieve the same height? Simplify the ratio!
    c. What is the ratio of the number of minutes it takes the real tree with a fast growth rate to achieve full height to the number of minutes it takes the fabricated tree with a fast growth rate to achieve the same height? Simplify the ratio!

Champion Trees

Out there in the forests surrounding us are Champion Trees. These trees are the largest trees known of their species, and they inspire people to find, admire, and protect both them and their surroundings. They are important not only because of their majestic and unique size, but also because that size often reflects their very advanced age and the potentially virgin state of the forest surrounding them. Their iconic status makes them critical rallying points in the drive to educate the general public and to protect the world's remaining forested land.

How to Build a Forest features a large, stately tree, which the audience might imagine to be a champion tree in this forest. Let's use math to compare that fabricated Champion Tree to several real Champion Trees.

1. The tallest tree in the United States is a Coast Redwood tree (*Sequoia sempervirens*). It actually was not officially discovered and measured until 2011! It stands an incredible 349 feet above the forest floor in Redwood National Park in California. If a story in a building is 10 feet tall, approximately how many stories tall would an equivalent structure be?
2. The fabricated forest's large tree stands approximately 20 feet tall. What percent of the champion redwood's 349 feet is that 20 feet?
3. That same champion tree does not have the largest circumference, but it still has a hefty girth of 845 inches. We know that the fabricated Champion Tree has a diameter of 3.5 feet. We want to know what fraction of the real Champion Tree's diameter the fabricated tree's diameter is. Answer the questions below to find out.
    a. Convert 845 inches to feet. Remember that 1 foot = 12 inches.
    b. Find the diameter of the real Champion Tree. Use the formula circumference = π x diameter.
    c. Calculate what fraction of the real Champion Tree's diameter the fabricated tree's diameter is.

Measure Tree Height, Part 1

Prepare the inclinometers ahead of time; the height measurements can be made during breaks of the performance or during another excursion to an area with trees.

Make a Fixed-Angle Inclinometer

Take a square piece of paper. If you need to make a rectangular piece square, fold one corner of the paper down until it meets the opposite edge, forming a triangle on top of a rectangle. Cut off the remaining rectangle. Unfold the triangle to reveal the square.

1. Fold the square piece of paper in half from corner to corner to form two triangles with one 90-degree angle and two 45-degree angles. Do not unfold it.
2. Tape a straight drinking straw to the hypotenuse of the triangle, making sure that one end of the straw extends slightly beyond the end of the paper. This straw is your eyepiece or "sight".
3. On the side where the straw does not extend beyond the paper, punch a small hole in the paper.
4. Insert string through the hole and tie a knot. There should be several inches of string hanging free, enough so that it hangs below the paper.
5. Tie a washer or fishing weight to the bottom of the string. The weight should hang a few inches below the corner of the paper so that it can swing freely.

During the performance

Measure Tree Height, Part 2

It is much easier to use this instrument with a partner. One person can sight the top of the object and the other person can observe the angle of inclination. It will also make measuring distance much easier.

How to Use a Fixed Angle Inclinometer

1. Have one person look through the straw and sight the top of the tree you are attempting to measure.
2. Choose a direction away from or towards the tree as appropriate where the ground stays relatively flat and you believe you will have a fairly clear sight line to the top of the tree. Move towards or away from the tree in this direction, keeping the top of the tree in view through the straw.
3. Stop moving when the other partner sees that the string is hanging straight up and down, lining up with the leg of the triangle. That means that the angle of elevation between your eye and the top of the object is 45 degrees.
4. Measure the distance between you and the base of the tree. This distance is also the height of the tree! We know this because in any 45-45-90 triangle, the two legs are always equal in length. To be more accurate, however, this is the height of the tree from your eye level to the top of the tree, so you should add your height from your feet to your eyes to the total in order to get the full height of the tree.
5. For more advanced students, you can also calculate the distance from the student's eye to the top of the tree. For that, you use the Pythagorean Theorem ($a^2+b^2=c^2$). The distance from the student to the tree is both a and b. The distance from the student's eye to the top of the tree is c, the hypotenuse of the triangle.

Have the students measure and record the heights of three trees. Back in the classroom, have the students share their data with the class and compare measured heights.

I Spy Game – why do we notice what we notice?

It is best if this game is played outside, either during a break at *How to Build a Forest* or in the schoolyard. However, it can also be played inside.

This game serves two purposes. The first purpose is to embolden students who feel intimidated by the idea of "making observations". Often students are wary of making observations because they feel unsure of how to go about making an observation or are afraid of being wrong. This activity is a way of opening the door to freely flowing observations and opening your students' eyes to parts of their surroundings to which they might otherwise never have paid any attention.

The second purpose is to spark a discussion about why we notice what we notice. After playing the game for a while, you and your students can evaluate the patterns in what they are noticing. Are they mostly certain distances from the ground? Are they mostly certain distances away? Are they mostly man-made objects? Are they mostly objects that could pose a danger? Why would we notice these objects and not others? It is very important not to mention to your students this second purpose until you have played the game for a significant amount of time. Otherwise, their knowledge will skew the results.

An excellent follow-up to playing this game would be to show the students one of the Test Your Awareness ads originally created to generate mindfulness of cyclists on London streets. One of the best is the ad set up like the game Clue, but with 21 set changes. Again, do not tell the students ahead of time to watch for the changes. Just show them the clip and let them be surprised. It will generate excellent discussion about what we notice and why!

How to play the game:

1. You are the person "spying". You say, "I spy …" and then choose a description that could fit multiple objects in the area.
2. You now have four options.
   - One option is to have the students silently or quietly in pairs write down everything they can spy that fits that description. This option has the benefit of increasing total participation.
   - The second option is to have students raise their hands and call on them for their observations. Here you will need to be careful in order to ensure that every student is contributing.
   - The third option, which will only work in classrooms where management is not a concern, is to have the students run to the first object that caught their eye that matched that description. This would work best if you gave them wait time first in order to make sure that everyone had identified their own object and students were not simply running with the majority of their classmates. It would be important for them to wait for a signal for you to run. This would, however, have the benefit of bringing out which objects were the most noticeable for the students.
   - You can also start out using one option and then transition to another option as the game progresses.
3. Once you have played the game for a significant period of time, lead the students in a discussion about what patterns they see in the objects they are noticing. Ask them why they think they might notice these objects rather than others. It would be a

good idea to point out a few objects that fit previous descriptions that they missed and did not notice. (This means you will have to be very observant!)

4. Take the students back to the classroom to watch the Awareness Test video and to finish their discussion. Especially pertinent to this discussion are the following questions. You could also have the students answer these questions in writing as a final assessment.
   - Why don't we tend to notice trees in our daily lives?
   - Why do we tend to notice things that move more than stationary objects?
   - Why do we tend to notice brightly colored objects rather than dully colored objects?
   - What do you think this means for trees in the fall? Might there be a reason other than just needing to shed excess tissue before winter for trees' leaves to turn such brilliant colors? (In fact, there is. Trees often time their fall showing of color with their production of nuts. Their showy colors advertise that they are ready harvest to passing birds and small mammals. This aids in the distribution of their seeds around the forest.)
   - Is there a benefit to paying more attention to the less noticeable things surrounding us? If so, what? If not, why not?

What's missing?

Part I – What's Missing?

During the performance, have each student make a list of the components of an ecosystem that they do not see represented in the fabricated forest to use in an exercise after the performance.

After the performance

What's missing?

Part I – What's Missing?

1. During the performance, have each student make a list of the components of an ecosystem that they do not see represented in the fabricated forest.
2. After the performance, make two lists either on chart paper or on the board. One list is for biotic factors and the other is for abiotic factors.
3. Have the students get into pairs or groups of three and share their lists, combining them into one list that is also divided into the two categories, biotic and abiotic.
4. Choose the first group that is finished to share their entire list for one of the categories. The other groups should cross off any components that they had in common to make sure that they do not repeat them.

5. Then each group should contribute any components remaining on their list until a master class list has been created for the first category. Repeat the process for the second category.
6. Have the students discuss why they think these particular elements were not included in the fabricated forest. Assign each group one or two specific, important components. If they had been the artists and they had wanted to include those components, how would they have done so? Why?

Part II – What's Invisible?

1. If possible, take your students into a forest ecosystem in a local park or even the schoolyard if there are enough trees. If that is not possible and you have access to a projector, show the students some photographs of different forest ecosystems. If you do not have access to a projector, print out a large picture of a forest for each student so that they can study it. Reinforce the knowledge that the flow of energy through an ecosystem begins with producers, which capture radiant energy and convert it to chemical energy. Introduce the idea that producers and consumers can both be influenced by the intricate web of relationships among one another as well as the many abiotic factors in their environment.
2. In pairs, have the students brainstorm about what parts of the forest are usually invisible to humans. These components may seem to be missing because we almost never see them, but they are essential parts of the functioning system. Let the students work for a while and then consider giving them a fresh wave of ideas by suggesting ideas such as "What happens in the forest at night?" or "What happens in the soil?" or "What happens in a fallen log?".

Part III – What If? A Town Hall Meeting

This culminating activity requires your students to grapple with real-world issues and situations. As adults they will face important decisions, such as this one and they will need to be able to make informed, educated choices that will support their communities and their environment. It is very important to convey to the students early on this process that, just like in a small community in the real world, this is not intended to be a debate, but an earnest discussion. We depend on each other and the goal is teamwork, not alienation.

Step 1 – Preparing to Work Together – Watershed Obstacle Course

This activity is an excellent introduction to the Town Hall Meeting. It prepares the students to listen to each other, to compromise, and to be aware of their words and actions. It also serves as a strong visual for how each person is an equal stakeholder in the fate of the watershed moving forward.

Preparation of the cups:

1. You can fit 6 children on one cup. Tie one string around the cup under the lip and knot it firmly.
2. Further secure the string around the cup with duct tape, making sure to leave at leave 6 places on the string exposed.
3. Measure out 6 identical lengths of string, each approximately two and a half feet long. Tie one piece of string to each exposed place on the string ringing the cup. These will be the strings the students will use to hold the cup.
4. Make a mark with permanent marker on the last 2 inches of each string farthest from the cup. The students' fingers cannot go past this mark.

Running the obstacle course:

1. Take the students outside. Demonstrate walking through whatever obstacle course you have devised. Obstacles that work particularly well are going under railings, winding through bike racks, climbing over low playground equipment, and sitting down and then standing up as a group. Remind the students that at no point may they set the cup down on the ground!
2. Talk the students through the course several times. Then have a few students talk the group through the course.
3. Put the students in groups of 6.
4. Have each student hold one string, no lower than the mark made by the permanent marker.
5. Fill the cup with water until it overflows. This cup represents the watershed. Each student is attached to and responsible for the fate of the watershed. They will need to cooperate in order to successfully navigate the course, while keeping as much water as possible in the cup.
6. Start that first group on their way and start their timer. Meanwhile, start preparing the second group. It is important to stagger the groups so they do not get entangled in the obstacles. Once the first group is sufficiently far ahead, release the second group and start their timer. Continue this until all the groups have gone. As each group returns to you, stop their timer and mark how much water remained in their cup. Also make a note of how well the group worked together.
7. After all the groups have completed the course, compare times, water levels, and cooperation to decide on the winning team, second place, and third place.
8. Lead a brief discussion.
    a. What was the most difficult aspect? Why?
    b. What was the easiest aspect? Why?
    c. What cooperation strategies worked? What didn't work?
    d. What are some lessons learned from this activity that we will need to bear in mind during our Town Hall Meeting?

Step 2 – Setting up the Meeting

Draw a diagram of a fictitious town and its environs on the board. It is important that the town is small. It is also important that it is located near a river and a forest. Announce to the students that they are all citizens of this fictitious town, which they will get to name.

The decision facing them and the reason for the Town Hall Meeting is the proposal for a new dam upriver of the town. This dam will create a reservoir, which will insure a consistent water supply for the town during years of drought as well as supplying many other benefits. However, among other potentially negative effects, the reservoir will also flood a large portion of the remaining forested land. Forests supply a number of important ecosystem services, such as water filtration, habitat for animals that might otherwise encroach on human populations, and habitat for predators of animals whose populations would otherwise grow out of control. (Briefly connect these ecosystem services to the students' own experiences. What cleans their water?) Show the students where the dam will be placed and the area that will be flooded. Give them this basic information, but not too much, since you want them to discover a lot of the pros and cons of the dam for themselves.

Brainstorm an initial class list of pros and cons of building the dam. Really push the students to reach and to continue to search for more effects of the dam. If they become completely at a loss, you can prompt them with a question such as, "Have you thought about what might happen to the soil?" Try not to contribute directly to the list yourself. Have all the students write down the list as it is generated. It will help them in their research later.

Now introduce the concept of a stakeholder. A stakeholder is someone who has an interest in the proceedings. The stakeholders will largely be citizens of this town, but a few might be outsiders, such as a CEO of a hydroelectric company. Brainstorm an extensive list of stakeholders, making sure to cover a broad spectrum of viewpoints. For example, if you have an ecology professor from a local community college, then you would also want to have a realtor, who might be interested in developing the lakefront property. The mayor is usually an important character, as are local businesspeople, who represent the often complicated arguments involving economics. Once you have a thorough list, whittle it down to the correct number according to the number of students you have. You can do this by eliminating positions that are similar to each other or that seem truly superfluous. Try to give the students a say in this. Finally, pull student names from a jar to allow them to choose which role they would like to assume. Be sure to record which role each student chooses.

Step 3 – Research

Have each student generate two lists of research questions. One list is about dams and forest ecosystem services in general. An alternate idea is for you to generate this list in advance and provide it to the students. The second list should be about their character's particular viewpoint. For example, if the student chose to be the logger, then among many other things, they would need to know how much money they would make from clear-cutting the area before it is flooded versus how much money they would make from sustainably logging the area were it not to be flooded. These are the things the student will need to know in order to be able to make reasonable, educated decisions and answers to other students' questions during the Town Hall Meeting.

Take the students to the library or media center. Have them conduct research to answer their lists of questions. Caution them also to mentally separate facts they find in their research from opinions relevant to the perspective of their character.

Step 4 – Town Hall Meeting.

1. Arrange the students in a circle.
2. Have each student create a large nametag with their character's profession on it in letters that can easily be read across the room. They will need to wear that nametag. They should address each other as Mr. Farmer or Ms. Mayor throughout the course of the Town Hall Meeting.
3. Have each student crumple up 3 pieces of paper of one color. Explain that every time they want to introduce a new topic, they must throw one piece of paper of this color into the center of the circle. They must use all their pieces of paper. They cannot use more than four pieces of paper. If you have a lot of students, you may want to reduce the number of pieces of paper. If you have very few students, you may want to increase the number.
4. Have each student crumple up 6 pieces of paper of a different color. Explain that every time they want to respond to something someone else has said, they must throw one piece of paper of this color into the circle. They must use all their pieces of paper. They cannot use more than sic pieces of paper. If you have a lot of students, you may want to reduce the number of pieces of paper. If you have very few students, you may want to increase the number.
5. You should introduce yourself as the moderator. Explain that while you will be calling on participants to contribute as they raise their hands, they are addressing each other and should face each other as they speak. Provide a brief summary of the reason for the Town Hall Meeting and call the meeting to order.
6. Don't worry if the meeting feels a bit stilted at first. The students may take a little while to get into the swing of it, but eventually their passion will come out as you delve deeper into the problem and more opinions are put out on the table. Solicit

opinions from interesting viewpoints and help shape and craft the narrative by your choices of whom to call on, but refrain from inserting your own opinion on the subject. Let them come to their own conclusion.

7. When you have reached the pre-assigned time limit, bring the meeting to a close and provide a summary of the various arguments and compromises brought forward during the meeting. State the situation as it now stands and ask for a simple aye/nay vote on it to see if it would pass as it stands.
8. In the following class period, lead a discussion about the decision as well as the experience of the Town Hall Meeting. What was challenging? What was true to life? What was surprising? What impact would your decision have on the forest? On your town? On the economics of your town? On the ecosystem services the forest provides to your town?

Assessment

Collect and score the mathematics assignments. During the Town Hall Meeting, assess students' abilities to explain ecosystem services for the purpose of negotiating with other stakeholders and evaluate the relationship of those ecosystem services to a given viewpoint.