Using Matchstick Models to Explore Wildland Fires

This activity is based on the US Forest Service's "FireWorks Northern Rocky Mountains & Northern Cascades" Curriculum

Overview

In this lesson, students use a matchstick model of the tallgrass prairie to investigate how fire behavior in a grassland area (or other standing fuel system) can be influenced by fuel, weather, and topography.

Lesson Goals:

Develop a better understanding of fire behavior in grasslands and other standing fuel systems. Describe conditions that contribute to extreme fire behavior and fire spread. Increase knowledge of experimental methods.

Objectives:

- Students will design a controlled experiment to investigate relationships among slope, wind, fuel/stand density, and fire spread.
- Students will write a hypothesis, conduct an experiment, summarize results, and draw conclusions.
- Students will present their hypothesis, experimental design, results, and conclusions to their classmates with a brief presentation.
- Students will compare their experiment and results to those of their classmates.

Anchoring Phenomena: Why does fire behavior/characteristics change as environmental factors change?

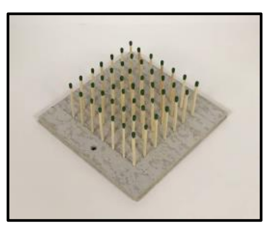
Subjects: Science, Mathematics, Writing, Speaking and Listening, Health and Safety

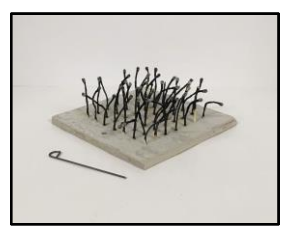
Duration: 45-90 minutes (class presentations would push the duration towards 90 minutes)

Group Size: Groups of 2-4

Setting: Classroom for introduction, laboratory for activity

Vocabulary: fire triangle, fire behavior triangle, hypothesis, slope, stand density, standing fuels, controlled experiment, variable, fuel continuity, trial, treatment,

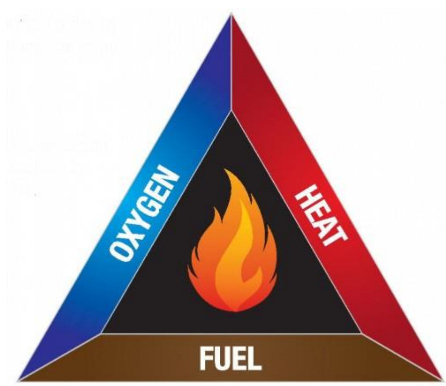




Academic Standards:

Standards		High School (9-12)
NGSS – Disciplinary Core Ideas	**HS-PS3 Energy**	• PS3.A, PS3.B, PS3.D
	HS-LS1 From Molecules to Organisms: Structures and Processes	• LS1.C
	HSLS2 Ecosystems: Interactions, Energy, and Dynamics	• LS2.B
NGSS – Performance Expectations	**HS-PS3 Energy**	• HS-PS3-4

Teacher Background:



After students understand the basic principles of combustion as described by the Fire Triangle (see Units 2-4 in the original *FireWorks,* they can apply that understanding specifically to how fires behave in the wildland environment.

In this activity, students design physical models of fuel arrays in which standing fuels are represented by matches. Because the model provides a demonstration of the way fire behaves in a grassland, it will be referred to as the "prairie" model. However, it could represent any array of standing fuels, including shrubs or trees with highly flammable crowns.

To complete this lesson, students will make brief class presentations. Prompts are provided on the student worksheet to assist students/groups.

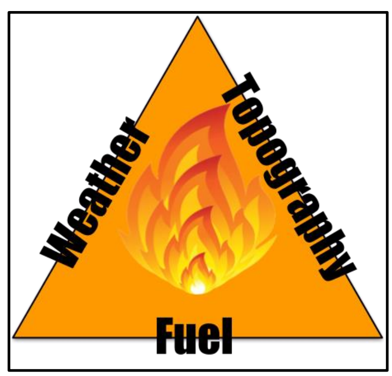
Note: Flames in this experiment could reach 40-50 cm in height. Be sure that this activity is conducted in an appropriate space. If you choose to do the experiment outdoors, even the slightest breeze will dramatically affect fire behavior. Conducting this activity outdoors will probably illustrate that fire spread is complex and often unpredictable.

One objective of this activity is developing the skills to design an experiment.

- As you are discussing experimental design, stress that each group should only vary or change one independent variable for each investigation conducted. If there is enough time, groups might be able to perform addition investigations. However, all data analysis should be completed from the first investigation before students move on to working with other independent variables or situations described in "**Extensions**" below.
- Try not to give students too much guidance as they develop their experiments. However, when students come to get their experimental designs "okayed" before they begin, check to see that there is only one independent variable and that students have a plan for measuring the dependent variable(s). Check that the hypothesis or null hypothesis is simple and easy to support/disprove. Students may have more than one hypothesis or null hypothesis, so be sure that they are all appropriate. If there are multiple hypotheses and/or null hypotheses, they should not be about the same relationship. For example: Hypothesis - An increase in slope will decrease the time needed for complete fuel consumption; Null hypothesis - An increase in slope will have no effect on the time needed for complete fuel consumption. Both examples are legitimate, but one group should not use both of these. They should choose only one about this "slope-time" relationship. It would be okay for the group to include another hypothesis or null hypothesis about another relationship such as: Hypothesis - An increase in slope will increase maximum flame height; or Null hypothesis - An increase in slope will have no effect on maximum flame height.
- If time is not a major concern, or if more time is available during another class period, class data sets could be developed. Groups that have the same independent variables could combine their data. Larger data sets from multiple groups could lead to some interesting discussions about reliability of data resources, experimental error, etc.

Students will use the matchstick model to investigate variables that affect the spread of fire (and are aspects of the Fire Environment Triangle). Here is a brief introduction to the three components of the Fire Environment Triangle.

- Slope/topography: If a fire is burning on a hillside, the fuels above it tend to be dried and warmed by its convective heat, and the flames are quite close to the uphill fuels. They are likely to ignite very quickly. The fuels below the fire are affected very little – at least until burning materials roll downhill and ignite new fires there. Thus, fires tend to spread upslope, and a fire that starts at the bottom of a hill is likely to spread faster than one that starts on a hilltop.



- Fuel density: Fire in a grassland can move very quickly in a grassland with dense fuel. In a grassland where fuel is not as dense (has less continuity), a fire will move more slowly or may go out.
- Weather/Wind: The effect of wind on fire spread is analogous to that of slope. Wind bends the flames and the heat plume so they are no longer vertical but instead lean downwind into the fuels, heating them more rapidly and increasing the rate of fire spread.

Here are some of the fire "behaviors" or fire characteristics that can be easily quantified in this activity are:

- Maximum flame height: students can use a ruler held out to the side of the flames to determine the maximum flame height attained during an experimental trial.
- Rate of fire spread: students can use a stopwatch to determine the amount of time needed for fire to spread from the starting point to some end point or for all matches to be consumed.
- Fuel consumed: students can determine the percentage of matches that were consumed. The starting number of matches may change with each trial depending on a group's experimental design.

Materials and Preparation:

Do this activity in a lab or outdoors. Note that even the air currents created by the lab's ventilation system will affect the experimental results.

- The day before the activity, review the "FireWorks Safety" poster and remind students to follow safety guidelines about clothing and hair when they get ready for school the day of the activity. Be sure the "FireWorks Safety" poster is hanging in the lab area.
- Get a box of wooden kitchen matches for each lab group/station. If there is more than one class, be sure to plan accordingly. **It is not appropriate for students to bring matches to school for this activity**.
- Make copies of the "Matchstick Prairie - Student Worksheet" for each group or for each student.
- Make copies of the "Matchstick Prairie - Rubric for Student Reference" for each group to assist with presentation preparations.
- Be sure that a fully-charged fire extinguisher is in the activity area.
- Have an empty metal bucket or trash can **without** a plastic liner available.
- Set up a lab bench or other safe space for each group, using the following equipment:
    - Safety glasses/goggles for each student
    - Leather gloves (one pair per group)
    - 1 metal tray (i.e., cookie sheet)
    - 1 spray bottle, filled with water
    - 1 box of matches
    - 1 stove lighter
    - 1 matchstick prairie board with accompanying bolt, nuts, and washer
    - 1 ruler
    - 1 protractor
    - 1 "burnt match remover" (short piece of wire)
    - A copy of the "Matchstick Prairie - Rubric for Student Reference" to assist with presentation preparations.
    - Make sure each student team has a time keeping device such as a smartphone
    - Smartphones could also be used to video trials (videos could be incorporated into the class presentation)

Procedure:

- Assign students to groups appropriately sized for your laboratory area and amount of supplies. It is best for the students to be in their groups during the introductory slide show since, at the end of the slide show, they will begin designing their group's investigation.
- Give each student a copy of the student worksheet.
- Go over this activity's slideshow. This slideshow also includes the "FireWorks Safety" poster for a quick review.
  - A script is provided in the speaker notes for the slide show.
  - A document of the slide show's speaker notes can be found in this activity's folder.
- After students have had their experiments approved, have the groups do a practice run to become familiar with the lighting and data collection processes. At this point monitor for safety and correct students appropriately. If you have a small number of groups, it might be a good idea to have the groups observe each other as they burn their "woodlands" one at a time.
- After experiments have been concluded, be sure students appropriately dispose of burnt matches and clean/organize the laboratory area.
- Groups should use their results to address the prompts on the student worksheet.
  - Data should be graphed and analyzed. If possible, conduct this analysis using a spreadsheet application.
  - Use results to draw conclusions about the hypothesis/hypotheses.
  - Prepare for class presentation.
- Have groups present to the class. A rubric is included for evaluating presentations.
- Students should complete the "Class Presentation" table while other groups are presenting.

Assessment:

- Group class presentations. Guidance for the presentations is included on the student worksheet.
- Sample quiz/review questions for "Matchstick Tallgrass Prairie"

1) Which of the following is **NOT** a "side" of the Fire Environment Triangle?

    a) Fuel
    b) Oxygen
    c) Weather
    d) Topography

    Answer: b

2) Which of the following is **NOT** one of the "weather factors" discussed that could influence a fire's behavior?

    a) Relative Humidity
    b) Wind Speed
    c) Greenhouse Gas Concentration
    d) Temperature

    Answer: c

3) What material should clothing be made of when conducting an activity with a flame/fire?

a) Polyester
b) Nylon
c) Gore-tex
d) Cotton

Answer: d

4) How are the independent and dependent variables related to each other in an experiment?

a) There is no difference between the two variables if they are both part of the same experiment.
b) Because it is changed by the investigator, the dependent variable differs in each experimental trial and, since it is "independent," the independent variable never changes.
c) The dependent variable could change between experimental trials as the independent variable is changed by the investigator.
d) The independent variable could change between experimental trials as the dependent variable is changed by the investigator.

Answer: c

5) Why does fire move more quickly uphill than downhill?

a) Because the concentration of oxygen increases as altitude increases.
b) The closer fuels are to the sun the warmer and drier they usually are allowing them to ignite more easily.
c) Convection transfers the heat of the fire upward which preheats or dries out fuels allowing them to ignite more easily.
d) This is a trick question. Fires move as quickly downhill as uphill.

Answer: c

Evaluation: A rubric for the class presentations can be found as a separate document entitled "Matchstick Prairie - Presentation Rubric & Score Sheet."

Extensions: There are many variations students can develop for this activity. However, it is strongly recommended that students do not combine boards of matches together in any way. The heat, smoke, and flames from combined boards may be surprising and dangerous.

- Vary the length of fuels by breaking matches before adding them to the board.
- Place a "votive candle structure" on the board amid a fuel array. If the candle's wax begins to melt, then the structure was damaged by the fire.
- A class discussion or short, opinion essay could be done over the following prompts:
  - What are some limitations of the matchstick model?
  - What "real-world" influences on fire spread could not be tested with this model?

- Could this model be revised, or a different model developed to test the "real-world" factors?
- Based on experimental results, what practices should be recommended to:
    - Firefighters
    - People with homes in fire prone areas
    - Land managers

Extensions:

- Teacher Background

  Stand definition

  http://www.uky.edu/~jmlhot2/courses/for350/Stand%20Descriptions%20and%20Supporting%20Material_UT%20Clatterbuck.pdf
- Slide Show

  Images and diagrams by Bryan Yockers unless listed below.

  "Fuel load" definition

  Pyne, S. J., P. L. Anderson, and R. D. Levin. 1996. *Introduction to Wildland Fire*, New York: Wiley.

  "Fuel continuity" definition

  Cheney, P., and A. Sullivan. 1997. *Grassfires: Fuels, weather and fire behavior*. Collingwood, Australia: CSIRO Publishing.

  Image of incident meteorologists taking weather reading during a fire

  NOAA

  https://scijinks.gov/imet/

  "Relative Humidity and Spotfires" slide

  The graph and both images from

  http://factsheets.okstate.edu/documents/nrem-2903-prescribed-burning-spotfires-and-escapes/

Matchstick Prairie – Presentation Rubric & Score Sheet

Rubric (20 points possible):

Points	0	1	2	3	4	5
Hypothesis	No hypothesis	General experimental question	Hypothesis with stated relationship between variables (testable)			
Independent & Dependent Variables	No variables mentioned	One variable mentioned	One variable mentioned and how it was varied or measured	Both variables mentioned	Both variables mentioned and how **ONE** was varied or measured	Both variables mentioned and how **BOTH** were varied or measured
Procedure	No procedure described	Procedure described with **1 of the 5** steps listed below the rubric	Procedure described with **2 of the 5** steps listed below the rubric	Procedure described with **3 of the 5** steps listed below the rubric	Procedure described with **4 of the 5** steps listed below the rubric	Procedure described with **5 of the 5** steps listed below the rubric
Results	No results presented	Results described without a graph regardless of detail	Results presented with a graph but no comments about correlation or threshold	Results presented with a graph with comments about **EITHER** correlation **OR** threshold	Results presented with a graph with comments about **BOTH** correlation **AND** threshold	
Conclusion	No conclusion	Conclusion not in CER format	Conclusion with one CER component	Conclusion with two CER components	Conclusion with three CER components	

5 General Procedure Steps:

- ➔ Description of student roles
- ➔ How the independent variable was changed (could be mentioned in the “variables” part of the presentation; mention in the “procedure” is sufficient for “variables” points)
- ➔ Which matches were lit with the stove lighter
- ➔ How and **when** the measurements were taken/made (could be mentioned in the “variables” part of the presentation; a mention in the “procedure” is sufficient for “variables” points)
- ➔ Partial description of at least two trials must be included

Presentation Score Sheet/Checklist:

Group Name	Hypothesis	Ind. & Dep. Variables	Procedure	Results	Conclusion	Total Score

Student Worksheet

Name:	Class/Period:	Date:

Group's Name:

Fire Safety in the Laboratory

1)
2)
3)
4)
5)
6)
Others:

Discussion Notes:

Experimental Design:

1) Experimental question: What is the effect of ______________________ on fire behavior?
2) What aspect(s) of fire behavior will be measured?
3) What is your group's hypothesis or null hypothesis?
4) What is your group's second hypothesis or null hypothesis?
5) What is your group's third hypothesis or null hypothesis?
6) Describe the independent variable in your experiment and how it will be varied for each treatment?
7) Describe some of the controlled factors for your experiment. Remember, the controlled conditions should not change from one trial to the next.
8) What is the dependent variable that will be measured in each trial and how it will be measured? If you have more than one dependent variable list them all and describe how each will be measured.

9) Prepare a table for recording data below (or on the other side of this worksheet) or prepare a spreadsheet appropriately. If using a spreadsheet, you must show this to your instructor before you begin.

Teacher's initials indicating your group's experiment has been approved: ______________

Conducting the Experiment:

1) Do a practice run to become familiar with the lighting and data collection processes. At this point monitor for safety and correct appropriately.
    a) All students help with "resetting" the matchstick model
    b) Possible student roles:
        i) Lighting
        ii) Timing
        iii) Videoing (could be used in the presentation)
        iv) Measuring with ruler
        v) Counting
        vi) Safety monitoring
2) Make any necessary adjustments to your experiment or procedures.
3) Collect and record data for all necessary trials.
4) Graph and analyze data using a spreadsheet application if possible. Ask for assistance if needed.
5) Use graphical results to draw conclusions about the hypothesis/hypotheses.
6) Prepare for class presentation. There is a rubric at each laboratory station to assist with presentation preparations. Be sure to include the following:
    a) State your group's name.
    b) Describe the variables for this experiment.
        i) Describe the independent variable and how it was changed between treatments.
        ii) Describe the dependent variable(s) investigated and how measurements were made.
    c) State the hypothesis.
    d) Describe the procedure used by the group to conduct the burns and to collect data. A video could be used.
    e) Present a graph of each data set.
        i) Describe the relationship(s) between the independent variable and dependent variable(s). (Best fit line or curve used?)
            (1) **Positive correlation** - as one variable increases, so does the other.
            (2) **Negative correlation** - as one variable increases, the other decreases.
            (3) **No correlation** - there is no apparent relationship between the variables.
        ii) Describe any thresholds shown in the graph(s).
        iii) If you had more time, more materials, different experimental setup, etc., could there be a different correlation between the variables tested?
    f) Discuss whether the hypothesis was supported or disproved.

Notes for Your Presentation

Table for Class Presentations - While other groups give their presentation, take notes using this table.

Group Name	Hypothesis	Independent Variable	Dependent Variable	Results	Conclusion