Ecology 101

Using "The Power of Story" to Overcome Ecological Misconceptions and Build Sophisticated Understanding

"Let me tell you a story." These are the words that E. O. Wilson (2002) used to engage readers in his article "The power of story," which refers to the use of a narrative to convey scientific information in such a way as to spark emotion and imagination in the student, in an effort to help the student better learn and understand the course material. For example, the use of story provides us with the ability to sort through the countless pieces of information to which we are subjected every day. When the brain encounters new information, it can fit it into an existing scaffold, which enhances more complete retrieval at a later time (Bransford et al. 1999).

However, students' assimilation of a story and an understanding of the concepts are influenced by previous understandings of the material, which may include misconceptions. Misconceptions are inaccurate explanations of phenomena constructed by students based on prior knowledge and experience (CUSE 1997, D'Avanzo 2003). Addressing the misconceptions in ecology is important because the misconceptions "strike at the heart of a general understanding of ecology"; furthermore, resistance to addressing environmental problems is tied to ecological misconceptions (Munson 1994).

A further limit to the assimilation of concepts is that, despite the wonderful stories we have to tell, the power of story has not been used well in textbooks (Stamp 2005). The level of sophistication in modern ecology is not apparent. Instead, students are swamped with terms and detail and cannot fathom the complexities of ecology.

Our research focuses on overcoming students' misconceptions in a large-enrollment undergraduate ecology course that has no laboratory component. Our goal is to help students reach a deeper, more sophisticated level of understanding of ecological principles, as described, for example, in Odum (1992) and Sinclair (2003). There have been relatively few studies on misconceptions in ecology (see Munson 1994 for an overview), and none on the power of story in teaching ecological issues. Using the "power of story" can help dispel misconceptions and also provide a framework in which students can place new concepts and correct old ones (Stamp 2004).

Our "power of story" units are constructed using the 5E teaching cycle (Engage, Explore, Explain, Elaborate, and Evaluate) (Bybee 1993). The term "cycle" refers to the need to revisit concepts throughout the unit, and across units, in order to challenge and overcome misconceptions. Although typically this method is used with more hands-on activities, it also works well in classes where laboratory materials or field activities cannot be used. The key is using activities such as concept mapping (Briscoe and LaMaster 1991) and pair-and-share assignments (Angelo and Cross 1993) within the 5E format to help students become the next generation of storytellers. This approach acknowledges that students don't want the textbook material repeated in the classroom (Light 2001), and fits the recommendation that more class time be spent on developing students' skills in assimilating material into long-term memory (Handelsman et al. 2004). With our approach, on average, about 60% of the class time was spent lecturing, and 40% discussing with students during pair-and-share, participating in class discussion such as generating lists of potential answers, and making and discussing concept maps. In contrast, one study, at a large public university that focused on the top 20 professors noted for promoting discussion, showed that even in those classes (average size was ~30), students spoke <3% of the time, and most of it was not substantive (Nunn 1996). Other studies reported students speaking on average up to 20% of the time (Fischer and Grant 1983, Smith 1983).

Here we provide an example of a "power of story" unit for the first third of a lecture course. Our undergraduates come mainly from the northeast United States. So we created a story, which has two sections, focused on the Eastern deciduous forest. The first section covers the ecology of Lyme disease, masting (peaks of nut production), gypsy moths, and accidentally introduced insect herbivores. The key concepts here are population growth cycles and models, interactions among trophic levels, life history traits, and human impact on ecosystems. The second section introduces frugivory, pit-and-mound topography, development of soils, and acid rain. Added to the previous key concepts are mutualism, nutrient cycling, succession, and evolution of ecosystems. Using the 5E teaching cycle, the major concepts are continually revisited so as to provide a framework in which students can place new ideas and examples, thus building their own understanding of ecological concepts. What follows is a brief description of this story unit.

Eastern deciduous forest: Section 1

Engage part 1: Lyme disease

Lyme disease (caused by a spirochete) was discovered in 1977 in Connecticut and is transmitted by ticks, which normally use mice, small birds, and deer as hosts. Lyme disease is now the most important vector-transmitted disease in the USA. What explains the sudden appearance of this disease and its spread? We list ideas from students, but do not as yet discuss the accuracy of the ideas. The presentation of Lyme disease as an engagement is effective because many of our students are from the northeast United States, have heard of Lyme disease, and know people with the disease.

In this phase we provide a minilecture about the relationships of Lyme disease, ticks, mice, deer, oaks, and habitat fragmentation. This lecture includes the effects of masting on deer populations, which affect tick density and mouse density, and how these affect the increase in Lyme disease. Then we revisit the original question and students' initial answers and ask students to articulate new answers. We finish this phase by having the students draw a concept map of the relationship between the spirochete that causes Lyme disease and its hosts and vectors, and having students pair-and-share their concept maps. We routinely follow up pair-and-share by asking some pairs to share their ideas for class discussion.

Engage part 2: Masting

Nut-producing tree species often produce huge numbers of nuts periodically and then little or no nuts for several years. Masting is often synchronized within and, at times, between species. What are the advantages and disadvantages of these patterns for nut-producing species? What causes these patterns? We list ideas from students, but do not discuss the accuracy of their ideas.

Next we provide a minilecture about the ecology and evolution of nuts and masting, which includes the benefits of producing large nuts rather than small seeds, toxins found in nuts, the activity of consumers and dispersers, and positive correlations between the number of acorns and mouse density, mouse density and predation on gypsy moth pupae, and acorn density and deer density. Then we revisit the original question about masting and ask students to articulate new answers. We have the students draw a three-part concept map of the effect of masting and nonmasting on the risk of Lyme disease: the first map is year one with masting, and the second and third maps (years two and three, respectively) with little or no nut production. Then students pair-and-share their maps.

Explore part 1: Gypsy moths

Gypsy moths exhibit a population cycle with peaks every 7–10 years. Gypsy moth caterpillars will eat 200+ woody species but prefer oaks. At population peaks, tree defoliation is widespread, and with successive years of defoliation, up to 20% of trees may die. Gypsy moths are not native to North America and do not cause as much of a problem in Europe and Asia. Why do populations cycle to widespread defoliation levels here? And what causes populations to decline or crash? We solicit ideas from students, but do not discuss the accuracy of their statements.

Next we provide a minilecture punctuated by questions about gypsy moths, and their host plants, including food quality for caterpillars, caterpillar gut pH and detoxification, predators, parasites, and climate effects. Then we revisit the initial questions about gypsy moths and have the students articulate new answers. We have the students draw a timeline of the effects of gypsy moths on the Eastern deciduous forest community we have thus far discussed.

Explore part 2: Introduced insect herbivores

Besides gypsy moths, there are many other accidentally introduced insect herbivores in North American forests. That Europe and North America were once joined predisposes these areas to successful interchange of insect herbivores. So why have European insects been 100 times more successful at invasion into North America than vice versa? Again we list ideas from students, but do not discuss accuracy.

In this phase we provide a minilecture describing the following hypotheses and evidence for each. (a) The number of invaders going in any direction is proportional to the size of the conduits of passage. (b) The number of invaders reflects fundamental differences in the number of species available for dispersal from the donor continent. (c) The number of successful invaders is determined by ecological opportunities upon arrival. (d) Invading species are intrinsically competitively superior to natives.

After the lecture, we have students develop a chart estimating the percentage contribution of each hypothesis' explanation to the skewed proportion of invasion into North America. While reflecting on the probability chart, students discuss whether this is still a concern for North American forests and, if so, what is the most reasonable course of action? We also ask students how they think this pattern of invasive insect herbivores might affect the entire food web in the Eastern deciduous forest ecosystem.

Explain: Population dynamics

Here we provide a lecture on population dynamics, which covers exponential and sigmoid population growth patterns and carrying capacity, as well as how population models can be applied to real-world situations. Then we ask students to tie in other ecological concepts involved so far in this "story"; they draw a concept map of the hierarchy of all of these concepts. There is no one or right answer. Mapping shows individual perception. What is important is that students: (a) express their understanding, and (b) develop reasonable linking and sufficient complexity in their maps.

Elaborate: Past and future forests

Precolonial Northeastern forests were dominated by oaks and chestnut. Chestnut was wiped out by an Asian blight, and so the oaks have dominated until recently. Now red maple is taking over as a dominant species. What explains this change? We list ideas from students, but do not discuss accuracy.

Next we provide a minilecture punctuated by questions about: the evolution of Eastern deciduous forest from the Pleistocene to the present, role of seed predators, role of fire, effect of gypsy moths, effect of climate change, and how these factors benefit red maples. Then we revisit the question about forest change and have the students articulate new answers. We have students draw a time line showing the dominant vegetation for the area that is now Eastern deciduous forest, from 16,000 years ago, through the present, to 100 years into future. We then have students pair-and-share and follow with a class discussion.

Evaluate: Songbird decline

Birds reduce densities of leaf-eating insects in forests. Birds, by eating these insects, cause an increase in tree growth. Songbirds (many of which are insectivores) are vanishing from North America. Why?

For this section, students read Terborgh's (1992) "Why American Songbirds Are Vanishing" before coming to class. Using the information from this article and the concepts and information we have covered thus far on Eastern deciduous forests, students in groups of 4–5 discuss a set of questions, which includes identifying hypotheses for why songbirds are vanishing from North America, summarizing the critical evidence for each hypothesis, and assigning a probability for each hypothesis or explanation's contribution to the vanishing of songbirds. Additionally, these groups split into two subgroups, each constructing a concept map that includes all of the information covered thus far in the Eastern deciduous forest story. Once finished, each subgroup presents their concept map to the other subgroup, which listens for completeness and accuracy.

The Evaluate phase has students reflect upon: (1) their development of habits of mind via pair-and-share, conceptual mapping, and application of the hypothesis-evidence-probability process and (2) the conceptual framework of both Eastern deciduous forest and application of key ecological concepts. As one student said a semester after the course, the "activities such as the in-class pair-and-shares and concept maps were useful to explore the complexities of certain ideas. . . . The students' misconceptions were challenged by themselves (with their concept maps) and by classmates (pair-and-share). With both activities, students were forced to explain the concepts to themselves or others and, in doing so, misconceptions clashed with the new correct conceptions."

Eastern deciduous forest: Section 2

Engage part 1: Pit-and-mound topography

If you removed the leaves on the forest floor, you would see that the forest floor is not flat. You would find that much of the surface consists of pits and mounds, even in the areas that, thousands of years ago, were covered by a glacial ice sheet. How do you explain that? Do these pits and mounds affect the plants? We list ideas from students, but do not discuss the accuracy of their ideas.

Next we provide a minilecture about pits and mounds, including physical characteristics such as litter depth, organic matter, available nitrogen, calcium, and cation exchange capacity, and what these mean for plant diversity. Then we revisit student responses to the question above. We have students pair-and-share about what else might create patches of different environmental conditions for plants growing within a forest.

Engage part 2: Ants and seeds

Woodland ants gather seeds and small insects for food. Some seeds are routinely gathered but then dumped on the trash piles of ant colonies. Why would ants spend the time and energy to transport large items over many meters and then discard them? We ask for ideas from the students, but do not discuss accuracy.

Next we provide a minilecture about ants gathering seeds with elaiosomes (external appendages containing lipids), the fate of seeds, and the establishment and success of seeds. We revisit the initial question, and then have students pair-and-share ideas about what kind of environmental conditions promote the mutualism of ants collecting seeds with elaiosomes. We ask some pairs to share their ideas for class discussion.

Engage part 3: Frugivory

In contrast to fruits that ripen in the fall, many summer fruits exhibit three rather than two distinct color changes. For example, blackberries and wild cherries, both fruits of summer, go from green to pink/red to black; blueberries go from green to pink to blue. Why is this such a common pattern for summer fruits but not for fall fruits?

We give a minilecture on the mutualism of frugivory, focusing on the differences between summer and fall fruits (e.g., summer fruits have high sugar and low lipid content, whereas some fall fruits have high lipid content), and how these differences affect, and are affected by, behavior of seed dispersers. Afterward, we have students pair-and-share ideas about what kinds of environmental conditions promote this kind of mutualism; we then have them draw and explain the seed shadow for fruiting plants that produce fruits in (1) summer, (2) fall with fruits eaten then, and (3) fall with fruits held on the plants through winter.

Explore part 1: Mycorrhizae

Before class, students seek answers to a list of questions about mycorrhizae, including what are mycorrhizae, how widespread are mycorrhizae, what kinds of plants have an association with them, what exactly do plants gain by the association, what happens to plants that do not have the association, what exactly do mycorrhizae get from plants, can mycorrhizae exist without plants, and what would the world be like without mycorrhizae? During class, the questions are presented and volunteers are asked to give their answers. If the answer is correct, a piece of candy is tossed to the student. The class is asked whether anyone feels the answer requires clarification, qualification or expansion. Candy is tossed to those that contribute correctly and appropriately. When no further correct answers are given to a particular question, the instructor proceeds to the next question. Not surprisingly, the students are especially attentive and enjoy the competition. After this discussion, students are asked to construct, from the plant's point of view, a concept map incorporating pits, mounds, ants, elaiosomes, frugivory, and mycorrhizae. Note that a semester after the course, a student commented that this "was a great assignment because the students were forced to become miniexperts and so were more understanding or accepting of the complex nature of mutualisms as a whole."

Explore part 2: Nutrient cycling

We pose this multiple-choice question: What happens to the nutrients locked up in a forest if the plants are killed? (a) The nutrients are lost through physical decomposition. (b) The nutrients are lost though microbial decomposition. (c) The nutrients are absorbed by the soil. (d) The nutrients are carried off by water into a stream system. (e) I don't know. We take a hand tally for each answer and record the vote so that the students can see the total for each answer.

Next we give a minilecture on the nutrient study in Hubbard Brook Experimental Forest, which is described in most ecology textbooks. Afterward, we revisit the question and take a recount of the students' choices and have some discussion.

Explain: Soils, succession, and nutrient runoff

We ask where soil comes from, and then give a lecture on the creation of soils and succession based on work at Glacier Bay, Alaska, another example described in most ecology textbooks. This lecture covers the succession of soils and plants from glacial retreat to late-successional spruce–hemlock forests, nutrient cycling and cation exchange capacity. We then ask for and list students' ideas about where the nutrients that are carried off by water to the stream system end up. With reference to this forest system vs. that of the Hubbard Brook study, we provide details about natural and unnatural eutrophication in adjacent lake ecosystems. After this lecture, we ask students to list the ecological concepts that we have covered in this second section of the Eastern deciduous forest and to draw a concept map of the hierarchy of these concepts.

Elaborate: Acid rain

We begin by having students provide their opinions about the problems of acid rain and whether it is being solved. We follow this discussion with a minilecture on acid rain, covering formation of acid rain, calcium depletion in soil, nitrogen saturation in soil, and what is being done to correct the problems. We then ask students to create a three-part concept map about the effects of acid rain on soil cations: the first part involves the natural movement of nutrients through a forest ecosystem, the second is about the movement of nutrients through an ecosystem with the trees removed, and the third is about the movement of nutrients through an ecosystem subjected to acid rain.

Evaluate: Earthworms

Native earthworms do not usually occur in Northeastern forests. These forests are now being invaded by exotic earthworms. Before class, we have students read a short summary about earthworm ecology and the effects of introduced earthworms. In class, students, working in groups of 4–5, answer and discuss: (a) why were there no native earthworms in these forests, (b) why is there a concern about the exotics, (c) what long-term effects might exotics have on forests, and (d) compare and contrast the movement of a nutrient atom (e.g., nitrogen) through a forest ecosystem in an earthworm-free vs. an earthworm-invaded situation. Where is the travel of the atom slowed down or sped up? Then students pair-and-share about where they can fit the information they have covered on earthworms into the concept maps they have constructed for this section. In addition, students review in its entirety what we have covered about the Eastern deciduous forest by talking through how they would create a master concept map that includes all that we have covered about the Eastern deciduous forest. Alternatively, students can develop a master concept map outside of class and then exchange maps for critique.

Again, the point is that students are asked to reflect and build upon the entire story of the Eastern deciduous forest and repeatedly use key ecological concepts. Armed with this example ecosystem, students are better able to integrate the array of ecological concepts and then apply these concepts to other ecosystems.

Student response

About halfway through the semester, students described what they thought was the most important thing they had learned thus far in the semester. Even though the unit on the Eastern deciduous forest was completed two weeks prior to this evaluation, students largely chose to write about aspects that pertained to the Eastern deciduous forest. In addition, many students provided syntheses of ideas that were not presented as such during the Eastern deciduous forest unit. For example, one student wrote, "An important thing so far is that there isn't usually one simple explanation for a particular event. Many events (like [outbreak of] Lyme disease and gypsy moths) are affected by several factors and may not even occur if one of those factors is not there." Often, students chose a specific concept and used evidence from the course to explain: "I feel that population growth is the most important concept of all we have studied. When populations of any species get larger (or smaller), they have effects across their entire ecosystem. Diseases are spread or not spread. Food for other species is made available or not made available. Populations of other species will rise or fall." Another student wrote, "A lack of mutualisms would cause a breakdown in any ecosystem. For example, if there were no mycorrhizae there would be almost no plants like oaks [i.e., plants would do poorly], which would affect deer, mice, and other nut eaters, and so Lyme disease, nutrient levels, eutrophication, and eventually people."

Conclusion

Lecture periods and ecology textbooks play an important part in students' conceptual development, but both need to be designed with a bigger picture in mind. As stated in Wilson (2002), "Storytelling is not something we just happen to do. It is something we virtually have to do if we want to remember anything at all." However, students seem to learn the "paragraph" examples in lectures and textbooks without being able to generalize or evaluate the limits of applicability. Whether in a textbook or in a lecture course, a few detailed stories about ecosystems, tying together ecological concepts and framed clearly as examples that illustrate common themes, would be more effective than "paragraph" examples for each concept. Such stories can better demonstrate the increasingly sophisticated understanding that we have about ecology (for example, as outlined by Odum [1992] and Sinclair [2003]), but which is seldom apparent to students using the current ecology textbooks. Importantly, if students are to remember the stories, they must have sufficient opportunities to become the storytellers. Lastly, the power of story with the 5E teaching cycle as a framework can be the format for development of a single concept, a lecture period, an entire course, or even a textbook.

More about this project, more explanation of the 5E teaching cycle, a detailed version of the Eastern deciduous forest story (with "answers" to the questions posed) plus references and examples of student concept maps are posted at: ‹http://ecomisconceptions.binghamton.edu/index.htm›

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