TIEE

Teaching Issues and Experiments in Ecology - Volume 5, July 2007

RESEARCH

Evaluating the impact of *TIEE* activities on student learning: lessons for the instructor.

Jaclyn Schnurr
Biological and Chemical Sciences
Wells College
Aurora, New York 13026
jschnurr@wells.edu

ABSTRACT

As part of a larger research study on the effectiveness of *Teaching Issues and Experiments in Ecology (TIEE)* on student learning, I assessed the use of *TIEE* activities to increase student ability to use scientific methodology in conducting ecological studies, as well as to increase understanding of basic ecological concepts. To do so I used note card activities to gain more insight into student misconceptions, plus *TIEE* exercises, such as turn-to-your-neighbor and jigsaw activities during lecture and experiments in lab, to engage students. This study was conducted in Fall 2005 with 18 students in a sophomore level ecology course at Wells College, NY. Although students performed similarly on an 8 item instructor developed pre- and post-test (t=-1.21, P= 0.23), there were some qualitative improvements on open- answer questions. In the post test, 72% of the students had a better answer for “What is ecology?” and 33% had a better explanation for “What is science?”. Similarly, 43% were better able to create and interpret a graph, and 33% could better detect a flaw in experimental design. Using responses from final reflective essays, 58% of students volunteered that outdoor labs (mainly using *TIEE* experiments) were the most effective part of the course. However, I believe that the real value of this study was using the *TIEE* activities, which gave me confidence to utilize new teaching methods in the classroom.

Keywords: student active learning, *Teaching Issues and Experiments in Ecology (TIEE),* reflective essays, ecology education

INTRODUCTION

Although the importance of active learning is well known, many educators have not yet incorporated it into their classrooms (Sherman 1985, Mattingly 1997, Alters and Nelson 2002). The reasons for this are many, but the one most cited is that more information is conveyed in a shorter time by using traditional lectures to cover the material (Terenzini 1999). Although that may be true, the aim of teaching is to have students learn the material, and traditional 50-minute lecture periods where the students passively write down what the instructor says may not be an effective teaching method for most students. Instead, there is evidence that students learn more when they become actively involved in their education (McNeal and D'Avanzo 1997, Terenzini 1999), either in cooperative learning situations, where students work in small groups to learn a concept or to answer a posed question (Spurlin *et al.* 1984, Ebert-May *et al.* 1997, Terenzini 1999), or in other active-learning scenarios, where the students can pose and answer a question with guidance from the teacher (McNeal and D'Avanzo 1997, Terenzini 1999).

Teaching Investigations and Experiments in Ecology (*TIEE*) activities help educators incorporate student active learning into their lectures and labs with support from other active learning practitioners (D'Avanzo *et al.*, 2006). Included in each volume are peer-reviewed figure sets, data activities, issues and directed experiments designed to help instructors begin to use active techniques in their classroom with some guidance and expected outcomes. This allows the instructor to try something new with the confidence that it will lead to successful student learning.

This preliminary study was conducted to determine if *TIEE* activities provide a viable link between traditional-style lectures and "cook-book" laboratory exercises and active student-based inquiry to facilitate student learning. I used *TIEE* activities to meet several learning objectives for both the student and me as instructor. Instructor goals were first, to develop the role of student input for planning lectures and lecture activities, and second, to develop the use of student-centered activities during lecture and laboratory classes. Before undertaking this study I had not used any active-learning techniques in the classroom – I was the "sage on the stage." Under the guise of doing research for this study, I felt I had the freedom to try new techniques in the classroom. One of these was to ask, before covering a topic, about student background knowledge and misconceptions to better structure my lectures. Student-centered objectives were: 1) to increase understanding of basic ecological concepts by using active learning, and 2) to increase the ability to use the scientific method to answer

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ecological questions. The student objectives are very similar to my learning outcomes for the course in general (see Syllabus in Resources) so that by addressing the student objectives for this study I was also meeting the basic objectives for the course.

METHODS

I conducted this preliminary study in Fall 2005 at Wells College, a small (~450 students) liberal arts college located in the Finger Lakes region of New York State. Wells College was historically an all women's college, but in Fall 2005 began to admit men. The class that I chose for the study was Biology 213: Ecology and Evolution, a required 3 lecture hour/ 3 hour lab course for all students in the Biological and Chemical Sciences major. During this semester there were initially19 female students in the class (one dropped the class for personal reasons). I only taught this course for one year as a sabbatical replacement, and I inherited the textbook for the course, which was *Ecology: Applications and Concepts* (Molles, 2002), supplemented only by *TIEE* materials.

At the start of the course, I gave the students an eight-item, instructor-created pre-test to gain insight into their background knowledge about the course (See Pre/post test in Resources). I chose 5 very general multiple-choice questions, from past materials I had used in classes, and 3 open-ended short answer questions, so that the students would have to write their answers and develop their thoughts before even starting the course, to assess the background knowledge that the students had about Ecology. In order to maintain student anonymity the students created a code name to identify their tests. At the finish of the course, I gave the students the same test as a post- test along with a list of the code names that they used to help them remember their name. This way I was able to utilize paired t-tests upon completion of the course to assess student learning with the eight-question test. Unfortunately, the use of code names did not allow me to correlate the final course grades with the results of the pre- and post- test.

I created "Ecology Fun Days" where we used a *TIEE* figure set "What are the impacts of introduced species?" *TIEE* Volume 1, Figure sets 1, 2, 5 (D'Avanzo and Musante, 2004), and the *TIEE* data set "Energy Balance and Trophic Status in Fish" (D'Avanzo, 2004) as lecture activities. I chose this figure set mainly because it started with simple activities, such as reading charts and graphs, and became more complex as the students completed more activities. By the time we got to the more complex figure set 5 (Gypsy moth invasion and links to outbreaks of Lyme disease), the students understood the importance of collaboration and thinking through each task. The data set allowed the students to gain familiarity with excel and making and interpreting graphs. By putting these days on my syllabus, I was able to stick to them and not use the excuse of having insufficient time.

Throughout the course, usually once a week to get ongoing feedback, I gave students note cards at the end of a class session with specific questions. I used this assessment approach at the beginning and end of sections of the textbook, when introducing difficult concepts, to reinforce topics covered during lecture, and to identify student misconceptions. For example, I asked students to answer questions such as: “What did we talk about today?”, or “Tell me the main ideas behind (major concept here)”, or “How does temperature relate to species distributions?”, and my favorite, “Why are we talking about both ecology and evolution in this course?” I also used the note cards to ‘check in’ with the students - I asked if there were any major problems with the way the course was going, or if the exam was fair, or what I could do to help their learning. I asked students to answer questions anonymously, so that they were honest in their answers. The following lecture I would discuss what they said on the cards. Further discussion of the concept would often follow because other students had questions as well.

I also used several *TIEE* experiments in lab, namely Effects of Eastern Hemlock on the establishment of interspecific seedlings, *TIEE* Volume 1 (Murray and Winnett-Murray, 2004), and Life under your feet: measuring soil invertebrate diversity, *TIEE* Volume 3 (Boyce, 2005). Because the labs are available as freeware by downloading, I mainly followed the lab activities as written.

I made use of standard assessment measures, such as two exams plus the final comprehensive exam, a reflective essay at the end of the course (see Reflective Essay in Resources), and several other lab activities, to calculate a final grade for each student..

RESULTS

Students did equally well on the lab and the lecture (Figure 1; $t=0.235$, $P=0.81$). The final average for the course was 83.5%, with a standard deviation of 9%. The grades ranged from 63-96%.

Students scored similarly on the multiple-choice portion of the pre- and post-test ($t=-1.24$, $P=0.23$). However, qualitative comparison of responses to the written questions showed that 72 % of students finished the course with more knowledge of “What is ecology?” (see Pre/post test question 6 in Resources; Figure 2A), 33 % of students finished the course with more knowledge of “What is science?” (see Pre/post test question 7 in Resources; Figure 2B), 45 % of students finished the course with more knowledge of graphing and 33 % of students finished the course with more knowledge of experimental design (see Pre/post test question 8 in Resources; Figures 2C and 2D). Table 1 gives the pre- and post- test responses to the “What is ecology?” and the “What is science?” questions, as well as my qualitative ranking of “better” or “same”. No student had a worse answer for these 2 questions on the post-test.

The final reflective essays yielded meaningful results to understand how students learned during the course. Students varied in what they learned most from the course (Table 2), but most students said that they learned more from labs than the lectures. Although 56% of the students mentioned the general category of ‘field studies’ as the most effective portion of the course, the *TIEE* activity, *Effects of Eastern Hemlock on the establishment of interspecific seedlings* (Murray and Winnett-Murray, 2004) was named most frequently as being the most effective field experiment (27%). Students stated that the hemlock lab was valuable because: “It was good to design experiments somewhat independently and do something resembling original research…”; “ …I do enjoy designing experiments, which made the hemlock lab one of my favorites.”; “I especially enjoyed the hemlock lab because it was a study that ecologists are still not sure about so it was cool knowing that we could potentially discover something.”; and “At first we had to go out and make observations, return a week later to collect samples, and then do some research and greenhouse experiments. All of this is enough to make a student feel like a real ecologist for a while.”

I was also able to stick to the five scheduled “Ecology Fun Days” in lecture throughout the semester. Although most students did not find them as effective as I hoped (Table 2), others stated that they were a valuable part of the course.

DISCUSSION

Overall, *TIEE* activities helped me to incorporate more student-centered activities in both the lecture and lab of a sophomore-level majors Ecology class. Students increased their understanding of what ecology is, based on posttest responses. In addition, by using the *TIEE* Hemlock activity, students were better able to utilize the scientific method to answer a question they posed. Similarly, I was able to incorporate more student active techniques, such as the use of note cards to tailor lectures based on student misconceptions and discussion based on the *TIEE* figure sets to teach important ecological concepts, while still reaching the learning outcomes I had set for this course. Thus, I met the objectives of this study, although the data is limited in showing the effectiveness of *TIEE* activities on student learning.

Research in learning theory has demonstrated that constructivist learning, or actively participating in gaining knowledge and building on past experiences, is how most students learn (D’Avanzo 2003a). Because of this, misconceptions that students have learned in previous courses can greatly influence the amount of knowledge they gain in a course (D’Avanzo 2003a). By addressing these misconceptions, instructors can help students advance in their learning. During this course, I made use of note cards to ask about student misconceptions, and we discussed their answers before starting a new topic. Addressing their prior thinking about a subject allowed students to question their ‘knowledge’ about a topic – causing them to think about why they thought what they did, and hopefully increasing their ability to think critically about what they ‘know’ (D’Avanzo 2003a, D’Avanzo 2003b).

PRACTITIONER REFLECTIONS

Educational research is necessary to elucidate pedagological methods that lead to greater student learning, and recently more instructors are becoming interested in researching the effect of their teaching methods on student learning (Alters and Nelson 2002). Many of us are trained as quantitative scientists, and lack knowledge of many of the qualitative methods that will be useful to determine changes in student comprehension. This leads to interesting studies that have limited replication and thus, limited generality. This study falls under that category: it was conducted for one semester, with only eighteen students, and due to the use of anonymous code names, I cannot even trace individual student results. However, the value of this study was more for my own benefit: I gained confidence in utilizing active-learning in a traditional lecture course, and because of this study, I continue to use those methods in other courses.

Researchers have been publishing the results of active learning studies in journals such as *Higher Education*, and *Journal of Higher Education*; however, most of us are just beginning to incorporate these methods into our courses. Using *TIEE* activities, I was able to draw on materials implemented successfully in other courses, with notes from the author that helped explain unknown

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concepts. For example, "think-pair-share" and "jigsaw" activities (D'Avanzo and Musante, 2004) allowed me to visualize the activity before using it in class. When I did use it in class, the instructor notes were helpful enough for me to feel prepared – even though it was a completely new experience for both the students and me. One student said in the reflective essay at the end of the semester: "I was surprised to find that I enjoyed the ecology fun days on zebra mussels and gypsy moths. Mainly I attribute this to the surprisingly cooperative and interested attitude of fellow students... Besides learning some basic things about both case studies it was a good experience in practicing ecological logic."

This course did increase student learning about ecology and the process of science. Students were better able to answer scientific questions and make conclusions based on data at the end of the course. However, the limited data does not allow me to conclude that these improvements were due to the use of *TIEE* activities. The reflective essays do allow me to make some conclusions. In the words of one student: "Overall, I feel like I was much more interested in the labs this semester and thought about them in the context of 'real life' a lot more in comparison to the labs that were done solely in the lab in previous courses." Not only does being an active participant in their education help students succeed in a particular course, it allows them to see the interconnectedness of their courses – indicating that they are, in fact, learning (Terenzini 1999). At least one student in this ecology course made that connection: "Accepting a learning opportunity in one discipline may help you understand certain concepts in another." Finally, becoming active in their own education may allow a student to learn much more than we, the instructors, expect: "Learning that it is not only the professor's job to make me understand the material was also a big step in my road as a student. I became aware that while the professor is there to teach me and help me understand it is also essential for me to read and make an effort to understand the material because I am the only one responsible for my learning….What we learn in school is not only to pass an exam but to help grow as intellectuals and be more productive in making the world a better place."

Participating in the *TIEE* study has allowed me to expand my use of student-active techniques in my courses. In all courses that I teach, I now use note cards frequently to keep communication open with the students. Most recently I asked a freshmen Biology course to explain on note cards why they did poorly on their first exam (the average was a 68). Although I was nervous to read their answers, I was shocked to learn that most viewed the exam as fair, and they realized that the problem was with their lack of studying. This self-reflection on their part will hopefully allow them to perform better on future exams. Before participating in this *TIEE* study, I never would have considered asking the students how things were going in the course, and now that I see the value in it, I can not imagine not asking the students how their learning is progressing in my courses.

ACKNOWLEDGEMENTS

I would like to thank the Wells College biology students, especially those in the Fall 2005 Biol 213: Ecology and Evolution course, and my undergraduate teaching assistant Krystle Bouchard. The manuscript was much improved by comments by 2 anonymous reviewers, Charlene D'Avanzo, and Jennifer Riem. *TIEE* is supported through several grants from the National Science Foundation (DUE 0127388, DUE 0443714, and DUE 9952347.)

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Table 1. Student answers to the pre – and post- test questions (see Pre/post test in Resources). A) "What is Ecology?" (question 6) and B) "What is Science?" (question 7) as well as my subjective scoring of "better" or "same". Student numbers in both A and B refer to the same student.

A. What is Ecology?

Student Number	Pre-Test Answer	Post-Test Answer	Subjective grading
1	The study of the environment and how it changes/adapts	The study of environments and organisms and how they affect each other	Better
2	Ecology is the study of organisms and their environment, how they interact and how one may affect the other	Ecology is the study of organisms and environments and their interactions	Same
3	The study of the ecosystem	Ecology is the relationship between organisms and their environment. It is the interactions that occur between the 2 and with each one.	Better
4	The study of an environment and its inhabitants	The study of organisms and their interactions within the environment	Better
5	Ecology is the study of how species, both plant and animal, interact	Ecology is the study of the interactions of species and their environments	Better
6	The study of the way organisms interact in their environments	Study of organism/ecosystem interactions	Same
7	Seeing how the organisms and the environment in which they live interact – relationships between organisms and organisms and the environment	The biotic and abiotic variables in a system and all their complex relationships/influences on each other and the environment	Better
8	The study of biotic and abiotic conditions on earth	The study of abiotic vs. biotic factors in an environment	Same

9	Study of the environment	The study of interactions between organisms and their environment	Better
10	The study of the ecosystem and environment	The study of our environment(s) and the interactions found within the biomes that characterize different communities	Better
11	Study of the environment and relationships between environment and species	The study of interactions between populations, animals, and the environment and how species survive	Better
12	The study of how organisms interact	The study of living things and how they interact with their environment	Better
13	The study of differing environments and how they interact with each other	The study of animals/organisms and their interactions in the environment	Better
14	The study of organisms interacting with the environment	The study of natural environments and their populations	Same
15	Ecology is the study of natural systems and how various parts of those systems interact	Ecology is the study of how living things interact with each other and the environment	Same
16	Ecology is a science of the environment	Study of the environment and animals in it and how they interact	Better
17	Ecology is the study of plants and the environment	Ecology is the study of organisms and their environments	Better
18	Ecology is studying the environment, and ecologists study the factors that influence the environment	The study of the relationships between organisms and the environment	Better

B. What is Science?

Student Number	Pre-Test Answer	Post-Test Answer	Subjective Grading
1	none	A way of asking a question or study	Better
2	Science is the how and why and pretty much everything… don't forget the why not part…. That's a big one	A way of knowing and a way to learn/discover new things	Better
3	Science is based on facts, data, observations, etc.	Science is data and information that was collected, obtained, etc.	Same
4	none	Obtaining knowledge and the study of things around/within us	Better
5	Science is anything relating to technology, life, mathematics, etc.	Science is a collection of fields of study which rely on evidence based facts	Same
6	An attempt to understand and explain how the world works according to physical laws	A method of obtaining knowledge by observation and testing hypotheses	Better
7	Critical look at the world – use of scientific method to try to make sense of nature/math/universe	An objective, logical inquiry into life and all its components using the scientific method: observe, hypothesize, predict, test, decipher	Same
8	Science is a form of learning how things work, using educated guesses and confirmations resulting from experiments	Science is using hypotheses and experimental data to try to account for various life activities	Same
9	All sciences use the scientific method. Sciences find out the mechanisms of how nature works and prove hypotheses	Testing of hypotheses and exploring the world	Same
10	A way of thinking that promotes educated guesses about how to explain unknown ideas	A way of asking/answering questions that we have no explanation for	Same
11	The study of life and	The study of life and	Same

	processes	processes	
12	The study of life	The study of life	Same
13	The study of different parts of life including the functions and other aspects	The study of living and non-living matter and organisms	Same
14	A discipline concerning testable explanations for the world at large	"A way of knowing" thru testable and reproducible theories	Better
15	Science is using observations of the natural world to form conclusions about how it works	Learning through observing the natural world and asking/attempting to answer questions	Same
16	Science is how things function. It's how we explain pretty much everything.	Study of the natural world, pretty much everything (very hard to define)	Same
17	Science is the study of life and all its components	Science is the study of all living things and the world around us	Same
18	Science is the nature in the living world	The study of an organisms' life, based on examining tests and proving facts	Better

Table 2. Percentage of reflective essay responses that mentioned class activities that students believed to be the most and least effective learning experiences (see Reflective essay in Resources).

Activity	***Most effective***	***Least effective***
TIEE: Hemlock	27 %	0
TIEE: Soil	0	17 %
TIEE: Figure Sets	11 %	11 %
General: Field Studies	56 %	5 %
General: Quantitative analyses	0	22 %

FIGURES

Figure 1: Average student grades (percentages of total possible points) on class exams and lectures. Averages were similar between lecture and lab.

Figure 2: Qualitative differences between the pre-and post-tests in answering questions (see Pre/post test in Resources). A. "What is ecology?" (question 6) B. "What is science?" (question 7) C. Students were asked to make a graph (question 8), and D. Students were asked to evaluate an experimental design (question 8).

Figure 1.

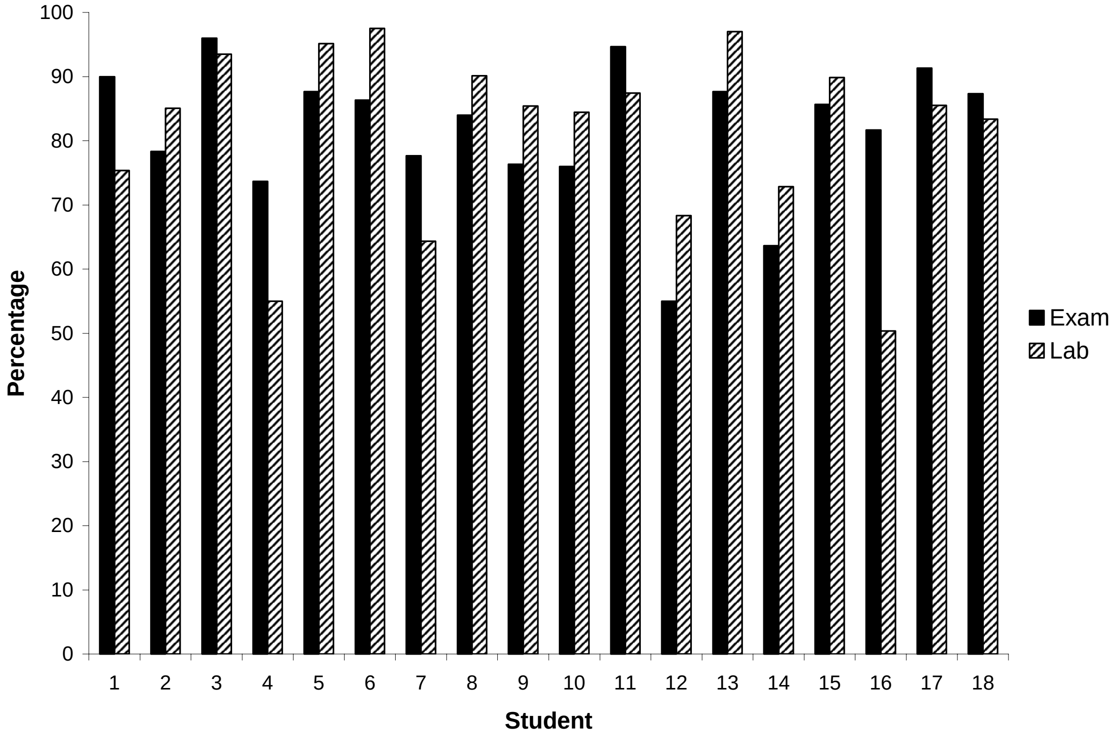
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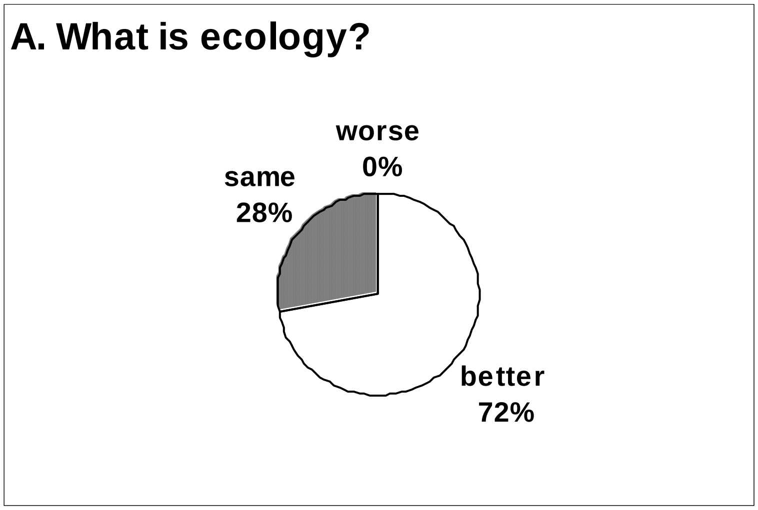
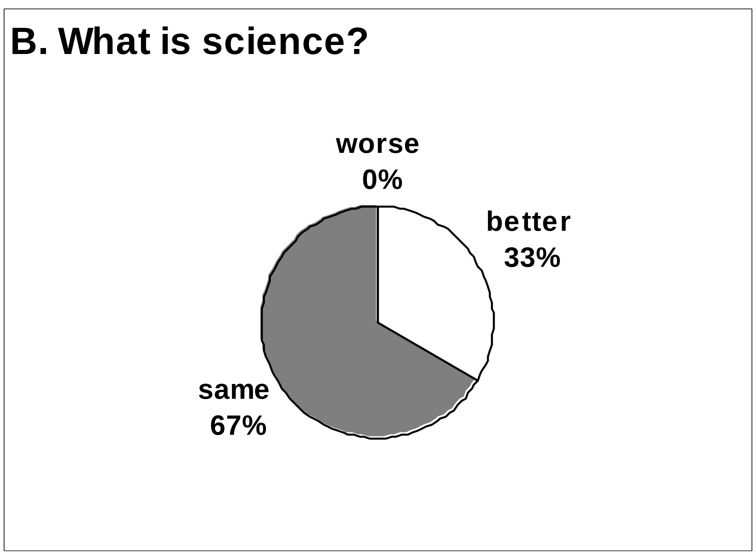
Figure 2.





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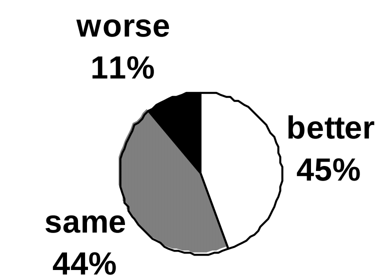
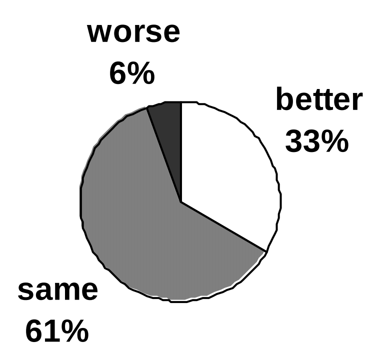
C. graphing skills



D. experimental design skills



RESOURCES

Syllabus
BIOS 213L: Ecology and Evolution Fall 2005

Lecture Times: MWF 10:30 to 11:20, Rm 202 Zabriskie
Lab Time: Monday, 1:30-4:30

Instructor: Dr. Jackie Schnurr - office: 105 Zabriskie
- phone: 364-3274
- AOL screen name: NictinastyJackie
- Email: jschnurr@wells.edu

Office Hours: M,T,W,Th,F 9-10, or whenever I'm in my office!

Text: Manuel C. Molles Jr. 2005. Ecology: Concepts and Applications. McGraw Hill publishers.

I would also like you to buy some 3x5 index cards, which you bring to class each day.

Course Philosophy: This course is designed to give a general overview of the science of Ecology, as well as providing an understanding of the importance of evolution to the understanding of science. Ecology is a hands-on science, and the labs will provide you with a deeper understanding of the research ecologists perform. Because of this, you will be spending several laboratories in the field (dress appropriately!). Also, although field work is the part of Ecology most scientists enjoy the most, Ecologists are also charged with communicating their results to other scientists and the public. Therefore, another large portion of the lab will be writing up your results from the field. The lab and the lectures are designed to give you a general feel for the science of Ecology.

Course Objectives: Upon successful completion of this course, student will be able to:

1. Understand the basic components of the physical environment and describe how they interact to affect the living component of the environment, at multiple scales.

2. Understand basic evolutionary concepts, and why they are central to ecology.
3. Outline basic world climate patterns, and their importance.
4. Outline the pathways energy and nutrients take as they flow through an ecosystem.
5. Describe environmental interactions and behavior at the level of the organism, including homeostasis, acclimation, and developmental response.
6. Describe how species interact, showing how competition, predation, and co-evolution operate to influence the interdependence of species.
7. Describe the concept of the population, including growth and regulators.
8. Describe the concept of the community, giving special attention to biodiversity and its role in community well being.
9. Use the scientific method to formulate and test hypotheses, as well as communicate the results with the greater scientific community.
10. Have a basic understanding of statistics, and be able to construct, read, and interpret graphs!

Grading:

Lecture Exams: 40 %
- Exam 1: 10 %
- Exam 2: 15 %
- Exam 3: 15 %

Final Exam: 15%

Laboratory: 45 %
- Field Write-Ups: 25 %
- Class Assignments: 20%

Exams will consist of multiple choice, short answer, essay and graphical questions.

Labs make up a large portion of your final grade. I will try to have the lab handouts prepared for the Friday lectures so that you can read them prior to lab. All lab write-ups (both papers based on the field research and in class assignments) need to be TYPED.

Lecture Schedule

Dates	**Topic**	**Reading**

August 26	Pre-test and Introduction to Ecology	Ch.1
29	Ecology Fun Day!	Ch.2
31, Sept. 2	Climate and Biomes	Ch.3
Sept. 5, 7	Temperature Relations	Ch 4
9,12	Water Relations	Ch 5
14,16	Energy and Nutrient Relations	Ch.6
19	Ecology Fun Day!	
21	Social Relations	Ch.7
23	**FIRST EXAM**	
26, 28	Population genetics & Nat Sel	Ch.8
30, Oct. 3	Population dist. & abund.	Ch.9
Oct. 5	Ecology Fun Day!	
7, 12	Population Dynamics	Ch.10
10	**FALL BREAK**	
14, 17	Population Growth	Ch.11
19	Life Histories	Ch.12
21	**SECOND EXAM**	
24, 26	Competition	Ch.13
28	Exploitation	Ch.14
31	Ecology Fun Day!	
Nov. 2	Mutualisms	Ch.15
4, 7	Species Abundances & Diversity	Ch.16
9	Species Interactions & Comm. Structure	Ch.17
11	Ecology Fun Day!	
14, 16	Primary Production and Energy Flow	Ch. 18
18	Nutrient Cycling and Retention	Ch. 19
21	**THIRD EXAM**	
22-27	THANKSGIVING BREAK	
28, 30	Sucession and Stability	Ch.20
Dec. 2	Landscape Ecology	Ch.21
5	Geographic Ecology	Ch.22
7	Global Ecology	Ch.23

FINAL EXAM: WEDNESDAY, DECEMBER 14, 7-10 PM

BIOL 213L LAB SCHEDULE

Week of:	**Lab Title**	**Hand-In**

Aug. 29	Intro. to Labs, Library Assign.	
September 5	Learn to use Excel	*Ecology* Assign.
Sept. 12	Floating Classroom?	Excel assignment
Sept. 19	Life under your feet – field	Floating classroom
Sept. 26	Life under your feet - lab	
Oct. 3	Seedling recruitment I	*Life* lab report
Oct. 10	NO LAB – FALL BREAK	
Oct. 17	Seedling recruitment II	*Seedling* proposal
Oct. 24	Seedling recruitment III	
Oct. 31	Tales from the Crypt	*Seedling* lab draft
Nov. 7	TBA	*Tales* assignment
Nov. 14	TBA	
Nov. 21	TBA	*Seedling* paper due
Nov. 27	TBA	
Dec. 5	GROUP PRESENTATIONS	

Resources Pre/post test: The pre- and post-test given to Wells College students on the first and last days of class, Fall 2005. In hindsight the multiple choice questions do not adequately address student learning in this course.

1. A hypothesis:
    a. May be proven by experimental data.
    b. Is a confirmation of events or observations.
    c. May be refuted by experimental data.
    d. All of the above.

2. Ecology and environmentalism differ in that:
    a. Ecologists base their arguments on ethical or moral criteria.
    b. Environmentalists formulate and test hypotheses.
    c. Ecology is a science, environmentalism is a concern.
    d. There is no difference between ecology and environmentalism.

3. Which of the following statements best describes evolution?
    a. Evolution is survival of the fittest.
    b. Evolution is a passive process of losing all the population except those which have the best traits for survival.
    c. Evolution is an active process towards an ideal form.
    d. Evolution increases a population's fitness through time.

4. The general equation for photosynthesis is:
    a. Sunlight + O_2 = CH_2O + CO_2 + H_2O
    b. Sunlight + CO_2 + H_2O = CH_2O
    c. Sunlight + CO_2 + H_2O = CH_2O + O_2
    d. Sunlight + H_2O + O_2 = CH_2O + CO_2

5. Which of the following statements best represents a testable hypothesis?
    a. All striped fish have stripes for camouflage purposes.
    b. Fish stripes have evolved for predator avoidance.
    c. Striped fish are less vulnerable to predators than non-striped fish in sea grass habitats.
    d. Striped fish live in sea grass habitats.

6. What is ecology?

7. What is science?

8. Student A hypothesized that plants obtained their energy from light and student B hypothesized that plants obtained their energy from nutrients in the soil. They set up the following experiment: Each of several groups of plants received different treatments of light and fertilizer. After all the seedlings grew for 21 days, the energy in each group of plants was measured using an instrument called a bomb calorimeter. The treatments and the results of the energy measurements are shown below:

Light Intensity	10	20	30	40	50
Fertilizer (grams)	1	2	3	4	5
Energy content (Kcal)	974	1190	1510	2170	2865

Which of the following would be the best statement about the data from the students' experiment?

a. The data contradict student A's hypothesis but support student B's hypothesis.
b. The data contradict both hypotheses.
c. The data contradict student B's hypothesis but support student A's hypothesis.
d. The data are consistent with both hypotheses.
e. The data show that energy is obtained from both light and fertilizer.

Would you redesign their experiment, and if so, how? If not, why not?

On the back, graph the data in a way that makes sense to you.

Resources – Reflective essay: The reflective essay assignment given to Wells College students during the last lab, Fall 2005.

Final Reflection
As another semester comes to an end, it is a good time to reflect on your experiences and your learning. To summarize your experiences in this course, I would like you to write up a 1-5 page paper about your experiences in this class. It will count as one lab grade, but I am not really grading the content, just if you put effort into it.

It should address three main areas:

1. **Your newly acquired knowledge of ecology.** Think back to when you started this course, think about what you knew about ecology. Describe what you learned and what you'd still like to learn. This section should describe how your ideas about 1 or 2 topics changed as a result of taking this course. Were they topics you misunderstood previously that you feel you understand better now? Were they topics that you felt were not relevant to your life that you are glad you learned more about? How has learning about these topics affected your thinking about ecology or science in general?
2. **Newly acquired knowledge about you as a learner**. This section should describe your experiences as a student in this course. What did you enjoy most about this course and what would you rather forget? Describe at least 2 specific class activities, labs or lectures that you liked and ones you did not like, and why. What advice would you give a student in BIOL 213 next year? What did you do well as a student in this course? What advice will you give yourself as you take on other courses?
3. **Personal reflection**. This section should address your personal experiences in the course. What did you learn about yourself as a person? If you could look at yourself through my eyes, what would you want me to know about your growth as a person, a student and an intellectual over the course of the semester? What grade do you think you deserve and why? Describe one challenge you faced in this course and how you handled it (did you overcome it? How? If not, why not?)