A Module-Based Environmental Science Course for Teaching Ecology to Non-Majors

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Abstract: Using module-based courses has been suggested to improve undergraduate science courses. A course based around a series of modules focused on major environmental issues might be an effective way to teach non-science majors about ecology and ecology's role in helping to solve environmental problems. I have used such a module-based environmental science course for non-majors. The course is divided into 5 modules, with each module addressing a key environmental issue, specifically global climate change, human population growth, sustainable use of natural resources, habitat loss, and the value of biodiversity. Each module follows the same basic structure: 1) an introduction to the question, 2) an investigation of the basic science underlying the question, and 3) an investigation and discussion of the human aspect of the question (i.e., what can we do?, what are the costs and benefits of addressing the question?, are there any social, economic, or cultural factors that affect our ability to address the issue?, etc.). Each module has associated laboratory exercises that culminate with field-based student-designed surveys of biodiversity on the Denison University Biological Reserve. The module-nature of the course allows for the integration of science and non-science disciplines around basic environmental questions, and appears to be an effective means of teaching environmental science and ecology to non-majors.

Keywords: ecology, environmental science, module-based, non-majors course

Introduction

Teaching ecology to non-majors, especially non-science majors, can often be challenging as students sometimes do not feel or see a need to learn what they see as material that is irrelevant to their real life or future career. Linking the teaching of ecology to discussions of real world environmental problems or controversies is one way to engage students in the study of ecological principles (Pallant, 1996; Gill and Burke, 1999; Battles et al., 2003). Different approaches to making these connections have been suggested (e.g., use of service-learning, Bixby et al., 2003; problem-based learning, Keller, 2002). Here I describe a course for first-year non-science majors designed around modules that use major environmental issues as a context in which students can learn and apply basic ecological principles to questions they may encounter as citizens once they leave college.

The Course.-- The course is a First-year Seminar, a writing intensive course that is part of the first-year experience at Denison University. The particular course, FYS102, is a multi-section course with each section taught by a different professor and focusing on a different theme related to the professor's discipline - thus there are science, humanities, social science, and fine arts sections. Each section of FYS102 has 12 – 20 students, and represents a self-contained course lasting 14 weeks. My section was focused on the ecology of environmental problems and fulfilled a lab science general education requirement, as well as a quantitative reasoning competency requirement. My course met for three 1-hour long "lecture" periods and one 3-hour long lab period each week. I have taught this course twice (Spring 2005, Spring 2008). Both times I taught the course the majority of students were non-science majors, although in Spring 2008 there were a substantial minority of students who were science majors or environmental studies (ENVS) majors (in Spring 2008, this course could count as a core course for ENVS majors).

Basic Course Organization.-- The course was organized around 5 modules covering a variety of environmental issues and each module was focused on a guiding question. Each module started with an introductory exercise, explored the underlying science, and concluded with an exploration of broader issues (see Table 1 for details of the content covered in each module).

Table 1. Summary of content of the five modules used in the environmental science course for non-majors.

	Science Content	Other Considerations
Module 1: Is the Climate Changing?	Determinants of climate – local determinants, Hadley cells, global determinants, ocean circulation History of Earth's climate – ice age periodicity, what causes heating and cooling cycles Greenhouse effect – greenhouse gases, mechanisms Evidence of climate change – evidence of changes in CO_2, instrumental records, changes in glaciers, biological evidence, Predictions of future climate change – climate models Biotic consequences of climate change – changes in plant and animal distributions, phonological changes, health related issues	Economic and health-related consequences of climate change Political issues – Kyoto Protocol
Module 2: Can the human population grow indefinitely?	Life tables – m_x, calculating l_x, R_o, survivorship and fecundity curves Lotka-Volterra population equations – exponential and logistic forms Carrying capacity – definition, can it change?	Social, cultural, political, and religious aspects of addressing human population growth
Module 3: Can exploitation of natural resources be sustainable?	Food webs – trophic levels, food chains, terminology Trophic cascades – top-down control vs bottom-up control Keystone species – definition, how determine a keystone species, role in community structure Direct and indirect effects – definitions, how generated in food webs Ecological efficiencies – calculations of how much energy is lost in primary producers and in consumers, how ecological efficiencies impact how long food chains can be Maximum sustainable yield – definition, relationship to logistic growth curve	"Tragedy of the Commons" Government subsidies – how influence impact of fisheries on fish populations Economic and political issues related to natural resources and fisheries
Module 4: How can the forests of Madagascar be saved?	Edge and matrix effects – definitions, how impact abiotic conditions, how affect populations, how relate to habitat fragmentation and loss	Cultural, socioeconomic, and political aspects of habitat loss and fragmentation in Madagascar

	Minimum viable population – definition Succession – primary vs secondary succession	
Module 5: What is biodiversity worth?	Measures of diversity – species richness, relative abundance, evenness, dominance, Simpson's Index Patterns and gradients of diversity – latitudinal gradients, altitudinal gradients, species-area curves, explanations for these patterns	Traditional economics -- supply and demand curves Environmental economics – externalities, valuation of natural products and ecosystem services

The labs for each module supplemented and reinforced lecture material. In addition, some labs provided students the skills needed to become informed citizens (e.g., web page critiques in Module 1, biodiversity field survey projects in Modules 4 & 5).

Each module had an associated writing exercise. Such writing assignments can be effective in helping students understand ecological or environmental science concepts (e.g., Tessier, 2006). Writing assignments ranged in length and focus, as well as in style. In addition, each student wrote a media critique in which they compared popular media articles on an environmental problem or topic of their choosing to scientific papers on the same topic. As part of this assignment, I taught students how to access the scientific literature using Biological Abstracts On-Line as well as an electronic journal database provided by a consortium of Ohio College and University libraries. No special instruction was given on how to read a scientific paper beyond a general introduction to the structure of a scientific paper.

MODULE 1: Is the climate changing?

The introductory activity for this module was a screening of "An Inconvenient Truth" that takes place during the very first lab of the semester. Students were asked to note any questions on the science they had while watching the film, as well as any issues or topics (scientific, political, or ethical) that were brought up in the film that they would like to know more about. These observations were then used to guide the content of the rest of the module.

For this module I mostly lectured on the scientific underpinnings of global climate change, including lectures on the history of the Earth's climate and determinants of climate on Earth, as well as details about the evidence for and potential causes of global climate change. In addition, I assigned topics related to the economic, social/ethical, and political considerations of global climate change to small groups of students (usually 2 or 3). For example, a group assigned the social/ethical consideration was given the question "From a societal standpoint, what might be some acceptable solutions to global climate change? Are these solutions personal or collective?", and a group assigned the political consideration was given the question "What are the arguments of each side of the ‚global warming debate'? What are the primary points of tension and disagreement? (focus on USA)." Each group then investigated the question(s) they were assigned and developed a presentation (5 to 10 minutes) that they gave to the rest of the class. I provided time in lab for them to work on gathering their information, primarily from web resources.

Laboratories in this module consisted of a critical evaluation of pro and con websites related to climate change. The initial lab had pairs of students find and evaluate websites from both sides of the climate change debate. I began the lab by discussing what characteristics can be used to determine the quality of a website (i.e., is it a credible source?). At the end of the lab students presented their critiques of the two websites, explaining to their peers how credible the websites are. One particular benefit of this exercise was that these websites could be used by students later in the module as they investigated the "Other Considerations" assignment (see above).

Students were given an assignment to write a brief report to the President outlining the evidence related to global climate change, and based upon this evidence, provide their perspective on what should be done, if anything, to address global climate change. Because FYS102 is supposed to help improve Denison students' writing skills, this and all other writing assignments described below were graded for both content and composition (i.e., grammar, organization, writing style, etc.).

MODULE 2: Can the human population grow indefinitely?

During the first lecture period for this module, students completed an exercise on von Foerster et al. (1960) based on exercise created by Biology faculty at Earlham College that has students read excerpts and a summary of von Foerster et al.'s (1960) main assumptions, model, and conclusions. Based on population estimates available at the time the paper was written, von Foerster et al. (1960) predicted a "doomsday" in the near future when the human population would instantaneously double. In this exercise, students used up-to-date estimates of the human population (http://www.census.gov/ipc/www/idb/worldpopinfo.php) to compare observed human population growth to predicted growth, prompting discussions about what controls human population growth, as well as what can be done to slow human population growth.

I used lecture and worksheets to introduce students to basic population growth models, the concept of carrying capacity, and the use of life table calculations to determine population growth rates (see Appendix I for an example of a worksheet used in this class). Small groups of students (pairs or threes) also answered questions related to human population growth and carrying capacity using their textbooks. Questions included "What determines the carrying capacity for humans? Has this changed over human history?" and "What are some factors that might limit the increase of the human population? In other words how might we change/lower r or R_o?". These questions were designed to allow students to consider the ecological basis for human population growth and relate this to the social, cultural, political, and religious aspects of trying to control human population growth. Answers were discussed as a class.

The laboratories for this module included computer simulations using *Populus* (Alstad, 2001), and a cemetery demography exercise (Beiswenger, 1992). In lab, we used computer simulations in the program *Populus* to reinforce lecture material on population growth models (particularly the concepts of r and K). The cemetery demography lab used birth and death dates collected from a local cemetery dating back to the early 1800's. Students then used these birth and death dates to calculate survivorship curves for two periods in early Granville history. Comparisons of these two periods, as well as comparison with dates from a cemetery in South Carolina from the first half of the 19th Century (data provided in Beiswenger, 1992), made students think about how human demography and survivorship trends have changed over time, and the factors that may be influencing such trends.

For the writing assignment for this module, students were tasked with using the information on population growth, and in particular human population growth, to write an update to von Foerster et al. (1960). They had to evaluate the arguments of the article in light of the new data, determine if human population growth should be controlled, and make recommendations on how to limit human population growth.

MODULE 3: Can exploitation of natural resources be sustainable?

To introduce this module, students read and discussed Zabel et al. (2003), a secondary article that examines how fisheries can influence marine communities. In particular the article considers the relative merits of maximum sustainable yield and ecologically sustainable yield. Students were asked to read the article before coming to class, and generate a list of questions about the article. During class, small groups of students (threes or fours) were asked to answer questions about Zabel et al. (2003), followed by a discussion of these questions as a class.

As with the other modules, I lectured on the ecological background for the module. I used a worksheet to reinforce the students' understanding of ecological efficiencies. I used small groups to explore questions about the broader considerations of fisheries and the exploitation of natural resources. For example, students were asked to consider the "Tragedy of the Commons", the consequences of subsidies and natural fluctuations in fish stocks for the sustainability of fisheries, and possible solutions to allow for more sustainable exploitation of the fisheries. In addition, small groups designed a sustainable fishery and presented their designs to the rest of the class.

To reinforce the concept of keystone species one of the labs used in this module was the keystone predator simulation in Ecobeaker (Meir, 1996) that recreates the classic removal experiments of Paine (1966) by manipulating the presence and absence of species in the rocky intertidal community and seeing how the manipulations affect the community. A second lab used the EDM simulation of fisheries from the collection of software found in BioQuest. This simulation allowed students to explore energy flow through a pond, and along the way students examined the limits to harvesting fish, reinforcing the concepts of sustainability and the link to other ecosystem parameters, such as ecological efficiency.

For the writing assignment, students wrote short answers to questions arising from Zabel et al. (2003) that students brought to class after reading the paper. Students were required to answer two questions, each chosen from one of two sets of questions. One set of questions contained student-generated questions about the science in Zabel et al. (2003) (e.g., "If the ecosystem can already by altered at the turn of a dime by natural occurrences, is adding a fishery that bad?"). The other set of questions covered the conservation or sustainability issues raised by the article (e.g., "Compare and contrast „maximum sustainable yield' and „ecologically sustainable yield'. What are some advantages and disadvantages of these approaches to fisheries?").

MODULE 4: How can the forests of Madagascar be saved?

In both iterations of the course, the first class period of this module consisted of a screening of the video "Islands of Ghosts", a video that explores the natural diversity of Madagascar and also considers the challenges this diversity faces, including issues of an economic, cultural, and spiritual nature that might affect the ability to conserve Madagascar's biodiversity. Students were asked to note any questions or issues that the video raised. In the second iteration, I also invited Dr. Richard Lehtinen of the College of Wooster to give a guest lecture about Madagascar and his research on amphibians in Madagascar. His lecture provided background about habitat fragmentation, amphibians, as well as cultural factors that might affect the conservation of Madagascar's forests.

Following the video and guest lecture, students answered questions, using their textbook, on the science issues raised by the video compiled from those students generated while watching the video. As part of this exercise, students created a reserve design for Madagascar. As with the basic science material, I used a series of student-generated questions that focused on the socioeconomic, cultural, and political aspects of conservation on Madagascar to prompt small-group discussion, followed by class-wide discussion.

For this module, as well as the final module, the lab periods were devoted to performing a study of the diversity of the Denison University Biological Reserve. Students worked in small groups (3 or 4 students) to design their study, collect and analyze their data, and present their results in written and oral form. Each group designed their survey to compare the biodiversity of a taxonomic or ecological group (e.g., macroinvertebrates, plants, insects, fish, etc.) between two or more habitats (e.g., pools vs. riffles in a stream, upland vs. lowland woods, pine plantation vs. deciduous woods, etc.). Students designed their studies in consultation with me after getting a tour of the Biological Reserve and suggestions about possible habitats and organisms to study. As part of the design process, I discussed with the students the appropriate survey techniques to use, such as quadrat sampling, pitfall trapping, transect sampling. Based on this discussion, I provided students with the necessary field equipment. Students were given two lab periods to conduct their study, and one lab period to analyze their results statistically. During the field lab periods my TA and I circulated among the groups and helped them get started or trouble shoot any problems with their original design. Students then wrote a scientific paper and gave a 15 minute presentation of their study to the class.

For this module students wrote a plan to save Madagascar's forest. Their plan had to be based upon the scientific material they learned about park design and habitat fragmentation. However, they also had to explicitly consider the many other considerations that would impact the ability to create such as system. For example, they had to incorporate Malagasy cultural and spritual norms into their plan, as well as include economic factors (e.g., providing jobs and resources for the Malagasy who use the forests for subsistence).

MODULE 5: What is biodiversity worth?

The first lecture period revisited each of the previous modules and determined the potential economic considerations that each raised. This list formed the basis for thinking about environmental economics.

While most of this module was dedicated to traditional and environmental economics, I lectured on how to measure diversity and how diversity is distributed around the globe. The measures of diversity were also used in the group survey projects. Much of this module was devoted to understanding the basics of economics, starting with a small group exercise in which students answered questions about the principles of traditional and environmental economics. I then expanded on these topics in lecture. The module culminated with a discussion of sustainable economies.

Labs in this module were a continuation of the small group field project surveying biodiversity on the Denison University Biological Reserve outlined in Module 4.Students turned in the write-up of their survey project as the writing assignment for this module. I gave students guidelines on how to write a paper in the format of a scientific paper, and students had to use primary literature in the writing of their paper.

Throughout the semester, students were assessed using a variety of assignments and exams. I gave two 1-hour long exams (at the end of the 2nd and 4th modules) that were each worth 10% of the semester grade. A cumulative final exam accounted for 15% of the semester grade. Module specific writing assignments were weighted equally and together accounted for 25% of the semester grade. The first draft of the media critique assignment was worth 5% of the semester grade, and the second draft 7.5%. The group project paper was worth 10% of the semester grade. Miscellaneous lab and lecture assignments (e.g., worksheets, computer simulation assignments, in-class presentations, etc.) accounted for 10% of the semester grade. Class participation in both lab and lecture was worth 7.5%.

Students generally responded positively to both iterations of the course, with high quantitative ratings. In addition, several students commented qualitatively about the course (see Table 2). Several noted that the course was applicable to their real lives. Other students commented on how they liked the structure of the class. Finally, some student comments clearly suggested that this module approach was effective at teaching ecological topics.

Table 2. Qualitative responses of students to the course.

General Category of Response	Student Responses
Applicability to real life	"with the topics about global warming this class interested me because it seemed to have a topic which is hot now, about humans and their living in the environment." "course material was relatable to current times, easy to understand, informative" "information relevant to everyday life"
Structure of class	"I enjoyed the research at the bio reserve. It got us out of the classroom and made us apply what we have learned." "It was very interesting and something I would not normally take. I liked the structure of the class and the fact that we did a lot of group activities."
Effectiveness of course	"I actually learned more about ecology in this class than in Biology 202 (Ecology and Evolution)."

This module-based approach works well as it places abstract ecological principles in concrete and relevant contexts (see Swinehart and Mort, 1995, for a similar rationale for including environmental problems in chemistry curricula, and Swan and Spiro, 1995, for including environmental issues in teaching chemistry to non-science majors). The module approach can be tailored to address global or local environmental issues. For example, the next time I teach this course, I plan to replace some of the "global" modules with "local" modules (e.g., deer populations, invasive species). Such local modules will allow more hands-on data collection rather than computer simulations. In addition, such a module approach can be used to teach other biological subjects. For example, a course centered on bioethics or medical ethics could provide several modules focused on teaching cellular or molecular biology. One module could address the issue of genetically screening of embryos or individuals for genetic diseases. Lectures could consider basic molecular genetics, and labs could focus on techniques related to screening for genetic diseases. In addition, a "module" on natural selection could be used where students read a recent primary or popular article detailing antibiotic resistance in bacteria. Labs can experimentally demonstrate the evolution of antibiotic resistance (e.g., Krist and Showski, 2007).

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References

ALSTAD, D. 2001. *Basic* Populus *Models of Ecology*. Prentice Hall, Upper Saddle River, NJ.

BATTLES, D.A., FRANKS, M.E., MORRISON-SHETLAR, A.I., ORVIS, J.N., RICH, F.J., AND T.J. DEAL. 2003. Environmental literacy for all students: Evaluation of environmental science courses developed for a new core curriculum. *J. Coll. Sci. Teach.* 32: 458-465.

BEISWENGER, J.M., ed. 1992. *Experiments to Teach Ecology*. Ecological Society of America, Washington, D.C.

BIXBY, J.A., CARPENTER, J.R., JERMAN, P.L., AND B.C. COULL. 2003. Ecology on campus: Service learning in introductory environmental courses. *J. Coll. Sci. Teach.* 32: 327-332.

GILL, R.A. AND I.C. BURKE. 1999. Using an environmental science course to promote scientific literacy: Expanding critical thinking skills beyond the environmental sciences. *J. Coll. Sci. Teach.* 29: 105-111.

KELLER, G.E. III. 2002. Using problem-based and active learning in an interdisciplinary science course for non-science majors. *J. Gen. Educ*. 51: 272-281.

KRIST, A.C. AND S.A. SHOWSKI. 2007. Experimental evolution of antibiotic resistance in bacteria. *Am. Biol. Teach.* 69: 94-97.

MEIR, E. 1996. *EcoBeaker 1.0: An Ecological Simulation Program*. Sinauer Associates Inc., Sunderland, MA.

PAINE, R.T. 1966. Food web complexity and species diversity. *Am. Nat.* 100: 65-75.

PALLANT, E. 1996. Assessment and evaluation of environmental problems: Teaching students to think for themselves. *J. Coll. Sci. Teach.* 26: 167-172.

SWAN, J.A. AND T.G. SPIRO. 1995. Context in chemistry: Integrating environmental chemistry with the chemistry curriculum. *J. Chem. Educ*. 72: 967-970.

SWINEHART, J.H. AND G. MORT. 1995. Bringing environmental problems into the science classroom. *J. Coll. Sci. Teach.* 25: 58-61.

TESSIER, J. 2006. Writing assignments in a nonmajor introductory ecology class. *J. Coll. Sci. Teach.* 35: 25-29.

VON FOERSTER, H., MORA, P.M, AND L.W. AMIOT. 1960. Doomsday: Friday, 13 November, A.D. 2026. *Science* 132:1291-1295.

ZABEL, R.W., HARVEY, C.J., KATZ, S.L., GOOD, T.P., AND P.S. LEVIN. 2003. Ecologically sustainable yield. *Am. Sci*. 91: 150-157.

APPENDIX I: Example of a worksheet used to help teach population equations and life table calculations. Additional worksheets used for teaching are available by contacting the author.

LIFE TABLES AND POPULATION GROWTH WORKSHEET

1. Complete the following life table (#1) by calculating the values of l_x, and $l_x m_x$.

x (yr)	n_x	l_x	m_x	$l_x m_x$
1	1000	_____	0	_____
2	500	_____	2	_____
3	250	_____	3	_____
4	125	_____	0	_____
5	0	_____	0	_____

a. At what age (year) do females of this species start reproducing? _____

b. What proportion of the females survive to age 3? _____

c. At what age do females make their greatest contribution to the net reproductive rate? _____

d. What is the value of R_o for this population? _____

e. Is this population increasing or decreasing? _____

f. What will the population size be in two generations (assume N_o = 100)? _____

2. Consider the following life table (#2). Calculate the values of n_x, and $l_x m_x$.

x (yr)	n_x	l_x	m_x	$l_x m_x$
1	1000	1.0	0	_____
2	_____	0.1	5	_____
3	_____	0.08	2	_____
4	_____	0.07	2	_____
5	_____	0.06	2	_____
6	_____	0	0	_____

a. At what age do females make their greatest contribution to the net reproductive rate? _____

b. At what ages do females reproduce? from age _____ to _____

c. What is the value of R_o for this population? _____

d. Is this population increasing or decreasing? _____

3. Consider the following life table (#3). Calculate the values of l_x, and $l_x m_x$.

x (yr)	n_x	l_x	m_x	l_xm_x
1	1000	_____	0	_____
2	900	_____	0	_____
3	800	_____	0	_____
4	750	_____	2	_____
5	150	_____	2	_____
6	0	_____	0	_____

a. At what age do females make their greatest contribution to the net reproductive rate? _____

b. At what ages do females reproduce? from age _____ to age _____

c. What is the value of R_o for this population? _____

d. Is this population increasing or decreasing? _____

4. Which life table shows a population with a survivorship curve closest to a Type I curve? _____. Which life table shows a population with a survivorship curve closest to a Type 3 curve? _____

5. Explain: How can it be that in Life Table 2 females breed for so many years and in one year each produced 5 young yet that population is decreasing compared to the one in Life Table 3 with females only breeding in two years and never having more than 2 young per year?

6. If you had two management options for the population in Life Table 2, but could only implement one of them because of the lack of funds, which would you choose and why? Assume you want to make the population increase as much as possible.

a. One that doubles the number of individuals surviving to age 2 but doesn't change the number surviving to age 3.

b. One that increases the age-specific fecundity of 2 year olds to 6 from 5.

Editorial

This is my last issue as *Bioscene*'s editor. I've been doing this since 2005. Like a lot of worthwhile things in life, it has been both simultaneously fun and challenging. The fun involved reading manuscripts and getting novel and exciting ideas about teaching biology. The challenging involved actually putting together the issues in a timely fashion so that they looked somewhat competent. This pressure was relieved a bit when budget issues forced us to trim the publication from quarterly to two times a year. But dealing with computer codes, formatting, and large numbers of authors without staff support made for some rotten weekends in front of the computer (altogether now: BOO-HOO!).

The new editor of *Bioscene* will be Jim Clack from the Department of Biology at Indiana University. Jim is a long-time reviewer for our journal and is extremely tech-savvy. It should be a smooth transition. Nevertheless, I feel it is incumbent upon me to share some of the wisdom I've accumulated these past five years. I've reduced this to the following six points:

1. **Maintain and work closely with the chair of the editorial board.** This position is crucial. When I took over as editor, I did both the editing and the editorial board management. It was tough because manuscripts are constantly streaming in and I felt it was my duty to get them out to reviewers and back in a timely fashion. I would like to take this opportunity to thank Janice Bonner for taking on this task. She has been a terrific asset and I hope when her term expires, an equally able member assumes that position.

2. **Keep authors informed of manuscripts' progress from submission to publication.** I'm aware that this has been a source of frustration to many. The turnaround time from submission to publication can be over a year. Many of our authors are pre-tenured and need publications for tenure packets. Some type of notice by the editorial staff, however brief, would be always be appreciated.