FireWorks Curriculum
Featuring Lower and Upper Montane Sierra Nevada Mixed Conifer Forests

August, 2017

by Ilana Abrahamson, Jane Kapler Smith, and Caitlyn Berkowitz

The *FireWorks* program was originally completed and the curriculum published in 2000 (Smith and McMurray 2000). This version incorporates new science, new teaching techniques, and new standards, and is adapted for Sierra Nevada ecosystems.

***FireWorks*: Why?**

Change is an integral part of a healthy, enduring ecosystems in most temperate regions of the world. *FireWorks* provides students with interactive, hands-on materials to study the forces that cause change, particularly wildland fire. The program is based on the science of wildland fire, a highly interdisciplinary field, so it provides a context for learning about properties of matter, chemical and physical processes, ecosystem fluctuations and cycles, habitat and survival, and human interactions with ecosystems. These concepts are considered important for science literacy (American Association for the Advancement of Science 1993). Students using *FireWorks* ask questions, gather information, analyze and interpret it, and communicate their discoveries. They often work in pairs or small groups. These are learning styles that enhance understanding, cognitive skills, and social skills (Moreno 1999; National Research Council 1996).

Goals

FireWorks aims to increase understanding

- of the physical science of combustion, especially in wildland fuels
- that an ecosystem has many kinds of plants and animals, which change over time and influence one another
- that fire is an important natural process in many ecosystems
- that native plants and animals have ways to survive fire or reproduce after fire, or both
- that people influence the fire-dependent ecosystems where they live, and they always have done so

Meeting these goals helps implement the vision of the National Cohesive Wildland Fire Management Strategy (U.S. Department of Agriculture, Forest Service; Department of the Interior, Office of Wildland Fire Coordination. 2011) "*To safely and effectively extinguish fire when needed; use fire where allowable; manage our natural resources; and as a nation, to live with wildland fire*."

FireWorks also aims to increase student skills in

- making observations
- classifying information
- measuring, counting, and computing
- stating and testing hypotheses

- describing observations, both qualitatively and quantitatively
- explaining reasoning
- identifying and expressing responses to science-related questions
- working in teams to solve problems and
- critical listening and reading

These skills are crucial for developing an adult citizenry literate in science and attracting students to professional work in the sciences (National Research Council 1996).

Local learning:

Students learn best about ecology when it is close to home—when they can study the plants, animals, and fire regimes typical of local ecosystems (Lindholdt 1999; North American Association for Environmental Education 1999).

This version of *FireWorks* focuses on selected *ecological communities* in the Sierra Nevada–forests dominated by conifers. These communities are often called lower and upper *mixed conifer* or lower and upper *montane* communities. These lower and upper montane mixed-conifer forests have a long, intimate relationship with fire. The photo presentation created for Activity 1 in the Elementary and Middle School curricula shows many inhabitants of these communities and the different types of fire that occur in them.

Lower montane forests grow just uphill from the grassy and shrubby *foothill* communities in the Sierra Nevada. Thus they occur at relatively low elevations, not high in the mountains. Lower montane forests are dominated by oaks, ponderosa pine, sugar pine, white fir, Douglas-fir, and incense-cedar. Many of these forests, especially in historical times, were dominated by pines. They had an open structure, with old, large trees spaced far apart and a few young trees. They had many kinds of grasses, wildflowers, and shrubs in the understory. A few of these old-growth, pine-dominated forests remain today. In the past, fires in this kind of forest tended to spread through the surface fuels. They rarely jumped into the tree crowns. Even when they did, they could not spread from crown to crown because most of the trees were spaced far apart. Because these forests are relatively dry, they typically burned frequently. Repeated fires keep the forest structure open. They favor grasses, wildflowers, and shrubs that can sprout easily after fire, and they provide habitat for mammals and birds that need large, old trees and an open understory.

Upper montane forests occur at fairly high elevations, but not all the way up on mountainsides. These forests are usually dominated by Jeffrey pine, red fir, and lodgepole pine. There is a lot of overlap between lower and upper montane forests, so species from these communities often intermix. Because upper montane forests grow higher in the mountains, they are colder, receive more snow, and have a shorter growing season. Thus historical fires generally burned less frequently than in lower montane communities, although there is considerable variability. In the past, fires in upper montane forests tended to spread through the surface fuels but sometimes also jumped into the tree crowns. Fires killed trees in small patches, but most large trees survived.

Mixed-conifer forests in the Sierra Nevada have experienced very few low-severity fires in the past century. Because of this, the forests tend to be very dense and have a lot of litter, logs, and *ladder fuels* (shrubs and young trees that increase in the absence of fire and enable fires burning on the forest floor to climb into the tree tops). The forest canopy is fairly continuous (*closed*), and trees that grow well in shade are more common than they were historically. This is true throughout the mixed-conifer forests, but especially so in lower montane communities. When fires burn through dense forests during hot, dry, windy conditions, they tend to burn in the tree crowns more often than they did when the forest structure was open. Crown fires kill more large trees than the frequent surface fires of the past. Nowadays, it is common to see large patches of *stand-replacing fires* in forests that used to experience stand-replacing fire in small, isolated patches.

High in the mountains of the Sierra Nevada are the subalpine forests, dominated by lodgepole pine, western white pine, mountain hemlock, and whitebark pine. This curriculum does not cover the high-elevation forests, but they are very important to the ecology of the Sierra Nevada and to the quality of life of its plants and wildlife, and to the human communities living in the watersheds below.

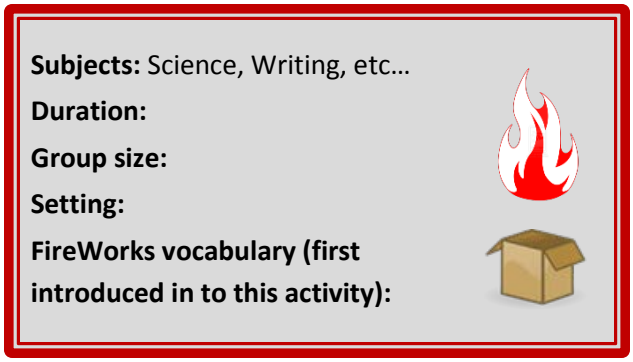
Table I-1—Summary of ecology and "fire story" of some forest communities of the Sierra Nevada

		Lower montane mixed conifer	Upper montane mixed conifer
Shade-intolerant tree species (grow well in sunny, open areas with bare soil)		Ponderosa pine Sugar pine California black oak	Jeffrey pine Sierra lodgepole pine
Shade-tolerant tree species (grow better than pine in shady places)		Douglas-fir White fir Incense-cedar	Red fir
Historical fire frequency	Crown fire	Infrequent, except in small patches	Infrequent, except in small to medium-sized patches
	Low-severity surface fire	4-14 per century	2-4 per century
Some animals		Mule deer Western gray squirrel Dusky-footed woodrat California spotted owl American black bear	Mule deer California spotted owl Yellow-legged frogs American black bear
Disturbances besides fire		Bark beetles White pine blister rust Drought	Bark beetles Drought

Design and Layout of Lessons in This Curriculum

Each activity has the following sections:

- **Lesson Overview**
- **Lesson Goal**
- **Objectives**
- **Teacher Background**
- **Materials and Preparation**
- **Procedure**
- **Assessment**
- **Evaluation**



Instructions for each activity also include a text box (example above) that lists subjects covered, the possible duration of the activity (a guess –take this with many grains of salt), group size, setting (laboratory, classroom, outdoors, etc.), and *FireWorks* vocabulary (list of terms in the *FireWorks Glossary* that are first introduced in this activity). The text box may also contain one or two icons – a red-and-white flame if the activity uses fire, and a brown box if the activity requires materials from a *FireWorks* trunk.

Handouts and other materials meant for students all begin with a large, bold-face header in **blue font**. Handout answer keys and other materials meant for teachers all begin with a large, bold-face header in **maroon font**. In the Procedures section and in handout answer keys for teachers, answers to questions are given in red font.

Links to Educational Standards

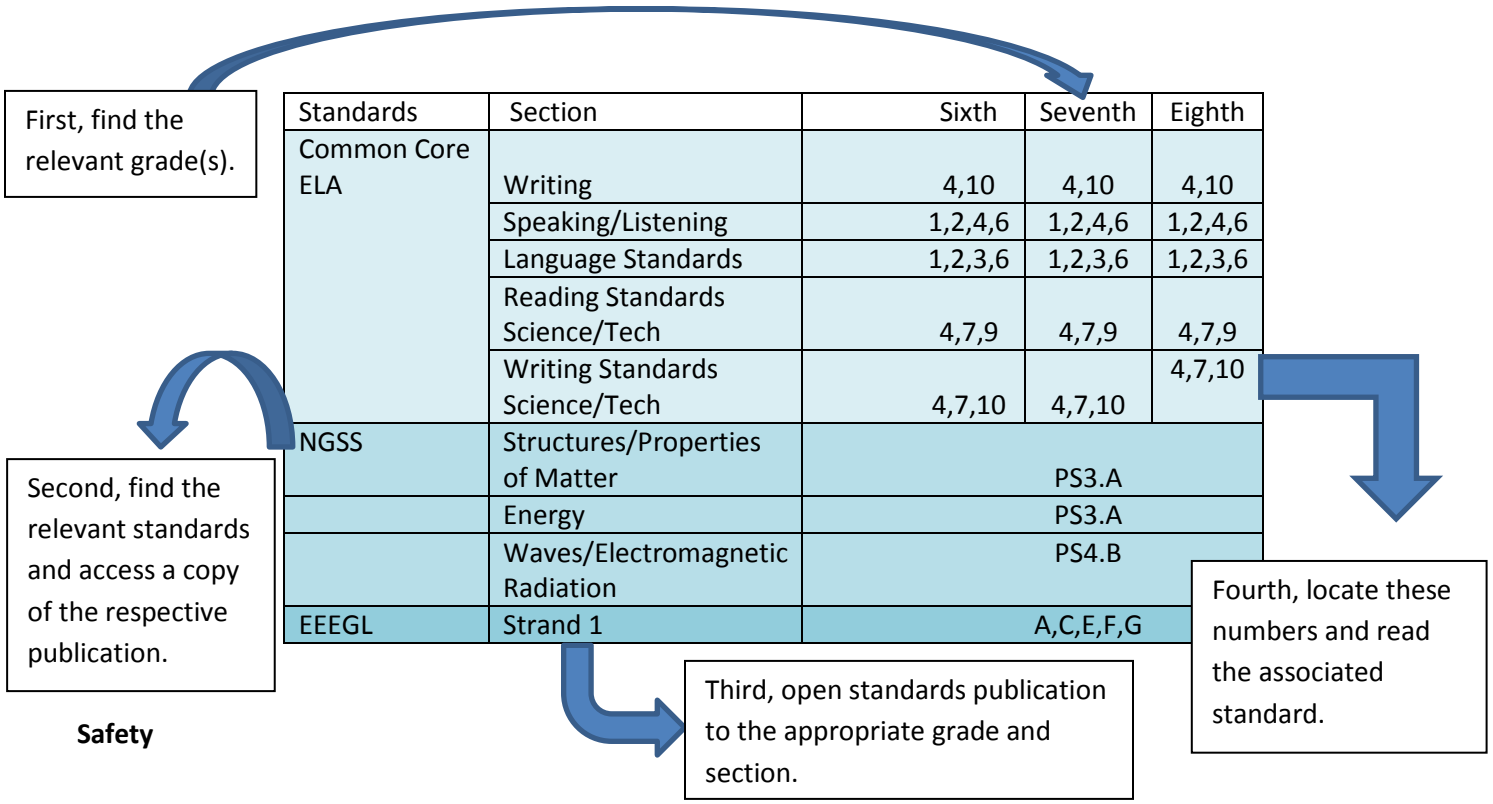
FireWorks need not compete with core curriculum for classroom time. Instead, it can help teachers cover core concepts and improve student skills by using hands-on materials based on science from their own local area. To help teachers identify the ways in which *FireWorks* can be used to meet their curriculum requirements, each activity is linked to educational standards.

FireWorks is correlated to the Common Core State Standards in English Language Arts (CCSS-ELA), Math (CCSS-Math), History and Social Studies, Science, and Technical Subjects; the Next Generation Science Standards (NGSS); the Excellence in Environmental Education: Guidelines for Learning standards (EEEGL); and the C3 Framework: College, Career and Civic Life for Social Studies State Standards (C3 SSSS)[1].

[1] Abbreviations and links to standards:

- CCSS-ELA: Common Core State Standards—English Language Arts (http://www.corestandards.org/assets/CCSSI_ELA%20Standards.pdf)
- CCSS-Math: Common Core State Standards—Math (http://www.corestandards.org/wp-content/uploads/Math_Standards.pdf)
- NGSS: Next Generation Science Standards (http://www.nextgenscience.org/sites/ngss/files/NGSS%20DCI%20Combined%2011.6.13.pdf)
- EEEGL: Excellence in Environmental Education: Guidelines for Learning (http://resources.spaces3.com/89c197bf-e630-42b0-ad9a-91f0bc55c72d.pdf)
- C3 SSSS: College, Career and Civic life for Social Studies State Standards (http://www.socialstudies.org/system/files/c3/C3-Framework-for-Social-Studies.pdf)

Each lesson has been correlated to the relevant standards. If a lesson does not have standards listed from a particular standard framework, then it probably does not meet standards in that framework. However, teachers are encouraged to reinterpret standards and lessons and also to adapt lessons to meet their educational objectives and particular standards.



Standards	Section	Sixth	Seventh	Eighth
Common Core ELA	Writing	4,10	4,10	4,10
	Speaking/Listening	1,2,4,6	1,2,4,6	1,2,4,6
	Language Standards	1,2,3,6	1,2,3,6	1,2,3,6
	Reading Standards Science/Tech	4,7,9	4,7,9	4,7,9
	Writing Standards Science/Tech	4,7,10	4,7,10	4,7,10
NGSS	Structures/Properties of Matter	PS3.A		
	Energy	PS3.A		
	Waves/Electromagnetic Radiation	PS4.B		
EEEGL	Strand 1	A,C,E,F,G		

Safety

Many of the experiments in this curriculum use fire and natural fuels in the classroom or laboratory. In these structured, well supervised environments, students can make discoveries about fire and improve their habits regarding fire safety. Help students learn about safe laboratory practices, such as using protective eyewear and wearing appropriate clothing. Help them learn that professional skills and years of experience are needed to use fire safely in wildlands. The following steps will help your students grow in responsibility and competence regarding lab safety and fire:

- Inform your maintenance staff about activities in which you will use fire.
- Inform your local fire protection unit if you plan to use fire outdoors.
- Consider informing parents about your plans and goals for teaching about fire.
- Choose your work space carefully, especially if you will not be using a laboratory. The fire engine must respond to every alarm, even if you tell them it's "only" an experiment.
- If you are working outdoors, watch carefully to prevent smoldering material from igniting schoolyard vegetation.
- Keep spray bottles filled with water. Have students use them to extinguish smoldering material at the end of each experiment. This will prevent trash-can fires.
- If you are working outdoors, keep a hose available and ready to use. Have a bucket or two of water available as well.

- Keep a fire extinguisher ready for use. Know how to use it. If you discharge a fire extinguisher, refill or replace it immediately. Don't burn anything without a charged fire extinguisher in the room.
- If you or any of your students have asthma or other respiratory problems, consider having them wear protective masks while working with fire.

Literature cited

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U.S. Department of Agriculture, Forest Service; Department of the Interior, Office of Wildland Fire Coordination. 2011. A national cohesive wildland fire management strategy. Washington, DC: Wildland Fire Leadership Council. 43 p.

This table summarizes the content for each activity at each grade level. Read across the table to find similar activities for students at other grade levels.

Unit & Theme	ELEMENTARY	MIDDLE	HIGH
Unit I. Introduction to Wildland Fire	E01. Visiting Wildland Fire in the Sierra Nevada	M01. Visiting Wildland Fire in the Sierra Nevada	H01. Introduction to Wildland Fire in the Sierra Nevada
Unit II. Physical Science of Wildland Fire	E02. Making Fires Burn or Go Out 1: Introduction to the Fire Triangle	M02. Where Does Heat Go? The Heat Plume from a Fire	H02. The Fire Triangle: Fuel, Heat, and Oxygen
	E03. Making Fires Burn or Go Out 2: Demonstrating the Fire Triangle and Heat Plume	M03. What Makes Fires Burn? The Fire Triangle 1—Heat and Fuel	H03. The Fire Triangle, Combustion, and the Carbon Cycle
		M04. What Makes Fires Burn? The Fire Triangle 2—Oxygen	H04. Heat Transfer
Unit III. The Wildland Fire Environment			H05. Fuel Properties
			H06. Pyrolysis
			H07. Fire Spread Processes: Putting it all together: Heat transfer, fuel properties, and pyrolysis
	E04. How Wildland Fires Spread 1: Experiment with a Matchstick Forest	M05. How Do Wildland Fires Spread? The Matchstick Forest Model	H08A. Fire Environment Triangle and Fire Spread: The Matchstick Model
			H08B. Fire Environment Triangle and Fire Spread: The Landscape Matchstick Model
		M06. Ladder Fuels and Fire Spread: The Tinker Tree Derby	H09. Ladder Fuels and Fire Spread
	E05. Fuel Properties: The Campfire Challenge	M07. Fuel Properties: The Campfire Challenge	See H05.
	E06. Effect of Wind: How Wildland Fires Spread	M08. Fire Behavior, Fire Weather, and Climate	H10. Fire Behavior, Fire Weather, and Climate

Unit IV. Fire Effects on the Environment	E07. Smoke from Wildland Fire: Just Hanging Around?	M09. Smoke from Wildland Fire: Just Hanging Around?	H11. Smoke from Wildland Fire: Just Hanging Around?
		M10. Fire, Soil, and Water Interactions	H12. Fire, Soil, and Water Interactions
Unit V. Fire's Relationship with Organisms and Communities	E08. Who Lives Here? Adopting a Plant, Animal, or Fungus	M11. Who Lives Here? Adopting a Plant, Animal, or Fungus	H14. Researching a Plant, Animal, or Fungus
	E09. Tree Parts and Fire: The Class Models a Living Tree	M12. Tree Parts and Fire: "Working Trees" Jeopardy-style Game	
	E10. Tree Identification: Using a Key to Identify "Mystery Trees"	M13. Tree Identification: Figure out the "Mystery Trees"	H13. Tree Identification: Create a Dichotomous Key
	E11. Recipe for a Baker Cypress Grove: Serotinous Cones		
		M14. Who Lives Here and Why? Modeling Forest Communities	H15. Forest Communities and Climate Change
		M15. Bark and Soil: Nature's Insulators	
	E12. Buried Treasure: Underground Parts that Help Plants Survive Fire	M16. Buried Treasures: Identifying Plants by their Underground Parts	
Unit VI. Fire History and Succession	E13-1. My Tree Autobiography: Seeing History through Trees' Growth Rings		
	E13-2. Story of a Fire-Scarred Tree	M17. Fire History 1: Long Stories Told By Old Trees	H16. Fire History 1: Long Stories Told by Old Trees
		M18. Fire History 2: History of Stand Replacing Fire	H17. Fire History 2: History of Stand Replacing Fire
	E14. Story Time: Fire and Succession	M19. Drama in the Forest: Fire and Succession, a Class Production	H18. Fire History 3: Fire Regime across a Sierra Nevada Landscape
Unit VII. People in Fire's Homeland	E15. Homes in the Forest: An Introduction to Firewise Practices	M20. Homes in the Forest: An Introduction to Firewise Practices	
	E16. Revisiting Wildland Fire	M21. Revisiting Wildland Fire	H19. Sierra Nevada Forests Today