Fire and Ecological Disturbance

A 5E lesson to address an important misconception

Michael Dentzau and Victor Sampson

"The most important single factor influencing learning is what the learner already knows."

—Ausubel 1968, p. iv

When considering this statement through the lens of constructivism, the significance of misconceptions takes center stage. Misconceptions are not simply factual errors or a lack of understanding, but rather explanations that are constructed based on past experiences (Hewson and Hewson 1988). If students' misconceptions are not directly engaged in the learning process, they may persist—even when faced with instruction to the contrary (Bransford, Brown, and Cocking 1999).

This article presents a 5E instructional model to help students overcome misconceptions about fire and its role in ecological succession. Through this activity, students learn that fire plays an important—and beneficial—role in ecology.

Ecology misconceptions

Much of the literature on misconceptions has centered on the physical sciences, with much less emphasis on biology, and even less on ecology (Driver, Guesne, and Tiberghien 1985; Munson 1994; McComas 2002). Marek (1986), however, found that even after instruction in an environmental unit, 33% of students still had misconceptions about ecosystems. Consider this in light of the goal of scientific literacy, which aims to equip students with the tools needed "to participate thoughtfully with fellow citizens in building and protecting a society that is open, decent, and vital" (AAAS 1989), and the relevance of ecological misconceptions to science education is unmistakable.

Based on the expert opinion of professional ecologists, Cherrett (1989) generated a list of 50 concepts integral to understanding ecology. Though agreement on all 50 concepts is not universal, it seems reasonable to consider the top 10 as essential to an operational understanding of the discipline (Munson 1994). These 10 concepts include

- the ecosystem,
- succession,
- energy flow,
- conservation of resources,
- competition,
- niche,
- materials cycling,
- the community,
- life-history strategies, and
- ecosystem fragility.

Understanding that these concepts are interconnected, we have selected an aspect of ecology that touches on many of them: the role of fire in the ecology of natural communities. Fire, or lack thereof, is directly related to an understanding of succession, but also involves energy flow, materials cycling, life-history strategies, and competition. Gibson (1996) found that succession is often oversimplified in textbooks, especially those for nonscience majors—

leading to the assumption that climax communities are the deterministic "end product" in ecology.

The notion of a climax community, however, is more widely viewed as the exception, and not the rule (Simberloff 1982; Noss and Cooperrider 1994). If students view succession on the traditional continuum of grasses to shrubs to forest, we would also expect them to view fire as an ecological negative.

But fire can be beneficial, even though it disrupts the process of succession. For example, southeastern coastal plain fire—driven by a combination of lightning strikes, Native Americans, and early European settlers—was once a consistent disturbance that shaped the plant and animal composition of natural communities in these areas (Wade, Ewel, and Hofstetter 1980). Frost (1995) suggests that, historically, less than 5% of the coastal plain landscape was protected from fire, with fire-return intervals ranging from 1 to 300 years. This lies in stark contrast to the popular conception that fire is negative and destructive, and has a predominant anthropogenic genesis (Hanson 2010).

The idea that naturally occurring fire has substantially shaped the form and function of wetland ecosystems can be difficult for students to understand. This association is not intuitive (Lugo 1995), largely because of another misconception that the hydrology of a wetland is constant (i.e., it provides "wet" land all of the time). In reality, the hydrology of wetlands fluctuates greatly, and even outside of a drought period, wetlands will burn.

To address this, we developed a unit that relies on the 5E—Engage, Explore, Explain, Elaborate, and Evaluate—instructional model (Bybee 1993; Bybee et al. 2006). Figure 1 provides a summary of the lesson. Each phase challenges the notion of an inevitable climax successional stage, advances fire as an integral part of the natural ecosystem, and reinforces the impacts of ecological disturbances.

Engage

The Engage phase is designed to pique students' interest in the topic and determine their prior knowledge and misconceptions. Though this phase is often enacted using a demonstration in physics and chemistry, many ecological concepts—and subsequent misconceptions—are not easily portrayed inside the classroom. We engage students by posing questions to the class, such as

- Tell me what you know about the impacts of fire in southeastern wetland ecosystems in states such as Florida and Mississippi.
- What happens when fire occurs in these systems?
- Is fire good or bad for ecosystems?
- Does fire naturally occur in a wetland?
- Does fire occur in all wetlands?

Responses to these questions might include common misconceptions, such as:

- Fire is an unnatural occurrence in wetlands, caused only by humans.
- Fire kills all animals and reduces biodiversity.
- Fire always destroys property, causes smoke, and leads to traffic accidents.
- Fire kills all plants and sterilizes soil.

Alternatively, some students may correctly see fire as a mechanism for ecosystem change, a natural occurrence, or something that is beneficial to biodiversity or important for some species' survival.

At this stage, we continue prompting students until they have voiced a variety of responses that can be documented for later reference by the class. We also gauge prior knowledge with a true-or-false assessment (Figure 2, p. 46). This is not a graded test, but rather a tool to determine what the class already brings to the discussion.

Explore

In the Explore phase, students have a chance to build their understanding of the phenomenon. In our example, they are provided with two sets of data generated by an actual vegetation-monitoring program in northwest Florida.

FIGURE 1

Summary of 5E lesson.

Engage	What can you tell me about fire in southeastern wetland communities? Is it good or bad? Natural or unnatural?
Explore	Use vegetation-monitoring data over time to reflect changes in the community with periodic fire. Analyze data.
Explain	Introduce material on fire ecology in the southeast, including publications and short video demonstrations.
Elaborate	Extend the discussion with prompts that require additional research and assimilation of information provided.
Evaluate	Implement a refutational writing exercise convincing a reader of the value of fire in southeastern ecosystems.

FIGURE 2

True-or-false assessment.

Fire in Pinelands	Circle one
1. Fires kill all of the wildlife in the wetlands.	T F
2. Some plants have adapted to survive and thrive with fire.	T F
3. Prior to the settlement of North America, lightning caused most fires.	T F
4. High-intensity fires are always ecologically destructive and bad.	T F
5. When fires occur regularly, the heat sterilizes the soil and kills most of the plants.	T F
6. Some wetlands historically burned as often as every one to three years.	T F
7. Many of our wetlands are less healthy because of reduced amounts of fire.	T F
8. Fires can increase the diversity of the vegetative landscape and foster a mosaic of habitats.	T F
9. Ecological communities always succeed from grasses to shrubs to trees.	T F
10. Fire recycles nutrients.	T F

Answer key: 1-F, 2-T, 3-T, 4-F, 5-F, 6-T, 7-T, 8-T, 9-F, 10-T. An answer guide is available online (see "On the web").

The first data set (Figure 3) represents the "frequency of occurrence," or the number of times a species occurred within 1 ft. intervals along a 100 ft. transect. The only other information provided is that a fire occurred in March of Year 1 and May of Year 4, after the annual monitoring data was collected.

The second data set (Figure 4, p. 48) provides information about the number of flowering stalks of a rare grass, *Calamovilfa curtissii,* or Curtiss' sandreed (Dentzau 2002). These data are complementary to the data collected in Figure 3 and demonstrate fire's effect on the flowering response of a rare target species. We ask students to review the data in both Figures 3 and 4, graph any trends as appropriate, analyze the data, and prepare a plausible explanation.

Explain

In the Explain phase, students discuss their findings and begin incorporating the appropriate framework for the ecological concept: the effect of fire on a wetland ecosystem. Working in groups, students discuss the following questions:

1. What trends did you observe in the frequency of occurrence data provided in Figure 3?
2. Which species exhibits a strong response to fire, based on frequency of occurrence data?
3. What is the impact of fire on the flowering response of Curtiss' sandreed?
4. Which species increased in frequency after the fires?
5. Which species decreased in frequency after the fires?
6. Which species seemed to be little affected by the fires?

Once these ideas, analyses, and inferences are shared in class, we introduce students to the concepts surrounding fire in the landscape. Potential resources are provided in the "On the web" section at the end of this article. In addition, we recommend consulting Wade, Ewel, and Hofstetter (1980), which is available online (see "References"). The essential ideas for understanding the ecological role of fire are provided in Figure 5 (p. 49).

In our sample data sets, there are some clear indications of fire's effects, and some that are more subtle. In Figure 3, *Lachnanthes caroliniana,* or redroot, an herbaceous species, shows a clear positive response in the sampling period after the fire, with increased numbers in the year following the fire and subsequent decreases until the next disturbance. With respect to woody species, fire appears to facilitate a decline in some species, but not all. In Figure 4, the Curtiss' sandreed flowering data show a dramatic response to fire.

Elaborate

In the Elaborate stage, we push students to extend their learning to new situations. The initial lesson questions and the true-or-false assessment (Figure 2) are a good place to start. These help students see how their conceptions have changed.

Next, we assign different prompts to student groups, and after some time for research and collaboration, have each share its information with the class. Sample prompts that require knowledge application and additional resources include the following:

1. Why would you think a beech or magnolia hardwood forest on a very dry, upland ridge would burn less fre-

quently than a dense coastal grass marsh? (An appropriate response focuses on the types of fuels available in each community and an understanding that grasses and pine needles [fine fuels] readily carry fire, whereas hardwood leaves do not.)

2. Do you think a catastrophic wetland fire can be beneficial? If so, how? (An appropriate response includes the conditions needed for a catastrophic wetland fire [i.e., drought] and how such fires can consume organic material and lower the elevation of the substrate, allowing different species to recolonize [i.e., reset succession].)
3. Identify one plant species and one animal species that are considered fire-dependent, and explain their responses to and requirement for periodic fire. (There are several appropriate responses to this question, but students should base their answers on available data.)
4. Why did we see different species responding differently to fire? (There are many acceptable responses for this item, including the plants' health, the amount of soil moisture present, fire intensity, weather conditions during the burn, standing water in some locations, and reduced fuel in some spots.)

Evaluate

The Evaluate phase brings the lesson back to the original concept—the ecological role of naturally occurring fire in community composition and succession—and students' misconceptions about it. We assess students' understanding of the target concept with a refutational writing assignment, which requires them to introduce a common misconception related to a phenomenon, refute it, describe the scientific concept, and then show that the scientific way of thinking is more valid or acceptable (Dlugokienski and Sampson 2008). A sample refutational writing prompt, which connects the fire ecology lesson and the fluctuating status of succession in natural systems, is available online (see "On the web").

So what?

Fire is an essential ecosystem component of many communities in the southeastern United States (Figure 5, p. 49). Yet, when students are first introduced to this counterintuitive concept, many ask, "So why do we suppress them?"

The answer to this question is relatively straightforward and explains why this lesson is so important: We have forever altered the historic landscape through our occupation of this country and, as a result, have changed the frequency and intensity of fire in the southeastern United States. Historically, fires in this area occurred frequently and burned for a long time at a low intensity, but today, naturally occurring fires start in areas where the amount of fuel is exceedingly high due to fragmented natural habitats. Though land managers actively seek to use controlled or prescribed fire to achieve restoration goals, there will likely always be a need for suppression in some areas, such as national parks, because of

FIGURE 3

Frequency of occurrence.

Species' frequency of occurrence was measured along a 100 ft. transect in a Northwest Florida wetland.

Species	Type	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Andropogon glomeratus (broomsedge)	Herbaceous	13	5	8	4	4	2
Calamovilfa curtissii (Curtiss' sandreed)	Herbaceous	52	67	61	66	65	63
Drosera intermedia (spoonleaf sundew)	Herbaceous	28	28	23	35	56	45
Gaylussacia mosieri (woolly huckleberry)	Woody	69	70	78	71	78	76
Ilex coriacea (sweet gallberry)	Woody	23	6	11	4	5	6
Ilex glabra (inkberry)	Woody	86	99	97	93	98	99
Ilex myrtifolia (myrtle-leaved holly)	Woody	2	0	0	0	0	0
Lachnanthes caroliniana (redroot)	Herbaceous	40	100	87	55	99	78
Myrica inodora (odorless bayberry)	Woody	24	11	14	14	3	2
Pinus elliottii (slash pine)	Woody	2	0	0	0	0	0
Rhexia alifanus (meadow beauty)	Herbaceous	0	11	0	0	0	10
Smilax laurifolia (bamboo vine)	Vine	3	8	0	5	2	2

FIGURE 4

Number of flower stalks: Curtiss' sandreed.

Measurements of the number of flower stalks of *Calamovilfa curtissii* (Curtiss' sandreed) in ten 3.28 $ft.^2$ plots were systematically placed along each of two 100 ft. transects in a North Florida wetland. One transect was within the area of prescribed fire and the second was in a control area, where no fire was implemented.

These additional data on flowering response were collected to supplement the frequency and cover data collected for all species represented in Figure 3 (p. 47). Even though fire's impact on this species was not clear in the frequency of occurrence data, there was a dramatic effect on the flowering response.

Plot number	Within the area that burned the prior year	Within the area that did not burn the prior year (control)
1	129	0
2	1	0
3	32	0
4	0	0
5	21	0
6	0	0
7	15	0
8	0	0
9	160	0
10	72	0

the hazardous conditions created by increased fuel loads and encroaching human development.

When considering scientific literacy and the subsumed goal of fostering productive citizens, the ability to understand ecological issues—such as the role of fire in ecosystems—is paramount. Students develop critical-thinking skills when they analyze authentic data sets and use them to construct evidence-based conclusions. The lesson we have provided here serves to actively engage student misconceptions of important ecological concepts and replace them with appropriate scientific knowledge. Such lessons assist the development of scientific literacy and bring students one step closer to becoming the citizens our society needs. ■

Michael Dentzau (mwd09c@fsu.edu) *is a graduate student and Victor Sampson* (vsampson@fsu.edu) *is an assistant professor, both in the School of Teacher Education at Florida State University in Tallahassee.*

On the web

Refutational writing prompt and assessment guide: *www.nsta.org/highschool/connections.aspx*

Fire ecology: *http://en.wikipedia.org/wiki/Fire_ecology*

Benefits of prescribed burning: *http://edis.ifas.ufl.edu/fr061*

Dome swamp: *www.fnai.org/PDF/NC/Dome_Swamp.pdf*

Wet flatwoods: *www.fnai.org/PDF/NC/Wet_Flatwds.pdf*

Communities: *www.dep.state.fl.us/water/wetlands/docs/fwric/flatlands_desc.doc*

Prescribed fire fact sheet: *www.nwrc.usgs.gov/factshts/018-00.pdf*

Prescribed fire training: *www.youtube.com/watch?v=dZybHZwmgZ0*

Restoring fire to native landscapes: *www.nature.org/wherewework/northamerica/states/florida/science/art29501.html*

Fire as a restoration tool: *www.youtube.com/watch?v=YCC6C5U60wA*

Fire-dependent animals and plants: *www.nature.org/popups/misc/art29551.html#*

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FIGURE 5

The ecological role of fire.

Adapted from Wade, Ewel, and Hofstetter 1980.

Fire influences the physical-chemical environment by
◆ directly releasing mineral elements such as ash.
◆ indirectly releasing elements by increasing decomposition rates.
◆ volatilizing some nutrients (e.g., nitrogen, sulfur).
◆ reducing plant cover and thereby increasing insolation.
◆ changing soil temperatures because of increased insolation.
Fire regulates dry-matter production and accumulation by
◆ recycling the stems, foliage, bark, and wood of plants.
◆ consuming litter, humus layers, and, occasionally, increments of organic soil.
◆ creating a large reservoir of dead organic matter by killing but not consuming vegetation.
◆ usually stimulating increased net primary production, at least on short time scales.
Fire controls plant species and communities by
◆ triggering the release of seeds.
◆ altering seedbeds.
◆ temporarily eliminating or reducing competition for moisture, nutrients, heat, and light.
◆ stimulating vegetative reproduction of top-killed plants.
◆ stimulating the flowering and fruiting of many shrubs and herbs.
◆ selectively eliminating components of a plant community.
◆ influencing community composition and successional stage through its frequency or intensity.
Fire determines wildlife habitat patterns and populations by
◆ usually increasing the amount, availability, and palatability of foods for herbivores.
◆ regulating yields of nut- and berry-producing plants.
◆ regulating insect populations, which are important food sources for many birds.
◆ controlling the scale of the total vegetative mosaic through fire size, intensity, and frequency.
◆ regulating macroinvertebrate and small-fish populations.
Fire influences insects, parasites, fungi, and so on by
◆ regulating the total vegetative mosaic and the age structure of individual stands with it.
◆ sanitizing plants against pathogens such as brownspot on longleaf pine.
◆ producing charcoal, which can stimulate ectomycorrhizae.
Fire also regulates the number and kinds of soil organisms, affects evapotranspiration patterns and surface waterflow, changes the accessibility through and aesthetic appeal of an area, and releases combustion products into the atmosphere.

Ecological terms.

Ecosystem: A dynamic complex of plant, animal, fungal, and microorganism communities and their associated nonliving environment interacting as an ecological unit.

Succession: The more-or-less predictable change in the composition of communities following a natural or human disturbance.

Energy flow: The movement of energy (the capacity to do work) through an ecosystem. The source of virtually all of the energy useful to organisms is the Sun and the basic way in which life captures this energy is through photosynthesis. Available energy is lost continuously as it moves through the ecosystem trophic levels.

Conservation of resources: The wise use of Earth's natural resources by humanity.

Competition: The struggle among organisms, both of the same and different species, for limited food, space, and other requirements needed for survival.

Niche: The place occupied by a species in its ecosystem—where it lives, what it eats, its foraging route, the season of its activity, and so on. In a more abstract sense, a niche is a potential place or role within a given ecosystem into which species may or may not have evolved.

Materials cycling: The movement of minerals, elements, and nutrients through ecosystems in a cycle of production and consumption.

Community: All of the organisms—plants, animals, and microorganisms—that live in a particular habitat and affect one another as part of the food web or through their various influences on the physical environment.

Life-history strategies: A species pattern of growth, development, age at sexual maturity, level of parental involvement, number of offspring, and senescence that are shaped by natural selection to produce the largest possible number of surviving offspring.

Ecosystem fragility: The degree to which an ecosystem can be easily damaged or changed, in part or in whole, in unexpected and undesirable ways.

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