6. Ladder Fuels & Fire Spread: The Tinker Tree/Shrub Derby

Overview
In this activity, students use a physical model to learn how the vertical arrangement of fuels (ladder fuels) affects the potential for fires to spread into tree and shrub crowns. Teams create “tinker tree” models and compete by lighting simulated surface fires under the “trees.” Those with unburned “foliage” advance to a final round with more surface fuel. Students use a handout to guide their inquiry and analysis.

Note: This activity applies to sagebrush ecosystems, as well as forests. For example, invasive plants like cheatgrass can act like ladder fuels, since they are fine, dry, and burn intensely; this allows surface fires to spread to the tops of large shrubs. Also, juniper and pinyon pine have been encroaching into sagebrush ecosystem areas. And forests containing a number of tree species can be found at higher elevations and in riparian areas adjacent to sagebrush ecosystem areas.

Lesson Goals
- Increase students’ understanding of the relationship between fuel arrangement and vertical fire spread
- Develop student skills in making predictions, engineering, experimentation, and written communication

Objectives
- Students will design a model tree/shrub and assess its ability to “survive” a surface fire.
- Students will analyze the role of different types of surface vegetation and litter in forest and sagebrush ecosystem fires.

Subjects: Science, Writing
Duration: 40 - 60 minutes
Setting: Indoor laboratory or outdoors

Vocabulary
- ladder fuels
- crown fires
- surface fires

<table>
<thead>
<tr>
<th>Standards</th>
<th>Middle School (Grades 6-8)</th>
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<tbody>
<tr>
<td>NGSS</td>
<td></td>
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<tr>
<td>Crosscutting Concepts</td>
<td>• Stability and Change</td>
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<td>Science &amp; Engineering Practices</td>
<td>• Systems and System Models</td>
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<td></td>
<td>• Developing and Using Models</td>
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<tr>
<td></td>
<td>• Constructing Explanations and Designing Solutions</td>
</tr>
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<td></td>
<td>• Obtaining, Evaluating, and Communicating Information</td>
</tr>
<tr>
<td></td>
<td>LS2.C: Ecosystem Dynamics, Functioning, and Resilience</td>
</tr>
<tr>
<td>Common Core</td>
<td></td>
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<tr>
<td>ELA</td>
<td></td>
</tr>
<tr>
<td>Writing</td>
<td>4, 7, 8, 10</td>
</tr>
<tr>
<td>Language Standards</td>
<td>1, 2, 6</td>
</tr>
<tr>
<td>Reading Standards</td>
<td>3, 9</td>
</tr>
<tr>
<td>Science &amp; Technical Subjects</td>
<td></td>
</tr>
<tr>
<td>Writing Standards</td>
<td>4, 10</td>
</tr>
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<td>Science &amp; Technical Subjects</td>
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<td>EEEGL Strand 1</td>
<td>B, C, E, F, G</td>
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**Teacher Background**

This activity explores the potential for a *surface fire* (burning of vegetation on the forest floor or shrubland surface) to spread up into the crowns of overhanging trees and/or shrubs. The more continuous the fuels, the more likely this will happen. The fuel that allows fire to climb from the forest/shrubland floor to the crowns of trees/shrubs is known as *ladder fuel*. Once fire is in a tree or shrub crown, it can spread directly from one tree or shrub 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 withstand fire passing beneath (surface fire), but that also has plenty of leaves so it can photosynthesize, grow, and produce seeds. A team’s success is tested by experimental burning. The tree/shrub that survives burning with the greatest potential for photosynthesis is the winner. Photosynthesis potential is quantified by the length of the “branches” with unburned “foliage” (newspaper strips on branches) after the fire.

The Derby has two phases, which enable students to see the effects of two different levels of surface fuels (and hence the effects of time between fires in allowing more fuels to accumulate). However, you should only tell students ahead of time about Phase 1 (the Qualifying Round), which uses relatively light fuels. Any trees that survive Phase 1 will then be tested in Phase 2 (the Championship Round), with more than twice as much fuel and greater vertical continuity, as might occur in forest *succession*.

While this version of the *FireWorks* program focuses on the sagebrush ecosystem, juniper and pinyon pine have been *encroaching* into these areas. While it is only half the size it was in the early 1800s, the sagebrush ecosystem is still the largest in North America, with 350+ species. A large area of the ecosystem is the sagebrush steppe (also known as the high desert), which is found in the higher elevation plains of the Western United States. It contains dense patches of shrubs and grasses, as well as patches of timber, such as juniper and pinyon pine. Historically, the steppe was a vast area with bunch grasses and shrubs with open spaces between. Due to this open spacing between vegetation, intense fires were rare, and a stand replacement fire occurred only about every 50-100 years. Low intensity fires were common between stand replacement fires. These fires typically remained on the ground, cleaning up litter and duff, not harming the larger shrubs. Changes in the ecosystem have resulted in larger and more intense fires.
**Materials + Preparation**

- Make copies of the “Tinker Tree Derby” handout (found at the end of the lesson) for each student.
- Work with students to prepare newspaper:
  - 4 bags, each containing about 30 strips of newspaper approximately 40 cm long and 4 cm wide. Each strip should be folded accordion-wise so it can be threaded onto a wire rod to represent tree/shrub foliage.
  - 24 half-sheets of newspaper, 25 x 35 cm. These will represent litter.
  - 8 quarter-sheets of newspaper, approximately 25 x 20 cm. These will represent saplings.
  - About 20 narrow strips of newspaper, cut into strips
  - 4 half-sheets of newspaper, 25 x 35 cm
- Set up 4 work stations. Each station should have:
  - 1 pair of safety goggles (Hardware Box in Box A)
  - 1 metal tray (Box A) with a support stand on it (Tinker Trees bag in Box A)
  - 10 – 15 segments of wire rod (Tinker Trees bag in Box A)
  - 1 ashtray (Hardware Box in Box A)
  - Paper towels for clean-up
- In addition, you should have:
  - 2 or more spray containers, filled with water (Hardware Box in Box A)
  - 1 measuring tape (Hardware Box in Box A)
  - 1 fire extinguisher (make sure it is charged, and know how to use it) (Box B)
  - 1 “Tinker Trees” kit which has pendants for awards in each phase (Box C)
  - 1 box of kitchen matches
  - 1 or more hole punches, in case students need them to push newspaper on rods
  - A handful of hair ties, in case students need them.
  - A metal trash can without a plastic liner
- The activity should be done in an area with good ventilation and a hood or 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 on concrete or asphalt 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 or responsible students help “patrol” for burning materials.
- The day before doing the activity, remind students to follow the safety guidelines about clothing and hair when they get ready for school tomorrow.
- Copy this results table onto the board (or a sheet of paper if you’re burning outdoors):

<table>
<thead>
<tr>
<th>Team name</th>
<th>Qualifying Round: Surviving foliage (cm)</th>
<th>Championship Round: Surviving foliage (cm)</th>
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<tbody>
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<td></td>
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</table>
Procedure

1. Project an image of a fire showing ladder fuels for students, such as:
   - http://mediad.publicbroadcasting.net/p/nwpr/files/styles/x_large/public/201603/ladder_fuels.jpg
   - https://goo.gl/jxV2oO

   You could also draw a simple illustration on the board illustrating the concept. Use the visual(s) to help explain that ladder fuels are the arrangement of fuels from the ground to the tree and/or shrub tops, which fire can climb like a ladder.

2. Explain the student challenge: to design a “tinker tree/shrub” model, with “foliage” high enough to withstand surface fire. It should avoid fire climbing up ladder fuels from surface to tree/shrub tops, and at the same time maximize the length of branches covered by foliage. (Surface fires burn in the vegetation on the ground surface, including fallen leaves, grasses and shrubs, small trees, and fallen twigs and branches. In the sagebrush ecosystem they often burn surface plants, such as cheatgrass.)

3. Ask each team to choose a team name while you pass out the “Tinker Tree Derby” handouts. Read the handout together and answer any questions. Ask them to tell you one thing that will disqualify their team from the competition. (Answer: Adding moisture to their model.)

4. Do a safety briefing in preparation for handling matches in these experiments. Use the FireWorks Safety poster as a visual aid, and review the location of spray bottles and a fire extinguisher. Display the poster prominently for the remainder of the activity.

5. Direct students to construct their trees. After about 10 minutes, have them ignite the trees one team at a time, so everyone gets to see every fire.

Phase 1 - Qualifying Round

6. Direct student teams to come forward one at a time:
   - Ask for the team name and have a student write it on the board in the table.
   - Check and modify the surface fuels to make them similar among trees so this variable will not confound the results.
   - Have a student on each team start the fire by igniting two corners of newspaper along one long edge of the metal tray. If they all use the same ignition pattern, this variable will not confound the results. The student lighting the fire should wear safety glasses, and others nearby can, too.
   - When the fire is out, use the measuring tape to determine the tree’s score: the length of branch, in centimeters, that still has unburned newspaper (“live foliage”) on it. Have a student record this on the board under “Qualifying Round” for that team.

7. After all teams have completed a burn, determine the winner of the Qualifying Round, that is, the entry with the greatest total branch length with “foliage.”

8. Optional: Award Tinker Tree Derby Champion badges to the winning team. Explain that they get to wear the badges until the end of class.
**Phase 2 – Championship Round**

9. For all teams whose tinker trees/shrubs 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/shrubs that did not survive the Qualifying Round (zero centimeters of unburned foliage) should observe.

10. Explain that accumulation of surface fuel often occurs in forests after many years of **succession** without surface fire.

11. 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/shrub under the branches. These are “tinker saplings,” young trees that grow up under the old survivor. Explain that this, too, often happens in forests after many years of succession without surface fire.

12. Repeat step 6 above for each tinker model. Determine the score and the winner, if any. Award Tinker Tree Grand Champion badges to the winning team. Explain that they get to wear these until the end of class.

13. Direct students to finish their answers to the questions on the handout, discussing the questions as a group while they each record their answers.

14. Lead a closing discussion with the class about their conclusions, and how these dynamics of wildland fire might impact the sagebrush ecosystem. For example, you could talk about how encroaching cheatgrass, as well as encroaching juniper and pinyon pine forest, can add to the potential severity of fires in sagebrush ecosystem areas.

**Assessment**

Review completed handouts for each student.

1. Check for at least 2 reasonable changes to the tinker models.

2. Some possible answers for how the tinker model is not real:
   - Its metal “trunk” cannot be damaged by fire.
   - It has no roots that could be damaged by fire.
   - It does not grow taller, gain new branches, or shed old ones as years go by.
   - It has flat, very dry “foliage.”

3. Compare fire spread potential:
   - “A” has:
     - More surface fuels; larger surface fuels
     - More ladder fuels
     - More continuous crowns than “B.”
     - Thus, A is more likely to have severe surface fire and/or crown fire than “B.”
• An additional point not covered in this activity: “B” is more open than “A,” so the wind at the ground surface is likely to be stronger. Thus, surface fire is likely to spread more quickly in “B” than in “A.”

**Surface fire:** a burn in vegetation on ground surface, including fallen leaves, grasses and shrubs, small trees, and fallen twigs and branches

**Ladder fuel:** arrangement of fuels from forest floor to the tree tops; fire can climb like ladder

### Evaluation

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<tr>
<th>Task</th>
<th>Very Good</th>
<th>Fair</th>
<th>Poor</th>
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<tbody>
<tr>
<td>1. Changes to tinker model</td>
<td>• 2 or more changes</td>
<td>• 1 change</td>
<td>• 0 changes</td>
</tr>
<tr>
<td>2. How tinker model is not real</td>
<td>• 2 or more examples</td>
<td>• 1 example</td>
<td>• 0 examples</td>
</tr>
<tr>
<td>3a. Compare fire spread potential</td>
<td>• Explained 2 or more fuel differences</td>
<td>• Lists 1 fuel difference or mentions crown fire potential</td>
<td>• Does not address question or include terms</td>
</tr>
<tr>
<td>3b. Define surface fire and ladder fuel</td>
<td>• Correctly explained surface fire and ladder fuel within explanation</td>
<td>• Included surface fire and ladder fuel, but did not explain terms</td>
<td>• Does not include terms</td>
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<tr>
<td>4. Compare fuels in “A” and “B”; incorporate role of encroaching species like cheatgrass in answer</td>
<td>• Correctly explained how dry, fine fuel, especially invasive grasses like cheatgrass, act like ladder fuels in the forest which can help fire climb beyond surface fire to shrub crowns to kill the shrubs</td>
<td>• Included surface fire and ladder fuel, but did not incorporate role of cheatgrass</td>
<td>• Does not include terms</td>
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Tinker Tree Derby

A tinker tree is a model of a tree, as shown to the right. Its “trunk” is a lab support stand. Its branches are wire rods stuck through holes in the trunk. Its “foliage” (leaves) are strips of newspaper. Your goal is to design and build a tinker tree that has foliage which survives a fire that burns the surface fuels beneath it. You have to decide how much foliage to use and how to arrange it so that the tree can survive a surface fire. The tree with the most foliage left after the fire burns wins!

Procedure

1. Place a support stand (metal post) in the center of the metal tray.
2. Crumple up two quarter-pages of newspaper. These are your 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. When the teacher tells you it’s time to “ignite,” start the fire by igniting two corners along one long edge of the metal tray. Groups will take turns lighting their experiments.

Scoring

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 will qualify for the Championship Round of the Tinker Tree Derby. Do not change anything about it until you receive further instructions.

Rules

- Do not add moisture to your tinker tree or experimental setup before it is burned, or it will be disqualified.
- Do not move or remove your tree’s foliage after the fire has burned.
Tinker Tree Analysis

1. List at least two changes you would make to your tinker tree or the surface fuels in this experiment to increase the tree’s chances of surviving a surface fire. Explain why you would make each change.

________________________________________________________________________

________________________________________________________________________

2. List at least two ways in which the Tinker Tree model does NOT resemble a real tree.

________________________________________________________________________

________________________________________________________________________

3. Study the two photographs below. How are the fuels in “A” different from those in “B”? How would that be likely to affect the kind of fire that could occur if conditions are dry and windy? Explain the terms surface fire and ladder fuels and how they impact wildland fires to support your explanation.

   A.

   B.

   Dave Powell, USDA Forest Service, Bugwood.org

   Photo courtesy of Rick Trembath

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________________________________________________________________________

________________________________________________________________________
4. Now compare fuels in the **sagebrush ecosystem**. Studying the two photos below, how are the fuels in “A” different from those in “B”? How does this fuel type compare to forest fuels when taking into consideration ladder fuels? Incorporate an explanation of how **encroaching** species like **cheatgrass** affect fire behavior in your answer.

**A. Sagebrush ecosystem (without cheatgrass)**

**B. Sagebrush ecosystem with cheatgrass**