# Ecology 101

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Dr. Brown tells me that he has only tried the following approaches to stimulating students' interest, imagination, and confidence in the "Third World" setting, but I am sure that similar issues occur in universities over the globe.

*Harold Ornes*

## THE USE OF FAIRY TALES AND BEER BETS AS WAYS TO HELP STUDENTS IN ECOLOGY AND ENVIRONMENTAL SCIENCE COURSES DEVELOP IMAGINATION AND CONFIDENCE

### *Imagination is more important than knowledge*

This phrase, typically attributed to Albert Einstein, has adorned many college dorm rooms and scientists' offices. Yet in spite of Einstein's opinion, most science teaching focuses on transferring knowledge instead of encouraging imagination. In our graduate program in environmental geochemistry, two techniques have been especially helpful to try to redress this imbalance: fairy tales of biogeochemical cycles, and symposia on imaginary applications of geographic information systems.

A fundamental concept for ecology and environmental sciences is the biogeochemical cycle. The classical means of portraying the cycle uses boxes representing the lithosphere, biosphere, hydrosphere, and atmosphere, or boxes representing components within ecosystems. Arrows going in and out of the boxes represent fluxes. While our students could easily see the linkages, I found that they were having difficulty integrating the roles of time and specific processes in global cycles.

To help this integration we moved from a frame reference of boxes fixed to the earth's surface, a Eulerian perspective in the parlance of fluid mechanics, to a frame of reference fixed to an individual particle, a Lagrangian perspective. The particle that I used was a calcium atom named Joe. As an introduction to this technique, I began with a fairy tale about Joe. The possibilities are endless for stories like this, as Aldo Leopold exemplified in his poetic tale of atoms X and Y (Leopold 1949).

### *To see a world in the path of a calcium atom named Joe* (with apologies to William Blake)

Joe's story begins with his birth in a supernova explosion six billion years ago. He drifts around in space for a couple of billion years until gravitational attraction pulls him into a forming Earth. Joe's life becomes more interesting as he integrates into the global geochemical cycle. Once on the earth's early surface, weathering releases him from his clinopyroxene home and Joe soon adsorbs onto a clay particle that settles on the ocean floor. Joe goes on a downhill ride as his oceanic plate gets subducted and experiences successively higher temperature and pressure, resulting in Joe being bonded in different mineral homes over time. Finally, Joe gets ejected back to the surface with volcanic material. Joe's life now turns hectic as he participates in local biogeochemical cycling. He is released by weathering, becomes an exchangeable cation in volcanic soil, is taken up by a root tip of a tropical forest tree, is fixed in a leaf, carried by a leaf-cutter herbivore into a underground nest, which in turn is eroded by a meandering river.

Cutting the story short by a hundred million years, Joe ends up in a soil solution in a pasture on which a farmer grazes dairy cattle. Joe gets absorbed by the grass, transferred to a cow, and complexed in her milk. The cow's milk becomes the cheese that I ate for lunch six months ago. Now Joe resides in the last bone segment of my left little finger.

The real educational value of this exercise grew when each student told his or her fairy tale with different atoms. The exercise encouraged students to be creative in linking biogeochemical processes to the specific properties of a given element, say phosphorus, nitrogen, or potassium. This technique helped both students and me figure out what concepts were not well understood. Typically, a student would detail those processes that she or he understood and gloss over a process if it wasn't well mastered. These fairy tales were in essence oral comprehensive exams with the opportunity for students to be creative and logical in linking the myriad processes affecting biogeochemical cycles.

Fairy tales such as this also reinforce a bond between students and

what they are learning. One early morning exercise for them consisted of looking into the mirror and contemplating a face made up of atoms created at the beginning of the university and from a supernova explosion. These atoms have been cycling for 100 million times longer than an average human lifetime. The number of atoms in a human body is on the order of $10^{27}$, give or take a factor of a hundred. The number of possible stories, therefore, is basically unlimited (at one a minute it would take millions of times the age of the universe to tell a story for each atom in the human body). Being one with nature is not an exotic metaphor, but a simple, mundane reality.

## Imaginary applications of geographic information systems

Another opportunity to encourage creative and logical thinking occurred during a short course on geographic information systems (GIS). The explosion of interest for GIS in ecology and environmental sciences has made it essential that young professionals have some notion of how a GIS works. Studying examples and theory is helpful, but students wanted to see how GIS would apply to their prospective thesis topics. It seemed that the best ones to determine the application would be the students themselves. Yet the time available was too short in our condensed course for the students to complete such an application.

The final exam became a symposium with each student presenting an application of GIS that they had imagined, preferably related to their research. The subjects ranged from geographic factors affecting malaria in a Mexican town, to siting of mercury-contaminated tailings from a gold mine in Columbia, to the effects of land use in drainage basins on the primary productivity of reservoirs in Brazil's northeast. The students evaluated the presentations of others for the clarity and logic of their applications of GIS principles. All students prepared abstracts that were later collated into an informal publication.

In the course evaluation, students reported this approach to be challenging and extremely useful for envisioning what they could do with GIS. They appreciated the opportunity to practice oral presentations in a symposium format because few had had any experience of that nature. The wide range of topics, selected and developed by the students themselves, helped illustrate how GIS can be used.

## Quantification and confidence building—the role of beer bets

Some of the best things in life—love, happiness, freedom, and their pursuit—are not measured on interval or ratio scales, but many parameters of environmental interest must be. Students need to develop quantification skills, particularly in back-of-the-envelope calculations (BOTECs), and have confidence in their answers. The stake associated with such calculations can be high: in a few years our graduate students will make quantitative decisions that can affect the livelihood or even the lives of many people when they propose solutions for agroforestry systems, heavy metal contamination, and radioactive pollution.

Mastering BOTECs typically requires considerable practice, yet exercises often seem trivial and boring. One way of developing interest is to engage the egos of students by placing bets on the outcome. This activity was done in the context of a course on the methodology of scientific research.

Once students realized that the objective of the bets was for them to gain confidence and that it was acceptable for them to err in a classroom setting (and therefore learn from the error), then the best became commonplace. Questions ranged from what would be the value of a mahogany tree with a diameter of 1 m, a height of 30 m with a price of \$300/$m^3$, to the mass of boulders used as a breakwater 700 m long, 4 m high, and 4 m wide, to how much mercury is discharged from a factory.

Answers needed to be accurate to one or two significant figures at most; alas, this level of accuracy is often the best that one can hope for in environmental sciences (Brown et al., *in press*). Initially, calculators were prohibited so as to help students be more self-reliant.

When students came up with an answer, I would ask "will you bet a beer/soft drink/fruit juice on it being right?" Typically, the trend was for me to win most of the bets at the beginning of the course, and then lose most of them as students developed their confidence in calculations. In these mock situations, students began to realize that when they turn professionals the cost of being wrong will be more than losing a bet for beer.

These and other techniques (Brown 1985, Brown and de Lacerda 1986, Brown et al., *in press*) have proven to be useful for helping students develop their imagination and confidence. They are not restricted to the graduate level; several students have adapted these techniques for use with secondary and elementary students and found them to be useful in generating enthusiasm for ecology or environmental sciences.

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