6. Ladder Fuels and Fire Spread: The Tinker Tree Derby

Lesson Overview: In this activity, students use a physical model to learn how the vertical arrangement of fuels affects the potential for fires to spread into tree crowns. This activity applies mainly to forests, shrublands, and woodlands.

Lesson Goal: Increase students' understanding of the relationship between fuel arrangement and vertical fire spread, especially in forests, shrublands, and woodlands.

Subjects: Science, Writing, Health and Safety

Duration: One to two half-hour sessions

Group size: Whole class, working in 4 teams to prepare

Setting: Indoor laboratory or outdoors

New FireWorks vocabulary: *ladder fuels, succession*

Objectives:

- Students can design a model tree and assess its ability to "survive" a surface fire.

Standards		6th	7th	8th
CCSS	Writing	4,10	4,10	4,10
	Language	1,2,3,4,6	1,2,3,4,6	1,2,3,4,6
	Writing: Science and Technology	4,10	4,10	4,10
NGSS	History of Earth	ESS2.A		
	Human Impacts	ESS3.B, ESS3.C		
	Engineering Design	EST1.A, ETS1.B,ETS1.C		
EEEGL	Strand 1	B, C, E, F, G		

Teacher Background: This activity explores the potential for a surface fire (burning in vegetation on the forest floor) to spread up into the crowns of overhanging trees. The more continuous the fuels, the more likely this will happen. Fuels that enable fire to climb from the forest floor to the crowns of trees are known as *ladder fuels*. Once fire is in a tree crown, it could spread directly from one tree crown to the next; such crown fires are usually more dangerous and harder to control than surface fires.

The Tinker Tree Derby is a competition among student teams. Each team constructs a "tinker tree" from a support stand, wire rods, and newspaper fuels. The goal is to design a tree that can "survive" a fire passing beneath (surface fire) but also has plenty of leaves so it can photosynthesize, continuing to grow and produce seeds. A team's success is tested by experimental burning. The tree that survives burning with the greatest potential for

photosynthesis is the winner. Photosynthesis potential is quantified in this activity by the **length of branch with unburned "foliage"** (newspaper strips on branches) remaining after the fire. Figure M06-1 below shows how to set up the tinker trees.

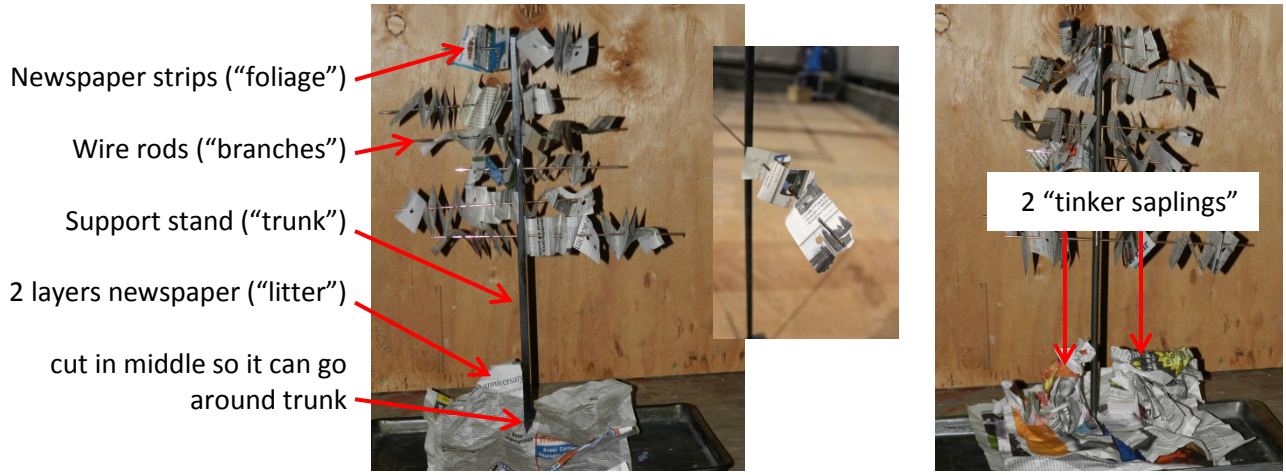


Figure M06-1. Setting up a tinker tree model. Place support stand ("trunk") on burning tray. For Phase 1 (shown at left), place 2 crinkled sheets of newspaper ("litter") around base of tree. Students insert as many wire rods ("branches") as desired into trunk. They thread hole-punched pieces of newspaper ("foliage") on branches. At outside end of foliage strips, use rod to punch hole (shown at center). For Phase 2 (shown at right), add 4 crinkled sheets of newspaper around base of tree and place 2 crumpled sheets ("tinker saplings") on top of them, 1 under each side of the tree.

The Tinker Tree Derby has two phases, which enable students to see the effects of two different amounts of surface fuels. Phase 1 uses relatively light surface fuels, and Phase 2 uses much more fuel. Any tinker trees that survive Phase 1 (the "Qualifying Round") will be tested again in Phase 2 (the "Championship Round"). **Thus it is important to not moisten or disturb the trees after they are burned in Phase 1.** The 2 phases model the potential for accumulation of surface fuel and development of the understory (tree saplings and shrubs) over time, during the process of *succession* (the process of change over time). We recommend that you don't give students any details about Phase 2 until after Phase 1.

Materials and preparation:

Do this activity in an area with good ventilation and a hood or a fairly high ceiling. Smoldering pieces of newspaper can rise as high as 20 feet on the heat plume. If your laboratory hood is not adequate, consider igniting the Tinker Trees outdoors – but not on a windy day. Use a large area that far from dry grass, bark chips, and other fuels. Have a bucket of water and a hose available, with the water on. Have another adult help "patrol" for burning materials.

The day before doing this activity, remind students to follow the safety guidelines about clothing and hair when they get ready for school tomorrow.

You will need a lot of newspaper. Get students to prepare

- four bags (1 per team), each containing about 30 strips of newspaper approximately 40 cm long and 4 cm wide. Each strip has to be folded accordion-wise and hole-punched so it can be threaded onto a wire rod to represent tree foliage. The strips represent tree foliage in the tinker tree model.
- 24 half-sheets of newspaper, 25 x 35 cm. These represent litter in the model.
- 8 quarter-sheets of newspaper, approximately 25 x 20 cm. These represent saplings in the model.

Set up four work stations. Each station should have

- 1 Tinker Tree support stand
- 1 pair of safety goggles
- 1 oven mitt
- 1 ashtray
- 1 metal tray with a support stand on it
- 10-15 segments of wire rod
- 6 half-sheets of newspaper, 25 x 35 cm
- about 30 narrow strips of newspaper, cut into strips and hole-punched
- 2 quarter-sheets of newspaper
- paper towels for clean-up
- 1 spray bottle, filled with water

In addition, you will need:

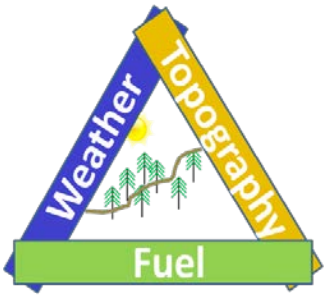
- 1 measuring tape
- 1 fire extinguisher (make sure it is charged and know how to use it)
- 1 "Tinker Trees" kit with 4 pendants (awards for the winners in each phase)
- 1 box of kitchen matches
- A handful of hair ties, in case students need them

Have an empty *metal* trash can *without a plastic liner* available in the room.

Display Posters:

- FireWorks safety
- Fire Environment Triangle

Download "ladder_fuels.jpg"



FireWorks Safety

When you do experiments with fire…

1. Wear cotton clothing. No synthetic pants, soccer shorts, etc.
2. Wear closed-toed shoes. No sandals or flipflops.
3. Tie back loose sleeves.
4. Tie back loose hair.
5. Make sure a fire extinguisher is close. Make sure it is charged. Know how to use it.
6. Make sure spray bottles are close and filled with water.
7. Wear safety goggles when burning.
8. *Never* lean over a fire.
9. Extinguish burned materials with water before putting them in the trash. *Fire is not out if there is any smoke or heat coming from the fuels.*
10. If a fire starts on you, stop, drop, and roll.

Use fire ONLY if a responsible adult is working with you.

Make 1 copy of **Handout M06-1. Tinker Tree Derby instructions and Rules** for each team and 1 copy of **Handout M06-2. Tinker Tree Model vs. Reality** for each student.

Copy this table onto the board (or a sheet of paper if you're burning outdoors):

Team name	Qualifying Round: Surviving foliage (cm)	Championship Round: Surviving foliage (cm)

Procedure:

1. Explain: In this activity, we'll look more carefully at the Fuels side of the Fire Environment Triangle (AKA Fire Behavior Triangle). We'll think about how fuels are arranged – especially in forests and shrublands – and how the arrangement of fuels changes as plant communities change over time, a process called *succession*.

2. Project this image (ladder_fuels.jpg). Explain: If fuels are continuous from the forest floor into the tree crowns, we call them *ladder fuels.* A surface fire can climb them like a ladder and get into the crowns, where it becomes much more powerful than a surface fire and more difficult to control.

3. Distribute **Handout M06-1: Tinker Tree Derby Instructions and Rules**. Explain: This is a competition between teams, where you apply what you know about fuels to design a model tree that can "survive" a surface fire without having the fire climb into the treetops, thus becoming a crown fire. The winning tree will not just avoid being burned up; it will also have lots of foliage left, so it can continue to photosynthesize, grow, and reproduce after the fire. Therefore, your task is to have your tree avoid crown fire and at the same time have lots of foliage left after the surface fire.

4. Have each team read Handout M06-1 together. Answer any questions. Show them how you will determine the tree's score: You will measure the length of branch (cm) that still has unburned newspaper ("live foliage") on it – NOT the total amount of newspaper or its weight. Ask the class to tell you one thing that will disqualify them from competition. (Any moisture that they add to their model.)

5. **Do a safety briefing** using the *FireWorks Safety* poster. Review the location of spray bottles and a fire extinguisher.

6. Give the students ~10 minutes to construct their trees. Watch for moisture violations! Then have them ignite the trees one team at a time, so everyone gets to see every fire.

Phase 1 - Qualifying round:

A. One team at a time…

- Ask for the team name and have a student write it on the board.
- Check and modify the surface fuels to make them similar among trees so this variable will not confound the results.
- Have the students start the fire by igniting two corners along one long edge of the metal tray. If they all use the same ignition pattern, this variable will not confound the results.
- When the fire is out, use the measuring tape to determine the tree's score: the length of branch (cm) that still has unburned " foliage." Have a student record this on the board under "Qualifying Round" for that team.

B. After all teams have completed a burn, determine the winner of the Qualifying Round, that is, the team with the greatest total branch length with living foliage.

C. Award Tinker Tree Derby Champion badges to the winning team. They get to wear the badges until the end of class.

Phase 2 – Championship Round:

D. For all teams whose tinker trees survived the Qualifying Round, have students leave the surviving foliage intact but gently remove the ash of the burned surface fuels and replace it with four new layers of surface fuel (crumpled half-sheets of newspaper). Teams with trees that did not survive the Qualifying Round (zero centimeters of unburned foliage) get to observe.

E. Explain: Surface fuels often accumulate as plant communities change over time without fire. Trees reproduce, and shrubs develop under the forest canopy in this process, which is called succession.

F. Have each team take two smaller pieces of newspaper (quarter-sheets), crumple them up, and place one on each side of their tinker tree trunk under the branches. These are "tinker saplings," young trees that grow up under the old survivor.

G. One team at a time, check their fuels… have them ignite… and determine the tree's score. Determine the winner, if any. Award Tinker Tree Grand Champion badges to the winning team. They get to wear these until the end of class.

Assessment: Have each student complete **Handout M06-2: Tinker Tree Model vs. Reality.**

Evaluation:
Question 1. Assess changes individually.

Question 2. Examples of model shortcomings:

- Tinker tree's metal trunk cannot be damaged by fire.
- Tinker tree is two-dimensional (has foliage only on 2 sides of trunk).
- Foliage is not alive, so it has no moisture and is not changing with the seasons.
- Tinker tree has no roots that could be damaged by fire.
- Tinker tree does not grow taller, gain new branches, or shed old ones as years go by and succession occurs.

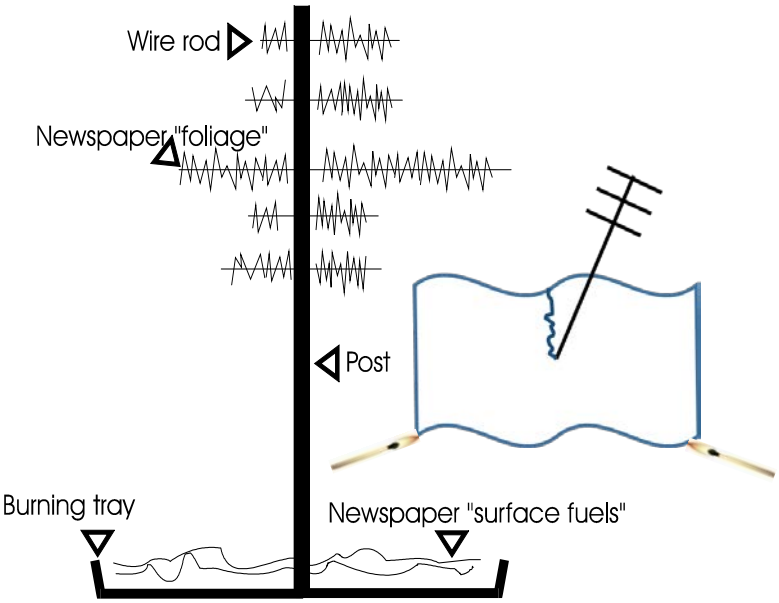
Question 3. A has more surface fuels, larger surface fuels, more ladder fuels, and closer spaced tree crowns than B. Thus A is more likely to have a crown fire on a dry, windy day than B. However, B is more open than A (i.e., lower stand density), so the wind at the ground surface is likely to be stronger and thus surface fire is likely to spread faster in B than in A. (A point not covered in this activity: Because of its heavy fuels, A is more likely to have a very severe surface fire than B – which could kill the trees even without burning their crowns.)

	Excellent	Good	Fair	Poor
1. Changes to Tinker Tree	>2 changes	2 changes	1 change	0 changes
2. How Tinker Tree is not real	>2 examples	2 examples	1 example	0 examples
3. Compare fuels and potential fire behavior	-Described 3 or more differences in fuels/density and explained 1-2 differences in potential fire behavior.	-Described 2 differences in fuels/density and explained at least crown fire potential.	-Described 1 difference in fuels/density or explained crown fire potential.	-Did not address questions.
3b. Use terms correctly (surface fire, crown fire, ladder fuels, stand density)	-Correctly used 4 terms	-Correctly used 3 terms.	-Correctly used 2 terms.	-Correctly used 1 or no terms.

Handout M06-1: Tinker Tree Derby Instructions and Rules

A tinker tree is a two-dimensional model of a tree. Its trunk is a lab support stand. Its branches are rods stuck through holes in the trunk. Its leaves are strips of newspaper. Your goal is to design and build a tinker tree with a crown that does not burn when a fire burns the surface fuels beneath it. Your job could be easy—just put together a tree with no leaves. But your tree must also have *foliage* (leaves) to win the Tinker Tree Derby – the more, the better. You have to figure out how much foliage to use and how to arrange it on the tree so the tree can survive a surface fire.

Procedure:



1. Place a support stand (metal post) in the center of the metal tray.
2. Crumple up two half-pages of newspaper. These are your litter and other surface fuels. Flatten them out a bit, but make sure that some air can get between the layers.
3. Cut or tear a line from one edge of the newspaper pieces to the middle. Then place both layers on the support stand base, with the stand's post at the center.
4. Slide wire "branches" through the holes in the post. You may use as many or as few branches as you want.
5. Use the long, narrow strips of newspaper for foliage. Slide a foliage strip onto each tinker tree branch. For short branches, you may shorten the newspaper strip. Use the branch to poke a small hole at the outer end of the foliage strip rather than using a punched hole, so the newspaper won't fly off the branch once you start burning.
6. Teams will ignite their tinker trees one at a time. When the teacher tells you it's time to ignite yours, start the fire by igniting two corners along **one long edge of the metal tray**.

Rules:

- Do not use any moisture on your tinker tree or experimental setup before it is burned. **If you do, your tree will be disqualified.**
- Do not move or moisten your tree's foliage after you have underburned it.
- Do not hang foliage so it dangles into the branches below.

Keeping score: After you have underburned your tinker tree, the teacher will assign it a score: **the number of centimeters of branch still covered by unburned foliage**. If your score is greater than zero, your tree has qualified for the Championship Round of the Tinker Tree Derby. Do not change anything about it until you receive further instructions.

Handout M06-2. Tinker Tree Model vs. Reality

Name _____

1. List at least three changes you would make to your Tinker Tree or surface fuels to increase the tree's chances of surviving a surface fire. Explain why you would make each change.

2. List at least three ways in which the Tinker Tree model does *not* resemble a real tree.

3. Study the photographs below. Write a paragraph that answers these questions:
   - How are the fuels in "A" different from those in "B"?
   - How are the different fuels likely to affect the kind of fire that would occur there on a dry, windy day?
   - How is the stand density (which was covered in the last activity – Matchstick Forests – likely to affect the kind of fire that would occur there on a dry, windy day?

   Use the following terms correctly in your explanation: surface fire, crown fire, ladder fuels, stand density.

A.

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B.

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