FireWorks EDUCATIONAL PROGRAM AND ITS EFFECTIVENESS

Jane Kapler Smith and Nancy E. McMurray
Rocky Mountain Research Station, Fire Sciences Laboratory, P.O. Box 8089, Missoula, MT 59807

ABSTRACT

FireWorks is an educational program that provides interactive, hands-on activities for studying fire behavior, fire ecology, and human influences on three fire-dependent forest types—ponderosa pine (*Pinus ponderosa*), interior lodgepole pine (*P. contorta* var. *latifolia*), and whitebark pine (*P. albicaulis*). Wildland fire provides a rich context for education because it promotes understanding and integration of numerous concepts: properties of matter, ecosystem fluctuations and cycles, plant and animal habitat and survival, and human interactions with ecosystems. The *FireWorks* curriculum uses a variety of learning styles and skills, including language and mathematics, to cover science and social studies content. The curriculum is linked to national and local educational standards. Research has shown that it increases understanding of wildland fire for both students and adults.

keywords: education, fire behavior, fire ecology, fire management, lodgepole pine, management, *Pinus albicaulis*, *Pinus contorta* var. *latifolia*, *Pinus ponderosa*, ponderosa pine, whitebark pine.

Citation: Smith, J.K., and N.E. McMurray. 2004. *FireWorks* educational program and its effectiveness. Pages 231–235 *in* R.T. Engstrom, K.E.M. Galley, and W.J. de Groot (eds.). Proceedings of the 22nd Tall Timbers Fire Ecology Conference: Fire in Temperate, Boreal, and Montane Ecosystems. Tall Timbers Research Station, Tallahassee, FL.

INTRODUCTION

Successful fire management requires that the public understand fire behavior, plant community dynamics, and adaptations to fire (U.S. Department of Interior and U.S. Department of Agriculture 1995). Furthermore, members of the public should know that fire plays different roles in different forest communities. These topics are complex but understandable. How can managers engage people's attention long enough to help them learn fundamental concepts about wildland fire? *FireWorks* can help solve the problem. *FireWorks* is an educational program that uses hands-on learning to investigate wildland fire. It was designed for students in grades 1–10 and has recently been adapted for adults. Research studies have evaluated the program's effectiveness with 7th-grade students and with adults. This paper describes the *FireWorks* program, summarizes what has been learned about its effectiveness, and describes its implementation. The Appendix describes construction of selected materials from *FireWorks*.

FireWorks PROGRAM

FireWorks consists of a curriculum linked to an educational "trunk." The curriculum (Smith and McMurray 2000) describes 36 hands-on activities in which students learn about wildland fire. It suggests a structured sequence of activities appropriate for each of four grade levels (primary, elementary, middle school, and high school). The curriculum links each activity to U.S. national science standards (National Research Council 1996) and national environmental education standards (North American Association for Environmental Education 1999). Links to Montana educational standards for all subject-matter categories—including science, mathematics, language, and social studies (Montana Office of Public Instruction [Helena, MT], unpublished documents)—are also provided; similar links can be developed to standards in other states. Parkinson et al. (2003) adapted four activities from the *FireWorks* curriculum for adult audiences. *FireWorks* has also been used for college-level instruction (Smith et al. 2001).

The *FireWorks* trunk contains laboratory equipment, plant specimens, kits for feltboard stories and learning games, posters, CD-ROMs, videotapes, and reference books. Students use the materials to learn about five themes: fire behavior, adaptations of plants and animals to fire, fire regimes, forest succession, and fire management.

Fire behavior activities focus on physical science. Students investigate the Fire Triangle (fuel, oxygen, and heat) and mechanisms of heat transfer (convection, conduction, and radiation) by burning single matches and candles. They burn "matchstick forests"

Figure 1. To learn about wildland fire, middle school students ignite a "matchstick forest" while younger students patrol for hazards as part of the *FireWorks* educational program.

(Figure 1) to discover the effects of slope and forest stand density on fire spread. In the "Tinker Tree Derby" competition, students attempt to construct model trees that can survive surface fires even when ladder fuels are present. (The Appendix describes construction of "matchstick forests" and "tinker trees.") Students also investigate the influence of fuel moisture, size, and arrangement on fire behavior. Students connect understanding of the Fire Triangle with discussion of fire safety practices, including "stop, drop and roll," use of fire extinguishers, and strategies for building firelines.

Botanical specimens in *FireWorks* provide hands-on learning about plant adaptations to fire. Specimens of herbs and shrubs provide examples of "buried treasures," that is, underground regenerative structures of plants—rhizomes, bulbs, corms, woody root crowns, and buried seed. Students examine leaves, buds, bark, and cones or flowers from nine tree species. They discover serotiny in lodgepole pine cones, extract seed, and calculate potential numbers of lodgepole pine seedlings that can establish after stand-replacing fire. To learn about the insulating properties of tree bark, students assemble a model tree trunk using a coffee can and quilting materials. A thermocouple is placed under the fabric and quilt batting used to simulate bark where the tree's cambium would be located. Using a hair dryer, they heat the model tree and record the thermocouple's temperature over time under various levels of insulation.

Historic fire regimes varied from one plant community to another, and native plants and animals survived and flourished within specific fire regimes. In *FireWorks*, three forest types are used to exemplify variation in historic fire regimes: ponderosa pine, interior lodgepole pine, and whitebark pine. By studying growth rings and fire scars on tree cross sections, students learn that many dry ponderosa pine forests experienced frequent low-intensity surface fires in presettlement times; lodgepole pine forests underburned occasionally but also experienced stand-replacing fires at long intervals; and whitebark pine forests burned infrequently with patchy, variable fires.

An understanding of forest succession requires that students integrate knowledge of fire behavior, adaptations, and fire regimes. Young students integrate this knowledge by telling "forest stories" with feltboard materials. They provide sound effects for thunder, wind, fire, and rain. Older students "adopt" an organism in a ponderosa pine, lodgepole pine, or whitebark pine forest, research their plant or animal's role in the forest community using reference materials provided in the trunk, and then dramatize food webs and succession with and without fire.

Students of all ages learn about one aspect of fire management—risk to homes in the wildland–urban interface. They evaluate homes from photographs, assessing the contribution of construction materials, landscaping, maintenance, and surrounding forest to risk of ignition. Teams of middle and high school students expand their understanding of fire management by setting objectives and writing a management plan for a hypothetical forested area. High school students examine smoke production and dispersal in laboratory experiments and discuss their own perceptions and values in regard to burned areas and use of fire for resource benefits.

The *FireWorks* program for adults (Parkinson et al. 2003) opens with a 12-minute videotape entitled "Managing Wildland Fire—A Matter of Choice" (Fire Sciences Laboratory, Missoula, Montana) followed by activities investigating four topics: the nature of human and forest communities, fuel size and moisture in relation to combustion, fire spread (using "matchstick forests"), and wildland–urban interface home safety.

FireWorks EFFECTIVENESS

To determine the effectiveness of *FireWorks* for students, Thomas et al. (2000) tested 313 seventh graders from 12 classrooms in western Montana. Written tests showed that students who used *FireWorks* mastered fire behavior and ecology concepts better than students who did not use *FireWorks* (1-way analysis of variance, $P < 0.0005$). Field tests indicated that *Fire-*

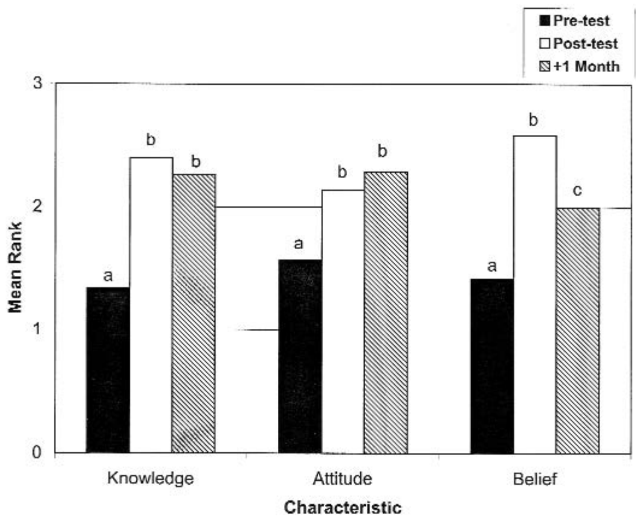

Figure 2. Knowledge, attitudes toward fire management, and beliefs about fire management actions before and after *FireWorks* workshops with adult audiences (Parkinson et al. 2003). Bars within a trio labeled by different letters are significantly different ($P < 0.05$) according to Friedman's ANOVA using mean ranks.

Works students could apply classroom learning to forest settings; their scores on field tests were significantly higher than those of students in the comparison group ($P < 0.0005$). The authors used a standardized measurement tool, the Classroom Environment Scale (Moos and Trickett 1995), to assess the effects of *FireWorks* on students' perceptions of their teachers and classroom environment. *FireWorks* students perceived their teachers as significantly ($P < 0.05$) more trusting, innovative, and interested in student contributions than did students who did not use *FireWorks*. Thomas et al. (2000) attributed the differences to the highly structured curriculum and hands-on nature of *FireWorks*.

To assess the effectiveness of *FireWorks* for adult audiences, Parkinson et al. (2003) hosted six evening workshops in rural communities of northern Idaho. Participants completed a pre-test, four *FireWorks* activities, and then a post-test. A month after each workshop, participants were asked to complete a mail-in questionnaire that served as a second post-test. Fifty of the original 61 participants complied. The knowledge of participants regarding wildland fire behavior and management increased significantly (Friedman's ANOVA, $P < 0.0001$) during the workshops and did not decline significantly after 1 month had elapsed (Figure 2). Attitudes toward fire management were significantly ($P < 0.0001$) more positive at the end of the workshop and did not decline significantly in the subsequent month. Participants' beliefs about taking action to reduce fire risk were significantly ($P < 0.0001$) more positive at the end of the workshop; they were significantly ($P < 0.0001$) less positive after a month had elapsed but did not decline to the pre-workshop level.

IMPLEMENTATION

Thousands of students in Montana and Idaho have used *FireWorks*, and college students and adults have participated in workshops based on the program. Twenty-eight copies of the trunk are currently in circulation, available for loan from land-management agencies and private sources. About 300 teachers and agency staff have participated in 3-day "train-the-trainers" workshops, where they carry out *FireWorks* activities and learn ways to share the program with educators. Train-the-trainers participants then offer workshops to classroom teachers in their local areas. Information about trunks available for loan and scheduled workshops is available on the Internet at www.firelab.org and clicking on the FireWorks link.

FireWorks is especially useful for students and adults living in Montana, Idaho, and Washington—the geographic range that includes all three forest types used to exemplify diversity in fire regimes and adaptations to fire (ponderosa, interior lodgepole, and whitebark pine), but the program is being used in other geographic areas as well. Trunks are now available in Oregon, Colorado, Utah, and Nevada, in areas with one or two of the forest types featured in *FireWorks*. The program is most effective when presenters integrate activities relating to local fire-dependent ecosystems. The Alaska Division of Forestry has integrated portions of the trunk and curriculum with its "Role of Fire in Alaska" curriculum (U.S. Fish and Wildlife Service 1995) and is circulating 10 kits to Alaska schools. Teachers who have used *FireWorks* commend the curriculum structure, hands-on approach, and high level of student interest generated by activities.

CONCLUSIONS

Wildland fire provides a rich context for education of children because it promotes integration of scientific concepts with mathematics, language skills, and social understanding. *FireWorks* employs a highly structured curriculum, hands-on materials, and diverse learning styles to enable students to investigate fire behavior, fire ecology, and fire management. Seventh graders who used *FireWorks* showed increased understanding of wildland fire and more positive attitudes toward their classroom environment. The workshop format and hands-on learning also enhanced learning in adult audiences and was accompanied by more positive attitudes toward fire management.

ACKNOWLEDGMENTS

We are grateful for support from the U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Northern Region, Intermountain Region, and Bitterroot Ecosystem Management Project; and from the National Wildfire Coordinating Group. We are grateful for the suggestions and thousands of hours of time donated by teachers, environmental educators, students, scientists, forest managers and staff, and staff of the Fire Sciences Laboratory.

LITERATURE CITED

Moos, R., and E. Trickett. 1995. Classroom environment scale: development, applications and research. Third edition. Consulting Psychologists Press, Palo Alto, CA.

National Research Council. 1996. National science education standards. National Academy Press, Washington, D.C.

North American Association for Environmental Education. 1999. Excellence in EE—guidelines for learning (K–12). NAAEE Publications and Membership Office, Rock Spring, GA.

Parkinson, T.M., J.E. Force, and J.K. Smith. 2003. Hands-on learning, its effectiveness in teaching the public about wildland fire. Journal of Forestry 101(7):21–26.

Smith, J.K., and N.E. McMurray. 2000. *FireWorks* curriculum featuring ponderosa, lodgepole, and whitebark pine forests. General Technical Report RMRS-GTR-65, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Smith, J.K., N.E. McMurray, and G.C. Smith. 2001. Educational program about wildland fire integrates plant science into curriculum. Plant Science Bulletin 47:86–90.

Thomas, L.R., J.A. Walsh, and J.K. Smith. 2000. Behavioral and cognitive evaluation of *FireWorks* education trunk. Pages 71–73 *in* H.Y. Smith (ed.). The Bitterroot Ecosystem Management Research Project: what we have learned—symposium proceedings. Proceedings RMRS-P-17, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ogden, UT.

U.S. Department of Interior and U.S. Department of Agriculture. 1995. Federal wildland fire management policy and program review, final report. National Interagency Fire Center, Bureau of Land Management, Office of Fire and Aviation, Boise, ID.

U.S. Fish and Wildlife Service. 1995. The role of fire in Alaska: fire information and resource education. U.S. Fish and Wildlife Service, Anchorage, AK.

Appendix. Construction of selected materials in *FireWorks*.

Matchstick Forests (kit contains 4)

Materials

0.63-cm thick masonite sufficient for 4 15 × 15-cm pieces; 0.63-cm bolts (3 10-cm long and 3 6.3-cm long); 4 washers; 4 nuts; 4 small nails.

Preparation

Cut 4 squares of masonite 15 cm on a side. Centered on each square, use a 0.32-cm (#30) bit to drill 7 rows of holes, 7 holes/row, 1.6 cm apart. These will hold the matches for model forests. In 1 margin of each masonite square, centered from left to right, drill a 0.63-cm hole.

Teaching

This section summarizes the "matchstick forest" activity; the activity is described in detail and linked to national education standards in the *FireWorks* curriculum at www.fs.fed.us/rm/pubs/rmrs_gtr65.html (Smith and McMurray 2000:43–46).

To demonstrate effect of slope on fire spread, place a match (pointing up) in each small hole in 3 masonite squares (49 matches/square). Leave one of the squares flat. To represent a moderately steep slope, insert a 6.3-cm bolt in the large hole on 1 square and fasten with washer and nut underneath. To represent a very steep slope, insert a 10-cm bolt in the large hole on the third square and fasten with washer and nut. Place on a cookie sheet or other non-flammable surface. Have fire extinguishers and water available for safety. Use goggles to protect eyes, and follow other safe laboratory procedures. Ignite matches on each masonite square separately, so the fire behavior from one will not influence that on the others. After burning is complete, use the nails to punch burned matches out of the small holes.

To demonstrate the effect of forest stand density on fire spread, place a match in each small hole on 1 square; let this represent the density of a lodgepole pine forest. To represent the relative density of a historic, open ponderosa pine forest, place 5 matches in random holes on another square. To represent whitebark pine, place 13 matches, in patches of 2 to 5, on a third square. Fasten a 10-cm bolt in the large hole in each square. Ignite matches on each board separately so the fire behavior from 1 will not influence that of the others.

Encourage students to design and carry out experiments on other aspects of fire spread. Possible questions include, "What is the effect of ignition pattern (point vs. line, head-fire vs. backfire) on fire spread?" and "How wide a fireline is needed to stop a fire from spreading (uphill vs. downhill vs. sideways)?"

Tinker Trees (kit contains 4)

Materials

Newspaper cut into strips of various lengths, approximately 5 cm wide; several sheets of newspaper, about 25 × 35 cm; 9 m of welding rod, 2.4 mm diameter; 1 chemistry support stand post with base, approximately 40 cm tall. (The support stand can be manufactured in a welding shop using square steel rod, nuts and bolts, and steel plate. Contact the authors for detailed instructions.)

Preparation

In each support stand post, at 2-cm intervals from bottom to top, mark, notch (with a spring-loaded punch), and drill a hole big enough for the welding rod to go through easily (2.5 mm diameter). Line holes up vertically, one above the other, so you will have a 2-dimensional "tinker tree" when finished. A drill press and vise are essential.

To go with each tinker tree, cut the following lengths of welding rod: 3 each 10, 15, 20, and 25 cm long. Remove shavings and file off rough edges.

Teaching

This section summarizes the "tinker trees" activity; the activity is described in detail and linked to national education standards in the *FireWorks* curriculum at www.fs.fed.us/rm/pubs/rmrs_gtr65.html (Smith and McMurray 2000:62–65).

A support stand post is the tinker tree's "trunk." Pieces of welding rod form the "branches." Newspaper strips form the "foliage;" they are easiest to use if they are folded accordion-style and then hole-punched prior to placing on the branch. Sheets of newspaper form the surface fuels.

To investigate effect of stand structure on torching, organize students into 4 teams, each of which will design a tinker tree. Their challenge is to design a tree that has plenty of foliage to conduct photosynthesis but can survive a surface fire. We determine the photosynthetic capacity of the tree by measuring length (in centimeters) of branch covered by unburned "foliage" rather than weighing "biomass."

For each tinker tree: Place the support stand base and rod on a cookie sheet or other nonflammable surface. Place 2 sheets of newspaper (25 × 35 cm, slightly wrinkled) on top of the support stand base to represent surface fuels. (A slit must be cut in the paper to go around the support stand post.) Insert rod segments through holes in support stand post and place newspaper foliage on rods. Each team decides how many rods to use and how much foliage to use. Ignite the tinker trees one at a time, lighting 2 adjacent corners of surface fuels to ignite each. Instruct students to predict the fire behavior for each burn and record observations. After burning, measure "photosynthetic capacity" for each tree as represented by the length of branches covered with unburned foliage (centimeters). Do not moisten or disassemble the tinker tree yet.

To learn about the effect of ladder fuels that develop during succession, take each tinker tree that had foliage surviving the fire in the first experiment. Replace the surface fuels consumed in the first experiment with 4 layers of newspaper. Add a crumpled sheet of newspaper (25 × 15 cm) on each side of the trunk, under the foliage. This is a "tinker sapling." Burn again. Measure "photosynthetic capacity" remaining. The winning tree is the one with the greatest length of branch still covered by unburned foliage.