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Stephen S. Daggett  
Avila University

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**Cover images:** Photographs of  
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article *Despotic Ducks* will be in  
an upcoming issue.

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# **Bioscene: Journal of College Biology Teaching**

## **Volume 34 (1) • June 2008**

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- Articles: Laboratory and field studies that work, course and curriculum development, innovative and workable teaching strategies that include some type of evaluation of the approaches, and approaches to teaching some of the ethical, cultural, and historical impacts of biology.
- Reviews: Web site, software, and book reviews
- Information: Technological advice, professional school advice, and funding sources
- Letters to the Editor: Letters should deal with pedagogical issues facing college and university biology educators

II. Preparation of Articles

Submissions can vary in length, but articles should be between 1500 and 4000 words in length. This includes references, but excludes figures. Authors must number all pages and lines of the document in sequence. This includes the abstract, but not figure or table legends. Concision, clarity, and originality are desirable. A complete submission will consist of the following:

A. Cover letter: All submissions should come with a cover letter indicating that the manuscript is being submitted exclusively to *Bioscene* and why it is appropriate for this journal. Authors may also offer graphics from the article as possible cover art.

B. Cover Sheet: Submissions should include a cover sheet that includes the title of the article, the number of words in the manuscript, the corresponding author's name, and all co-authors. Each author's name should be accompanied by complete postal and email addresses, as well as telephone and FAX numbers. Even with hardcopy submissions, email will be the primary method of communication with the editor of *Bioscene*.

C. Abstract: The first page of the manuscript should contain the title of the manuscript, the names of the authors and institutional addresses, a brief abstract (200 words or less) or important points in the manuscript, and keywords in that order.

D. Manuscript Text: The introduction to the manuscript begins on the second page. No subheading is needed for this section. This supply sufficient background for readers to appreciate the work without referring to previously published references dealing with the subject. Citations should be reports of credible scientific or pedagogical research.

The body follows the introduction. It is recommended that it be broken into sections with appropriate subheadings including Materials and Methods, Results, and Discussion. Some flexibility is permitted here depending upon the type of article being submitted.

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A variety of writing styles can be used depending upon the type of article. Active voice is encouraged whenever possible. Past tense is recommended for descriptions of events that occurred in the past such as methods, observations, and data collection. Present tense can be used for your conclusions and accepted facts. Because *Bioscene* has readers from a variety of biological specialties, authors should avoid extremely technical language and define all specialized terms. Also, gimmicks such as capitalization, underlining, italics, or boldface are discouraged. All weights and measures should be recorded in the SI (metric) system.

In- text citations should be done in the following manner:

"...rates varied when fruit flies were reared on media of sugar, tomatoes, and grapes" (Jaenike, 1986).

or

"Ulack (1978) presents alternative conceptual schemes for observations made..."

E. References: References cited within the text should be included alphabetically by the author's last name at the end of the manuscript text with an appropriate subheading. All listed references must be cited in the text and come

from published materials in the literature or the Internet. The following examples indicate *Bioscene's* style format for articles, books, book chapters, and web sites:

#### Articles-

##### Single author:

DEBURH, L.E. 1991. Using *Lemna* to study geometric population growth. *American Biology Teacher* 53(4): 229-32.

##### Multi-authored:

GREEN, H., GOLDBERG, B., SHWARTZ, M., AND D. BROWN. 1968. The synthesis of collagen during the development of *Xenopus laevis*. *Dev. Biol.* 18: 391-400.

#### Books-

BOSSEL, H. 1994. *Modeling and Simulation*. A.K. Peters, London. 504p.

#### Book chapters-

GLASE, J.C. AND M. ZIMMERMAN. 1991. Population ecology: experiments with Protistans. In Beiwenger, J.M. 1993. *Experiments to Teach Ecology*. Ecological Society of America, Washington, D.C. 170p.

#### Web sites-

MCKELVEY, S. 1995. Malthusian Growth Model. Accessed from <http://www.stolaf.edu/people/mckelvey/envision.dir/malthus.html> on 25 Nov 2005.

Note that for references with more than five authors, note the first five authors followed by *et al.*

#### F. Tables

Tables should be submitted as individual electronic files. Placement of tables should be indicated within the body of the manuscript. All tables should be accompanied by a descriptive legend using the following format:

TABLE 1. A comparison of student pre-test and post-test scores in a non-majors' biology class.

#### G. Figures

Figures should be submitted as individual electronic files, either TIFF or BMP. Placement of figures should be indicated within the body of the manuscript. Figures include both graphs and images. All figures should be accompanied by a descriptive legend using the following format:

FIG. 1. Polytene chromosomes of *Drosophila melanogaster*.

#### III. Letters to the Editor

Letters should be brief (400 words or less) and direct. Letters may be edited for length, clarity, and style. Authors must include institution address, contact phone number, and a signature.

#### IV. Other Submissions

Reviews and informational submissions may be edited for clarity, length, general interest, and timeliness. Guidelines for citations and references are the same for articles described above.

#### V. Manuscript Submissions

Article manuscripts may be sent to the current editor either electronically or by hard copy, accompanied by a disc copy. Electronic submissions are preferable. All authors will receive confirmation of the submission within three weeks. Manuscripts should be submitted either as a Microsoft Word or RTF (Rich Text File) to facilitate distribution of the manuscript to reviewers and for revisions. A single-email is required to submit electronically, as the review process is not blind unless requested by an author. If the article has a number of high resolution graphics, separate emails or separate discs mailed to the editor may be required.

If hard copy is sent it must be accompanied by a disc containing the complete submission. Three copies of the manuscript, as well as the original, should be submitted. Standard paper should be used with lines of sections of the manuscripts numbered and enough margin to permit reviewer comments. Two self-addressed stamped envelopes must be included if the authors wish to receive reviews and responses by methods other than email.

## VI. Editorial Review and Acceptance

All manuscripts will be sent to two anonymous reviewers as coordinated through the Editorial Board.

Reviewers will examine the submission for:

- **Suitability:** The manuscript relates to teaching biology at the college and university level.
- **Coherence:** The manuscript is well-written with a minimum of typographical errors, spelling and grammatical errors, with the information presented in an organized and thoughtful manner.
- **Novelty:** The manuscript presents new information of interest for college and university biology educators or examines well-known aspects of biology and biology education, such as model organisms or experimental protocols, in a new way.

Once the article has been reviewed, the corresponding author will receive a notification of whether the article has been accepted for publication in *Bioscene*. All notices will be accompanied by suggestions and comments from the reviewers. Acknowledgement of the reviewers' comments and suggestions must be made for resubmission and acceptance. Upon acceptance, the article will appear in *Bioscene* and will be posted on the ACUBE website. The review process can take 4-5 months. Upon final acceptance, the article will appear in *Bioscene* and will be posted on the ACUBE website within six months of publication. Depending upon volume, time from acceptance to publication may take up to a year.

## VII. Editorial Policy and Copyright

It is the policy of *Bioscene* that authors retain copyright of their published material.

# Call for Nominations for *Bioscene* Editorial Board, Call for Cover Art, and Letters to the Editor for *Bioscene*

We are (constantly) soliciting nominations for two (2) *Bioscene* Editorial Board positions (terms through 2011). Board members provide input in the form of reviews and suggestions concerning the publication of *Bioscene* to the Editor. Board members are also expected to assist in the solicitation of manuscripts and cover art for *Bioscene*. Board members may be called upon to proofread the final copy of *Bioscene* prior to publication and one member will be called upon to act as Book Review editor. **Preference will be given to individuals who regularly attend the annual meeting.** Also, the Editorial Board of *Bioscene* **welcomes cover images and letters to the editor** for future issues of *Bioscene*. Send images and letters according to the image guidelines given in the guidelines for submissions section of this journal to the editor. If you are interested in serving a 3-year term on the Editorial Board or have cover art for consideration, please email the editor, Stephen S. Daggett, at [stephen.daggett@avila.edu](mailto:stephen.daggett@avila.edu).

# Development and Assessment of Service Learning Projects in General Biology

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**Abstract** Service learning involves providing service to the community while requiring students to meet learning goals in a specific course. A service learning project was implemented in a general biology course at Rockhurst University to involve students in promoting scientific education in conjunction with community partner educators. Students were required to develop learning objectives, design and complete a community service exercise, and write reflection papers to assess the quality of their learning experience. Rockhurst students worked with high school or grade school students in the local community, providing learning experiences relating to course topics. Information gathered through reflection papers showed high student achievement and satisfaction in the following areas: 1) contributing to the learning of others, 2) contributing to their own learning, and 3) supporting the mission of the university.

**Keywords:** service learning, general biology, community education

## Introduction

Service-learning components in courses allow students to build their knowledge using experiential learning with a community partner. Connecting service to an academic field of study contributes to cognitive development and learning in the affective domain (Batchelder and Root, 1994, Giles and Eyler, 1994, Kezar and Rhoads 2001). Examples of outcomes in the affective domain include social responsibility, civic-mindedness, acceptance of cultural differences, and self-confidence. Thus, while making an impact in the community, students develop new knowledge and attitudes. Students also gain communication and teamwork skills that are necessary for post-undergraduate education and careers in science.

The three major components of effective service learning experiences are developing clear learning objectives, working on a project in cooperation with a community partner, and reflecting on the learning experience (Gelman *et. al.* 2001). We partnered with University Academy, a K-12 college preparatory charter school located within a mile of the Rockhurst University campus. Service learning requires that students are meeting a community need and integrating the experience into the academic goals of a particular course. The reflection component is structured and encourages students to address their interactions with peers, community partners, and course material (Daudelin, 1996). In

order for reflection to be effective, faculty members must consider the goals of the project, design a series of appropriate questions, and develop a structured reflection activity to that is appropriate for assessment of the service learning experience (Hatcher and Bringle, 1999). Questions for our project addressed group dynamics, interactions with students, and relation of the project to course goals.

In our project, the major components of service learning were achieved by requiring our undergraduate students to teach younger students in the local community about a variety of topics taken from their general biology course. Students were required to develop learning objectives, develop and deliver a learning activity, and complete a reflection paper on the project. We chose the teaching experience, as it provided an excellent opportunity for our students to gain competence in their subject matter. In addition, the experience provided an opportunity for Rockhurst students to make their course content relevant for a younger audience. Finding relevance is essential for encouraging students to learn more in the sciences (National Research Council, 1996). The students in the community were also exposed to unique and relevant approaches to learning science such as creative games, skits, and epidemic simulations. Student to student contact is an important element for promoting interest in further scientific educational opportunities, an achievement that is essential for the future of science education.

In addition to the benefits for Rockhurst students, service learning is also congruent with the mission and values of many colleges and universities. The mission of Rockhurst University involves an emphasis on inquiry and service. As expressed in our mission statement, Rockhurst is "...involved in the life and growth of the city and the region, and committed to the service of the contemporary world." Thus, service learning projects not only provide unique learning experiences for students but also support the goals of the university as a whole.

## Article II. Overview of Project

We selected two separate courses for implementation of a service learning experience. Courses in which a service learning project was undertaken and documented included three semesters of General Biology I and one semester of an Honors section of General Biology I. Each course is populated heavily by freshmen with varying levels of high school biology experience. Some students lack experience in applying scientific practice and using scientific language. The course is designed for science majors, but approximately 25% of the students in the course are not science majors. Students in the Honors section of the course enter Rockhurst with an ACT at or above 28, and a high school GPA of 3.5 or better on a 4.0 scale. Because Honors bring a special set of gifts and talents to the classroom, we thought it would be interesting to compare their performance with those in the General Biology sections.

Undergraduate students from General Biology I worked with two different groups from the community. The first group consisted of local grade school aged children who were involved in a community garden project. The second group consisted of high school students attending the University Academy, a Kansas City charter school for potential first generation college students located close to the Rockhurst University campus. Rockhurst University is located in an urban setting as is common for many Jesuit institutions. Our urban location provides significant opportunities for community outreach to individuals underrepresented in science.

Students in their first college biology course often struggle with gaining a clear conceptual understanding of many course topics. This student population is the one that lends itself to the type of meaningful active engagement provided by a service learning experience. The service learning project consists of four major phases: 1) Topic selection, 2) Development of learning objectives, 3) Completing the project and 4) Reflection. Each of the phases is described in detail in the subsequent sections. Table

1 displays the allotted classroom time for each phase of the project and student expectations outside of the classroom.

TABLE 1: Overview of project.

Phase of Project	Class or Lab Time Allotted	Expectations Outside of Class	Points Allotted
Topic Selection	20 minutes for students to consider course objectives and complete a survey to choose topics.	none	0
Development of Learning Objectives	1.5 hours for a project overview discussion and instructor feedback and guidance on developing age appropriate objectives.	Students met in groups to revise objectives.	0
Developing appropriate activities	1 hour for discussion and sharing of proposed activities.	Students generated demonstration materials, photocopied handouts, developed powerpoint presentations.	5 pts through peer review
Completing the Project	3 hours (1 lab period) for rehearsal and delivery of learning objectives. This portion was completed at either Rockhurst University or University Academy.	Students made final preparations for demonstrations/ activities prior to the start of class.	5 pts through peer review
Reflection	45 minutes to review the requirements for the reflection paper and discuss project outcomes.	Students wrote a 3 page reflection on their experience.	30 pts through instructor review

### Topic Selection

Typically, a portion of one lab period was allotted to introduce the service learning project, the expectations for students outside of the classroom, and the time line for project completion. For the first two classes undertaking the project, the topic of photosynthesis was selected by the instructor. This approach was chosen due to the observation that photosynthesis has traditionally been perceived as one of the most difficult course topics for students. In the last two courses in which the project was

completed, students were allowed to select their own project topic from a list of topics covered in the course (biological molecules, cell structure and function, photosynthesis, cellular respiration, molecular genetics, genetic inheritance, and virus structure and function). Table 2 summarizes the topic selection portion of the project.

TABLE 2: Topic Selection

Course	Undergraduate students	Projects	Community group
General Biology I, spring 2003	24	Photosynthesis	Community garden
General Biology I, spring 2004	24	Photosynthesis	University Academy
General Biology I, fall 2004	2 sections of 24	Course concepts, selected by students	University Academy
Honors General Biology I, fall 2005	18	Course concepts, selected by students	University Academy

### Developing learning objectives

The goals for the service-learning project were that students would: 1) collaborate to develop a meaningful service project that is relevant to a course objective; 2) design teaching approaches related to the chosen topic; 3) teach others about this concept; and 4) reflect on the effectiveness of the project for their learning and for the impact on the community. With this general framework, students were guided to develop their own specific learning objectives for their project at University Academy along with objectives they wanted to achieve with their student audience. Table 3 shows the questions formulated to help students to develop specific objectives and a plan for achieving them. Students were encouraged to use hands on activities or experiments to emphasize content for their specific topics. Most student objectives were centered on learning more about their chosen subject. For example, many student groups choosing genetics as their topic developed learning objectives relating to increasing their ability to solve genetics problems. Similar objectives were listed for their student audience. Some Rockhurst groups also generated objectives relating to learning how to work better with those in our local community. Students had about one-half of a three hour lab period to develop learning objectives, discuss them with the instructor, and modify them as needed.

TABLE 3: Generation of student objectives and plans

1.	List three learning objectives that you would like to achieve to help you with the material in this class (think mostly about what you need to know for the comprehensive final exam). This should explain what you would like to learn.
2.	List three learning objectives that you would like to achieve with the community group. Keep in mind that the goal of the project is to get these students excited about these areas of science by doing hands-on activities. In addition, these students already have some knowledge in these areas, so we want to try to show them additional information that they might not get exposed to in a high school biology class (i.e. we don't want our presentations to be too elementary). This should explain what you would like your audience to learn.
3.	Describe how you will accomplish your objectives above in the following ways. <ol style="list-style-type: none"> <li>Outline the concepts that you will present. Include information from your lecture notes, from your textbook, and from laboratory activities. Work as a group to make sure that this information is accurate and detailed.</li> <li>Outline the activities that you will develop for the students to allow them to learn the concepts.</li> <li>List the materials needed to accomplish your project.</li> </ol>

### Completing the project

Rockhurst students were guided to develop beneficial learning activities, including explanations and diagrams, demonstrations of experimentation, games, and other tasks promoting active learning. The learning activities were mostly developed by student groups meeting outside of class. However, the week before activities were presented, groups shared their plans with the rest of the class. The class then had the opportunity to make suggested changes to each group before final preparations were completed. Depending on the circumstances for each semester, community students either attended part of a Rockhurst laboratory period or Rockhurst students presented in the University Academy science laboratory room or at the community garden. Rockhurst students worked in groups of three or four, creating stations that community groups rotated through. Involvement of the student audience included answering questions, solving problems, completing experimentation, building biological structures, drawing diagrams, completing worksheets, and moving game pieces. Some examples of student projects include: 1) an overview of the steps of photosynthesis, including explanations and visual aids; 2) demonstrations of experiments such as observing oxygen production from plants with



different pigments and measuring carbon dioxide consumption by plants grown in the presence or absence of fertilizers; 3) observations of osmosis in plant cells; 4) games where students formulated genetic predictions; and 5) skits with students dressed as organelles. To work toward equal participation within the groups, students were required to evaluate the quantity and quality of participation by their peers, assigning 25 percent of the grade for the project.

### Reflecting on the project

An essential component of a service learning experience is structured reflection. Reflection is essential both for student learning and for faculty assessment of the project. Students were required to write about three major aspects of their project. The most current requirements for the reflection pieces

are shown in Table 4. The first section of the reflection paper focused on students documenting and critiquing their learning about their course topic for their project. The second section required students to assess their individual contributions, the ability of their group to work together, and possible future modifications of the project. The last section required students to reflect on how the project impacted them personally. This section included reflection on what they personally gained from working with the community group and any attitude changes that may have occurred about the subject of biology based on their experience. Students were encouraged to supply both positive and negative feedback. Table 5 provides samples of student comments from reflection papers showing discussion of learning from the project or personal development (see Discussion section for additional information).

TABLE 4: Requirements for the reflection paper

Paper section	Requirements for full credit
Critique of learning	<ul style="list-style-type: none"> <li>The learning objectives for the group and for the community students are clearly stated.</li> <li>A description of the biological process presented is detailed and thorough (at least ½ page).</li> <li>A description of whether learning goals were met is thorough, including the reasons for either meeting or not meeting the objectives (at least ½ page).</li> </ul>
Project logistics	<ul style="list-style-type: none"> <li>The ability of your group to work together to accomplish the objectives is evaluated.</li> <li>Your specific role in the project is identified.</li> <li>Ideas for things that you would do differently if you undertook the project again are included.</li> </ul>
Personal aspects	<ul style="list-style-type: none"> <li>An evaluation of whether the experience was worthwhile from a community service perspective is included.</li> <li>An explanation of what you learned from your student audience is included.</li> <li>An explanation of how the experience impacted your feelings about our student audience or social issues is included.</li> <li>An explanation of how this experience influenced your attitude about biology is included.</li> <li>Evidence that the student has put significant effort into thinking about the 4 areas above is apparent (at least 2/3 page).</li> </ul>

TABLE 5: Student reflection paper comments

Comments about conceptual understanding	Comments about personal development
It is easy to memorize facts then regurgitate them on a test or quiz. However, it is more of a challenge to find an application of the material or understand the material well enough to explain it to someone else and be able to answer questions concerning the topic.	Being a product of this city's urban public school system, we were not exposed to an opportunity such as this.... I know that so much of life's education is built on the foundation of having exposure and experiences. That is what separates so many people. On average, no one or groups of people are any smarter, it is the various experiences we have that will separate our learning.
Right before we were to teach the tri-hybrid cross, none of us could remember how to do one. We had to ask for help and look it up before we could even do it ourselves. After working one out with the students, I couldn't forget how they work. I remembered it right away on the exam.	The way the students responded made me feel like we really taught them something that they too valued as worthwhile. It made me feel good about myself and about what Rockhurst does and stands for.
I learned that I have a good biological background that allows me to communicate topics in a way that can help others learn. There were no questions that the students asked that we could not answer, and their questions helped me learn about the subject.	The service lab really helped me to see that it is important to spread the topics of biology. Biology is not for everyone, but if it is never presented or elaborated on, a student that has potential to be a biology whiz may never have the opportunity to meet that built in potential. Biology is also one area that the way it is presented is key to fully understanding its concepts.
This made me try to understand biology in a different way. I look at the complex things and try to break them down into something that I fully understand and use everyday. I also have tried to get a better attitude towards the things that I'm studying in biology and look at it in a different way.	This experience made me realize the importance of interaction between diverse groups of students. Often, we end up spending most of our time with people who are more similar to ourselves. I feel the whole society needs to promote activities and opportunities to interact with people from different neighborhoods, different school districts, and different.

**Reflection paper analysis**

To begin to assess the impact of the project on students, we analyzed reflection papers from three sections of General Biology I (groups 1-3) and one section of Honors General Biology I (group 4). We determined the percentages of students reporting positive, negative, or no responses in the categories of conceptual learning, group interactions, satisfaction with the results, and learning about community service. For the first two groups of students, these categories were the major required categories for the reflection paper. During the initial analysis, we noted that students sometimes volunteered additional information not required in the assignment. One major area of reflection not included in the original assignment was a section on personal development. Thus, personal development was documented for the first two groups but was not required in the reflection paper information until the third and fourth groups completed their projects.

discuss personal development in the reflection paper, while groups two and three completed projects on self-selected course topics and were required to discuss personal development in the reflection paper. Group four also differed in that it was an honors section of General Biology.

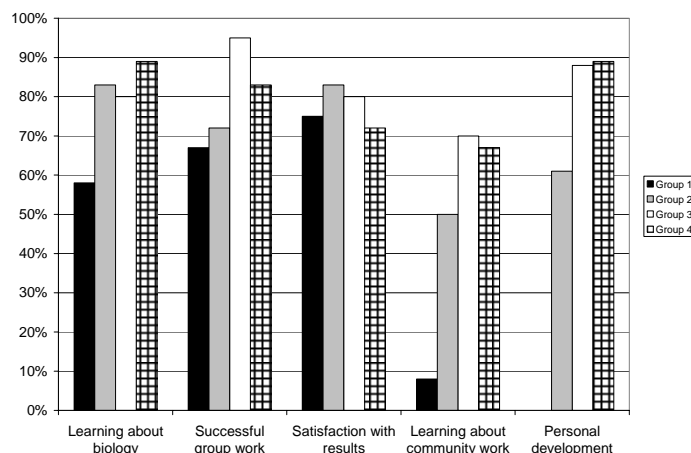


FIG. 1: Comparison of student responses in reflection papers: Percentages of students responding positively on items in the reflection paper (learning about biology, successful group work, satisfaction with results, learning about community work, and personal development) from all four groups are shown. Group one worked with grade-school aged children, and groups two through four worked with high school students. Groups one and two completed projects on photosynthesis and were not required to

Figure 1 summarizes a comparison of the percentages of positive results in each of the categories examined. The only difference in the projects from the first two classes was that the first class worked with grade school-aged students from the community garden and the second group worked with high school-aged students from the University Academy. Students perceived a greater level of learning about biology and community service when working with high school students (83% positive)

rather than elementary students (58% positive), leading us to continue the project at University Academy. We also wished to determine whether self-selection of projects (groups 3 and 4) influenced student reflections when compared to projects where photosynthesis was chosen for students (groups 1 and 2). The results for group 1 show that overall, the scores for this group in each category examined were the lowest. Group 2 had lower positive responses than groups 3 and 4 in the areas of successful group work, learning about community work, and personal development.

### Performance on Final Exams

All students took a common final exam in the lecture sections of the course. To evaluate student learning in relation to their service learning experiences, we looked at performance on the final

exam. Final exam scores for questions covering the four service learning topic areas were compared. Averages were taken for students who had completed service learning in a particular subject area versus students who did not complete service learning in that area. For example, the 11 students who completed service learning on the topic of cells were compared to all of the other students on questions about cell structure and function. Overall averages on the final exam for groups were also documented as a potential point of comparison. The areas of Cells, Genetics, and Viruses all show modest increases in exam performance when comparing service learning participants in that topic area with non-participants (Table 6). However, several changes to the project design need to be addressed before a more accurate picture of exam performance can be captured (see Discussion).

TABLE 6. Test score comparisons for one section of General Biology.

Student group	Cells		Genetics		Photosynthesis		Viruses	
	Service learning students (n=11)	Non-service learning students	Service learning students (n=32)	Non-service learning students	Service learning students (n=6)	Non-service learning students	Service learning students (n=6)	Non-service learning students
Service learning topic questions	89.5%	84.7%	91.7%	85.2%	69.4%	77.3%	89.8%	80.4%
Total Final exam percentage	77.5%	78.4%	79.3%	77.6%	78.7%	78.3%	88.6%	77.5%

### Discussion

We chose to implement a service learning project in the General Biology I course at Rockhurst University to promote a greater level of student understanding of course material. Our analysis of reflection papers showed that most students believe that they are gaining a better conceptual understanding for the material (58% for the first class, 83% for the second class, 80% for the third class, and 89% for the fourth class). While additional assessment methods are needed to further understand the impact on student understanding, we feel that student reflection about their own learning is an important first step in building confidence and helping with mastering difficult concepts. In addition, several students commented on how their project helped them succeed on exams in the course, suggesting that the service learning experience led to a better retention of course concepts for some students. Interestingly, students who worked with the

high school community group reported a higher level of increased knowledge, suggesting that the more complex projects undertaken with older students may better enhance learning. The community partner was the only factor examined that markedly affected student perceptions of learning, as only small differences were observed when comparing groups where the community partner was the same but self-selection of topics or level of student preparation were different (groups two through four).

Another anticipated outcome for the service learning project was some level of increased personal development. This expectation was due to research suggesting that service learning enhances acceptance of diverse groups and social responsibility. Even when we did not require students to document their level of personal development, up to 61% of students volunteered information about increased personal development. When we required students to discuss their personal development (groups three and four), 8-89% of students documented an increase in this area. Student comments documented in Table 5 add

additional support that students are developing greater self-confidence regarding their learning and greater respect for their minority student audience.

In addition to enhanced perceptions of learning and personal development, we found students to be highly satisfied with the project as a whole (72% or greater in all groups) and with the ability of their group members to work together (67% or greater in all groups). These findings are important, because of the inherent challenges of group work and the difficulties encountered when trying to engage a diverse student population in a survey level course. Students seemed particularly pleased with their group work in projects where topics were self-selected versus those in which the photosynthesis topic was assigned.

In the area of learning about community service, students initially reported lower levels of positive responses. This may be due to the fact that our time with the community groups is limited to 2-3 hours and that many of the students who come to Rockhurst have extensive service experience prior to their entry into college. Due to the commitment of Rockhurst to service, many students who are heavily involved in service are attracted to Rockhurst. When students were asked more specifically to address their learning about community service in the context of personal development, positive responses increased from a high of 50% to a high of 70%.

When our students were asked to discuss what they would do differently, a common theme was to have more time with the community groups. Some students also commented that they would get better at their presentation if given additional opportunities to practice and present their activity. Finally, specific changes in experimentation, preparation, level, detail, and assessment of learning in their audience were also recommended. These suggestions have helped us to improve the projects documented here as well as those planned for the future.

Future directions for this project will include more frequent visits with students at University Academy to encourage a longer collaboration with our community partner. In the Fall of 2007, students in the Honors course will visit University Academy 3 times during the semester to carry out their service projects and to reinforce relationships. Another area of assessment of this project will come from evaluating the experiences of students at University Academy. Students at University Academy will be asked to reflect on their experiences as learners. In addition to increasing our interaction and assessment of University Academy students, better tools for more accurate assessment of Rockhurst student

learning in relation to their service experience need to be developed.

Our general perceptions about the project have been extremely positive. We find that our students are enthusiastic about making contributions to providing a fun and engaging learning environment a younger audience (see comments in Table 5). We have observed students who have had difficulties with course material or who have been passive participants in the course make dramatic adjustments through service learning projects. Quiet students express their excitement and ideas about the projects, and struggling students frequently comment that service learning helped them understand the concept addressed in the project.

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# Using Service Learning in a Course Entitled *Biology of Women* to Promote Student Engagement and Awareness of Community Needs and Resources

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**Abstract:** Service learning projects were incorporated into the curriculum of an undergraduate course entitled *Biology of Women*. The goals of the service learning projects were: 1) to provide students with the opportunity to consider issues pertaining to human biology in real-world settings; 2) to foster student engagement with the community; and 3) to promote student awareness of community resources that are directly relevant to women's health issues. The success of the service learning projects in meeting these goals was assessed via analysis of student reaction papers, classroom presentations, and surveys administered at the end of the semester. Assessment results indicate that the service learning projects promoted student awareness of community needs and resources, demonstrated the relevance of course content to real life, and led some students to consider future service opportunities and/or careers in the field of women's health.

**Keywords:** service learning, women's health, human biology, student engagement

## Introduction

Laboratory exercises are invaluable for exposing biology students to the scientific process and for introducing them to the tools, techniques and model organisms used by scientists to test hypotheses. Yet often, laboratory exercises are inadequate for highlighting the human aspects of biomedical research; they fail to provide students with the opportunity to consider societal needs and the ethical responsibilities of the scientific and medical communities. While these topics can be addressed in classroom lectures and discussions, such settings lack a tangible, "real world" context for most effectively engaging students.

In an effort to "rehumanize" undergraduate science courses, educators are increasingly incorporating service learning projects into their curricula (McDonald and Dominguez, 2005; Wood, 2003). Service learning is defined as "a teaching and learning strategy that integrates meaningful community service with instruction and reflection to enrich the learning experience [and] teach civic responsibility" (National Service Learning Clearinghouse, 2006). Service learning projects are known to enhance the student experience in a variety of ways (Kennell, 2000). Firstly, they highlight the value of basic research, as students directly interact with individuals who suffer from

specific diseases or who are striving to improve the lives of those who suffer from these diseases. They provide a "real world" framework within which students can reconsider the types of questions scientists should ask. They enhance classroom discussions, as students share firsthand experiences from their service learning projects. Finally, they promote social activism, and often lead students to consider careers in the field of their service learning project (Ostroff and Brubaker, 2000).

For these reasons, a service learning project was incorporated into the curriculum of an undergraduate course entitled *Biology of Women*. For their service learning projects, students worked with community organizations that specialize in some aspect of women's health. The success of the service learning project in "humanizing" the course material, in enhancing student engagement, and in promoting student awareness of community needs and resources was assessed via student reaction papers, classroom presentations and responses to end-of-the-semester surveys. Assessment results indicate that the service learning projects were successful in meeting the aforementioned objectives, and that they had a positive impact on students' attitudes toward service and their

consideration of careers in the field of women's health.

### Background Information on Course

Biology of Women is an undergraduate course offered by the Human Biology Department at the University of Wisconsin – Green Bay. The course is an upper level elective that counts toward the Human Biology major. In addition to Human Biology majors enrolling in the course, a significant number of nonmajors who have successfully completed a two-semester sequence of introductory biology also enroll in the course (typically nursing, psychology, and social work students). Typically, the course is filled to capacity (40 students) with each annual offering.

A summary of the course syllabus is found in Table 1. Final grades are calculated based on students' performance in the following areas: two midterm exams, a final exam, participation in discussion, and service learning projects. Each of the five components counts for 20% of a student's final grade in the course.

TABLE 1: Syllabus for Biology of Women

Week of semester	Topic
1	Women, Science & Medicine
2	Female Anatomy
3	The Menstrual Cycle
4	Gynecological Difficulties
5	Review; Midterm Exam #1
6	Pregnancy and Delivery
7	Contraception & Abortion
8	Basis of Biological Differences
9	Women and Mental Health
10	Review; Midterm Exam #2
11	Menopause
12	Women and Cardiovascular Health
13	Women and Cancer
14	Women and Nutrition
15	Service Learning Project Presentations; Final Exam

### Structure and Assessment of Service Learning Projects

Students are introduced to the concept of service learning on the first day of class, as the course syllabus and general course requirements are reviewed. A concerted effort is made to differentiate service learning projects from volunteer work (i.e., there must be a significant "learning" component to the project that provides the student with the opportunity to learn about some aspect of women's health in depth). It is imperative that this distinction be made at the start of the semester, as students begin planning their projects and contacting agencies in the community with whom they will potentially work. Students need to be prepared to convey to their community contacts that they would like to do more than simply answer phones or file documents. While such activities fulfill the "service" requirement of the project (they provide the agency with assistance in meeting community or clients' needs), they don't allow for the in-depth "learning" that is also a critical component of the project. Finally, students are given a list of service learning projects conducted by students previously enrolled in the course, in order to encourage them to begin brainstorming about a potential topic for their own project.

On the second day of class, students are asked to identify areas of interest for their service learning projects. Students are then divided up by interest groups, and small group discussions take place to facilitate the planning of projects. Students often decide to work together to complete their projects, although some students prefer to work independently, so as not to be constrained by the scheduling conflicts they may face when working with other students. As these discussions are taking place, the instructor circulates and provides small groups with additional information about possible community agencies / contacts with whom students have worked in the past.

By the third week of the semester, students are required to submit a written description of their service learning project for approval. The description is expected to include the name of their community contact, as well as details regarding the "service" and "learning" components of the project.

After approval from the instructor, students are expected to conduct 15-20 hours of service learning with their community contact during the remainder of the semester. Upon completion of their project, students are required to submit a three page reaction paper to the instructor that describes the nature of their project (both the “service” and “learning” aspects). Furthermore, students are expected to give a brief (10 minute) presentation to the class that describes what they learned as they conducted their project. The purpose of the oral presentation is two-fold: 1) to inform the rest of the class about the nature of the organization with which the student worked and the services that the organizations offer; and 2) to allow the instructor to assess the depth of learning that took place as a result of the project. Lastly, students are asked to complete a brief survey that assesses practical aspects of the project, as well as student attitudes toward their specific projects and community service in general. Statements included in the survey are found in Table 2. For each statement, students were asked to respond using a variable scale from 1 to 7, with an answer of 1 indicating that the statement was “not at all true”, and an answer of 7 indicating that the statement was “absolutely true”.

### Examples of Service Learning Projects

A variety of factors can influence a student’s choice of subject matter for their service learning project. Some students choose projects that address an aspect of women’s health that has affected them personally or has affected a loved one. Others choose to learn about an aspect of women’s health about which they have no previous knowledge or experience. Still others choose a project simply because it requires a minimal amount of preparation and/or planning (e.g. working with an organization or professional with whom they or an acquaintance already has a connection) or because it allows them to work with their friends.

Listed below are summaries of successful service learning projects that students have conducted in *Biology of Women* (projects were considered successful if they met both the “service” and “learning” objectives of the assignment as defined previously):

- *Assisting local lay midwives with classes on pregnancy and the home birthing experience.* Students who have conducted this particular service learning project have assisted local lay midwives in a variety of

ways. One group of students educated themselves on the topic of nutrition and pregnancy, and then prepared a variety of nutritional foods (e.g. foods rich in calcium, iron and/or folic acid) to serve to expectant parents attending home birthing classes. Others compiled informational flyers on the topic of nutrition and pregnancy to hand out to class attendees. During another semester, students worked with midwives to research and compile information on other topics (e.g. the differences between hospital vs. home births) to distribute to expectant parents who are interested in learning more about the home birthing experience.

- *Working with the Women, Infants and Children (WIC) Program.* The WIC program is a federally funded program that provides low-income women and children with nutritious foods, nutrition counseling and referrals to healthcare and social workers. A number of students have elected to conduct their service learning projects with the local WIC office. Students have assisted the WIC program in a variety of ways, including researching and presenting (via colorful bulletin boards or informational brochures) information on specific nutrition topics (e.g. the importance of calcium for optimum health in mothers and children) in a manner that is accessible to individuals of all educational levels. Additionally, students have conducted cooking seminars for mothers and toddlers, promoting awareness of the importance – and ease – of preparing healthy and fun meals and snacks for the family.
- *Promoting awareness of risk factors for breast and cervical cancer among university women.* Several groups of students have assisted healthcare personnel from the university’s student health center and/or local hospitals to organize educational activities on campus that promote awareness of risk factors for cancers that are unique to women (e.g. cervical cancer) or more prevalent in women (e.g. breast cancer). These educational activities have ranged from seminars on the proper method for conducting self breast exams to information booths in the campus union that provide educational materials on the link between infection with human papilloma virus and cervical cancer.

TABLE 2: Service learning (SL) Survey and Results. The survey used a variable scale from 1 to 7, with an answer of 1 indicating that the statement is “not at all true” and an answer of 7 indicating that the statement is “absolutely true”.

<b>Statements</b>	<b>Response (mean + SD)</b>
1. <i>At the start of the semester, I approached my SL project with a positive attitude.</i>	4.9 ± 0.21
2. <i>I experienced difficulty in finding a community contact / agency that was willing to work with me for my SL project.</i>	3.14 ± 0.26
3. <i>I am satisfied with the amount of information I learned about women’s health while conducting my SL project.</i>	5.56 ± 0.18
4. <i>The work I conducted during my SL project was of great benefit to the community.</i>	5.08 ± 0.19
5. <i>I would have preferred the option of writing a term paper rather than conducting a SL project.</i>	2.91 ± 0.26
6. <i>My SL project made the coursework in Biology of Women seem relevant to real life.</i>	5.44 ± 0.18
7. <i>Too much time was required to complete my SL project.</i>	3.27 ± 0.21
8. <i>My SL project enhanced my learning of course material.</i>	4.81 ± 0.02
9. <i>The agency / organization / individuals with whom I conducted my SL project valued the service that I provided.</i>	5.71 ± 0.20
10. <i>My professor provided a clear definition of SL at the start of the semester.</i>	6.21 ± 0.15
11. <i>My SL project affected me at a personal level.</i>	5.33 ± 0.22
12. <i>I would take another SL course in the future.</i>	5.39 ± 0.21
13. <i>This was my first SL project.</i>	5.00 ± 0.34
14. <i>I plan to continue working with my SL organization / contact in the future.</i>	3.76 ± 0.31
15. <i>My SL experience has led me to consider a career in the field of women’s health.</i>	3.60 ± 0.25
16. <i>My SL project has made me more aware of community needs.</i>	5.64 ± 0.20
17. <i>My professor provided me with enough opportunities to reflect on my SL project.</i>	5.83 ± 0.16
18. <i>Please estimate the total number of SL hours conducted this semester for Biology of Women.</i>	19.73 ± 1.63

- *Assisting at local domestic abuse shelters.* Given that domestic abuse is a significant threat to women’s health, many students choose to conduct their service learning projects with local domestic abuse shelters. Training for positions at the shelters requires a significant time commitment (often 15-20 hours), and thus students who choose to conduct their projects in this context often devote a total of 40+ hours (training + service) to this endeavor. Students have served in a variety of capacities at local shelters, including serving as victim’s advocates and providing coverage of the shelters’ 24 hour hotlines.
- *Promoting a healthy body image among young girls.* Students interested in the prevention of eating disorders have taken some creative approaches to promoting a healthy body image among young girls. Some have designed and

conducted classroom activities at local elementary schools that celebrate differences in appearance and promote an awareness of the ways in which the media (e.g. television, magazines) influences the way girls feel about their bodies. Other students have served as leaders for local Girl Scout Troops, organizing activities that 1) promote physical fitness by introducing girls to a variety of fun physical activities; 2) educate girls about basic nutrition facts; and 3) promote an awareness of the signs and symptoms of eating disorders.

- *Conducting activities with young girls to enhance their science self-efficacy.* Often, students express an interest in conducting a service learning project that stimulates young girls’ interest in science and enhances their confidence in their abilities to engage in the scientific process. The ultimate goal of such



- projects is to encourage young girls to consider a career in the sciences and thereby increase the representation of women within the sciences. To this end, students have helped plan, prepare and participate in a local weekend science event, create and experiment with flying machines. A photo of an undergraduate student participating in an experiment at the event is found in Figure 1.



FIG 1. An undergraduate student works with a group of girls to conduct experiments with their self-designed airplanes at a science event sponsored by the Girl Scouts, entitled “Wings, Strings and Flying Things”.

## Results and Discussion

### *Assessment of practical aspects of service learning projects*

Both survey results (Table 1) and verbal feedback from students indicate that the time spent at the beginning of the semester providing a comprehensive definition and several specific examples of service learning is beneficial to students (statement 1). It allows them to judiciously choose the project and organization with whom they will work, in order to participate in an experience in which a significant amount of *learning* (and not just *service*) will occur. It is crucial to the success of the project to make the distinction between service learning vs. volunteer work, since most students reported that even though they had conducted volunteer work previously, this particular project was their first encounter with service learning (statement 13).

Interestingly, while students in general reported that they approached their service learning project at the start of the semester with a positive

sponsored by the Girl Scouts, which specifically addresses these goals. During this event, entitled “Wings, Strings, and Flying Things”, students work with young girls to explore the field of aeronautics and attitude (statement 1), nearly half reported that they would have preferred to write a term paper rather than conduct a service learning project (statement 5). This response likely reflects the fact that many students often encounter scheduling conflicts when conducting their projects, and feel that the project requires too much time outside of class to complete (statement 7). Others are frustrated by the difficulties they faced at the start of the semester in identifying an organization that is willing to collaborate with them on their project (statement 2). While the instructor provides students with a list of organizations in the community that are willing to oversee projects, many students develop unique projects for which it is often difficult to identify an appropriate sponsoring agency. Nevertheless, even in light of these difficulties, overall students report that they would take another service learning course in the future (statement 12), and that the service learning experience had a positive impact both on their learning of course material and their awareness of community needs and resources (as is described in detail in the next section). As one student commented in her response paper, “Initially, the project felt like just another dreaded expectation that would consume 15-20 hours of my time. Forty-six hours of service time has passed by, and I must admit that it turned out to be a very valuable assignment. I have benefited from the educational aspects, met a lot of interesting people, been offered a job in the near future, and helped others in their struggles concerning abuse issues”.

The positive impact of the service learning experience on students’ depth of learning of course content is evident not only from survey results but also from students’ engagement in classroom discussions throughout the semester. Responses to survey statements indicate that students are satisfied with the amount of information they learn about women’s health while conducting their projects (statement 3), that the project enhances their learning of course material (statement 8) and makes their coursework seem relevant to real life (statement 6). This learning is most evident during classroom discussions, as students participate much more thoughtfully and inquisitively when topics are discussed that are directly relevant to their service learning projects. As one student stated in a reaction paper on her service learning project with Planned Parenthood, “ When we got to [the topic of contraception] in Biology of Women, I felt like I had

an extra edge of experience...compared to the students who did not go through training with Planned Parenthood”.

Furthermore, service learning projects provide students with the ability to offer tangible, “real life” accounts of their experiences with the topic at hand, which greatly energizes classroom discourse. This is often evident during discussions on the topic of domestic abuse. Students who have experienced or witnessed domestic abuse are often able to comprehend the cycle theory of violence, and can comprehend how women often become trapped in situations of domestic violence. Students who do not have this firsthand experience, however, often cannot understand the cycle, and sometimes will place responsibility for the abusive behavior on the victim, who neglects to leave the relationship. The impact of a service learning project that deals with domestic abuse can drastically change students’ views on this issue; the anecdotes and experiences from such projects that are shared in class are invaluable for providing other students with insight into this phenomenon. As one student commented in her reaction paper, “It is difficult for someone who has never experienced these horrible situations to imagine the kind of inner pain and turmoil the victims live with on a daily basis. Because of that, I think too many people hold incorrect assumptions about victims of domestic violence and sexual assault. It is essential that our society is correctly informed that these things do exist and that too many women, children and men are being victimized. Only when we are accurately informed can we empathize, open our hearts, and truly put an end to these devastating events”.

#### *Assessment of the impact of service learning on students’ awareness of community needs and resources*

A long term goal of the service learning project is to create awareness among students of the resources that exist within the community for addressing women’s health needs. Students gain this awareness not only from conducting their own specific projects, but also from learning from their peers’ service learning experiences (often through end-of-the-semester presentations). At times, this information is immediately relevant to students (e.g. community resources that help women with eating disorders), and at other times this information will likely prove to be valuable to students in the future (e.g. local support groups for women who have been diagnosed with breast cancer). In either case, students report that they greatly value the opportunity to learn of these community resources through their

peers’ presentations at the end of the semester (statement 17).

The service learning experience also creates an awareness of community needs (statement 16). Time after time, students report in their reaction papers that the organizations with which they worked are “understaffed” or “lack resources”. In light of this, many students reported that the service they provided to their agency was greatly valued (statement 9) and that they felt that their project was of great benefit to the community (statement 4). Some, but not all, students reported that they intend to continue working with their service learning agency in the future (statement 14). One student who worked at a home for pregnant teens reported that “All around, this has been a great experience for me. I learned a lot about life and finally understand the perks of volunteering...[it] made me feel very good about myself and gave me a feeling that I was actually doing something to make a difference. I have decided to continue volunteering. I want to thank you for this project; it really affected my attitude about volunteering”. In fact, the majority of the class indicated on the survey that their service learning project had affected them at a personal level (statement 11).

#### *Impact of service learning on future career goals*

Both survey responses (statement 15) and verbal feedback from students have indicated that the service learning experience in women’s health has led some students to consider (and in some cases, pursue) a career in the field of women’s health. One former student now manages a Planned Parenthood clinic. Another is conducting graduate work to become a certified nurse midwife, and still others have obtained permanent full-time positions at agencies that deal with sexual assault and domestic abuse issues. Thus, in light of these outcomes, it appears that the service learning experience is a valuable tool for introducing students to career options that they may not have considered had they not conducted their service learning projects.

#### **Conclusions**

In conclusion, results from surveys, student reaction papers and presentations indicate that the service learning project in women’s health is a valuable component of the course. It fosters student engagement both within the classroom and the community, provides a “real life” context for information that is learned in the course, and creates an awareness of community needs and resources. For these reasons, the service learning project will

continue to be included in the curriculum of Biology of Women. Future studies are planned to assess the long term impact of the service learning projects on students' volunteer activities and career choices.

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# Use of the CO I Gene as a Species Indicator for Forensically Important Flies: A Forensic Entomology Laboratory Exercise

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**Abstract:** Forensic entomologists utilize insects (particularly flies) to establish the time interval between death and body discovery. This important piece of information may answer questions as to the circumstances of the individual's death and insects are now routinely utilized and recognized as being important forensic indicators. Of extreme importance is the correct identification of the fly species associated with the body, as misidentifications will cause inaccurate time of death estimates. Traditional fly identification methods rely on recognizing distinct physical traits each fly species may possess; however, this has given way to molecular techniques (i.e. DNA sequences) that are quicker and more reliable. Unfortunately no DNA sequence information exists on the forensically important fly species in the western U.S. although a molecular database has been advocated by a number of forensic entomologists. This laboratory experience allows students to develop general molecular based skills they will need later in their careers while simultaneously contributing data that will be used to create a molecular database containing DNA sequences for forensically important California flies.

**Keywords:** forensic entomology, undergraduate biotechnology laboratory, molecular techniques

## Introduction

Medicocriminal entomology examines the utility of insect evidence in solving crimes, most often violent crimes including homicides. One of the most crucial pieces of information is determining the time elapsed since death, or postmortem interval (PMI). Under most circumstances, this can be determined by a medical examiner as bodies generally are found within 48 hrs and indicators such as rigor mortis, algor mortis, or livor mortis can be used to determine PMI. However, bodies may often lie undiscovered for many days or months and those methods become less reliable. It has long been known that insects associated with remains display PMI-dependent processes, which includes the development of insect species whose larvae consume dead tissue. Thus, a PMI estimate can be based on the oldest developmental stage of an immature insect found on a body. Due to their size, numbers, and ubiquity, flies (i.e. Muscidae, Sarcophagidae, and Calliphoridae) are most noticeable and commonly found insects when a body is discovered. The most limiting factor in using flies as a PMI indicator is proper species identification as different fly species differ in terms of growth rate and arrival time on a body. Typically, identification is done through morphological examination of important setae (hairs) found on the body. This is a tedious, and

often impossible prospect as many of these setae break off. More recently, forensic entomologists have advocated using DNA sequences and it appears that the cytochrome oxidase (CO) I gene in the mitochondria is excellent in discriminating species and would allow non-entomologists to easily identify flies based on their DNA sequences (Malgorn and Coquoz 1999; Sperling et al. 1994; Wells and Sperling 1999). Although some work has been performed on a few common species found in the eastern U.S., no work has been attempted on flies found in the western U.S.

The Department of Biological Sciences at SJSU now offers a course in forensic entomology (Entomology 106) that serves undergraduate biology majors and criminal justice administration majors with a concentration in biology forensics. This course examines the science and methodology used to collect, analyze, and present information regarding insects and other arthropods that are important in legal investigations. The majority of the laboratory component is devoted to the collection and identification of carrion feeding flies in the family Calliphoridae because they are the most important forensic indicators in medicocriminal cases. Students begin the semester by trapping, identifying, and curating flies, followed by instruction in molecular based methods including: DNA extraction/purification, PCR, electrophoresis, and sequencing. Students then obtain the DNA sequences and are introduced to

bioinformatics programs that allow fly for identification.

The expected outcomes of this exercise are twofold. First, students will acquire a working knowledge of basic molecular techniques. Although, students enrolled in this course may not work specifically in biotechnology, they will at least have been exposed to various molecular techniques. The students most interested in this course generally are animal or ecological biology majors who rarely are afforded the opportunity to combine ecological study with molecular techniques. Second, the data students generate in this activity is extremely important to forensic entomologists as it will initiate an expandable database of calliphorid diversity in California.

### Article III. Materials and Methods

**Field Collection:** Students constructed their own fly traps to collect flies for their study. Traps consisted of two 2L plastic soft drink bottles in which the capped bottle served as a lid and the bottom half of the bottle was removed. This open-ended bottle was fitted snugly over a second, uncapped bottle. The bottom portion of the second bottle was spray painted with black paint and five small holes were cut at the base of the bottle (Fig. 1). Raw meat was placed inside the holes where the meat quickly rotted. This bait attracted flies that entered through the holes, and subsequently passed the painted portion of the trap towards the top where they were collected. Flies were then preserved in 95% ethanol with data (date and location) recorded by the student. Although this method was successful in obtaining large numbers of flies, the more enthusiastic students collected flies on carrion such as dead birds and mammals. In order for students to obtain a passing grade for this portion of the exercise they must have a collection with complete data of at least 50 flies in two different Calliphorid genera, and one representative each from the families Sarcophagidae, Fannidae, and Muscidae.

**DNA extraction:** A quick, inexpensive method was developed for extracting fly DNA. The right mid and hind leg of each fly were carefully removed with forceps and placed in a 1.5ml microfuge tube. The legs were washed for 10m in distilled water and



FIG 1. Fly trap constructed by students to collect specimens.

repeated twice more. After the final rinse, as much of the water was removed as possible, and the legs were ground with a plastic pestle with 4ul of proteinase K (20mg/ml). When the legs were sufficiently pulverized, 50 ul of a 5% Chelex<sup>®</sup> 100 (BioRad) solution was added to the tube and incubated overnight at 56°C. The DNA template was then heated for 10 min at 100°C then stored at -4°C until use.

**PCR/sequencing:** A small region of the COI gene was amplified using the following primers: 5'-CAG CTA CTT TAT GAG CTT TAG G-3' (forward) and 5'-CAT TTC AAG CTG TGT AAG CAT C-3' (reverse). PCR conditions were as described in Wallman and Donnellan (2001). PCR cycling was performed using a Perkin Elmer 9600 thermal cycler. After an initial incubation period at 95°C for 10min, 40 cycles were run (94°C for 30 sec, 52°C for 1 min, and 72°C for 1 min), followed by one cycle at 72°C for and a hold cycle at 4°C. PCR products were visualized via electrophoresis (1% agarose gel in TAE) and successfully amplified reactions were purified using a DNA Clean & Concentrator kit (Zymo Research). PCR products were then sequenced (one way only) using an ABIPrism<sup>®</sup> Big Dye Terminator sequencing kit and an ABI 373 (Applied Biosystems) sequencer.

**Sequence Analysis:** Chromatograms were examined by students, and the CO I gene region amplified was identified and imported into a Vector NTI database. Students were then able to

align their sequences and develop cladograms. Sequences were then compared with previously published sequences to verify their unknown species.

#### Article IV. Results and Discussion

A relatively short region (approximately 300bp) of the distal portion of the CO I gene was amplified by the students and corresponds to base pair numbers 1082-1380 found in Sperling *et al.* (1994). By comparing their unknown fly specimens with previously published sequences of known fly species via sequence alignment, students were quickly able to confirm their unknown specimens. For example, the sequence of the very common *Phaenicia serricata* from diverse geographic areas was remarkably conserved. In fact specimens AY842612 from Australia (Wallman *et al.* 2005) and AJ417717 from Hawaii (Stevens *et al.* 2002) were 99% similar when sequences were aligned and compared with specimens that students collected (Figure 2).

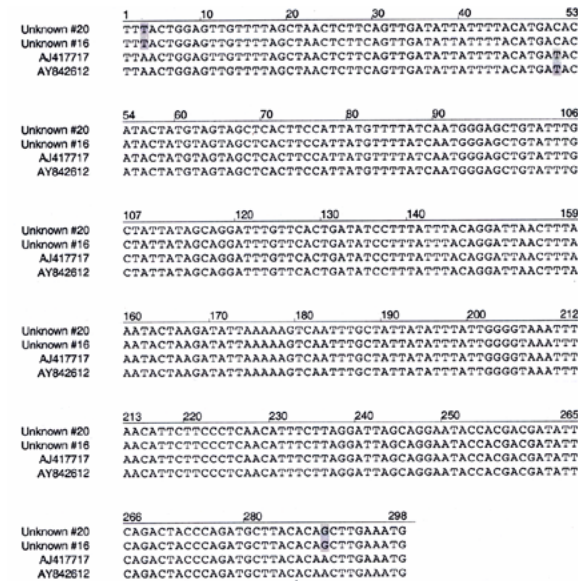


FIG 2. CO I gene sequence alignment. Note only three base pair differences (locations 3, 51, and 279) between published sequences of known fly species from two different geographical areas (Hawaii [AJ417717] and Australia [AY842612]), and two student samples of the same species.

During the first semester the course was taught, over 10 calliphorid species were collected. Of these, at least three are new collection records in

the San Francisco Bay Area, and we have collected enough data to confirm that one species of fly not thought to be important as a forensic indicator is one of the most commonly found species on human corpses found in the field. In succeeding semesters it is hoped that the different families of forensically important flies (i.e. Muscidae and Sarcophagidae) will be examined. Moreover, a number of colleagues have expressed interest in this project and are now submitting samples from across the globe.

Student assessment was performed by administering midterms on material discussed in class and laboratory practical examinations on equipment, and skills evaluation such as casting gels, pipetting, and sterile technique. This exercise also served as an introduction to bioinformatics.

#### Article V. Acknowledgements

I thank the California State University Program for Education and Research in Biotechnology for awarding me funds to develop this course through their Curriculum and Infrastructure Development grant program.

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### Call for Applications -- John Carlock Award

This Award was established to encourage biologists in the early stages of their professional careers to become involved with and excited by the profession of biology teaching. To this end, the Award provides partial support for graduate students in the field of Biology to attend the Fall Meeting of ACUBE.

**Guidelines:** The applicant must be actively pursuing graduate work in Biology. He/she must have the support of an active member of ACUBE. The Award will help defray the cost of attending the Fall meeting of ACUBE.

The recipient of the Award will receive a certificate or plaque that will be presented at the annual banquet; and the Executive Secretary will provide the recipient with letters that might be useful in furthering her/his career in teaching. The recipient is expected to submit a brief report on how he/she benefited by attendance at the meeting. This report will be published in *Bioscene*.

**Application:** Applications, in the form of a letter, can be submitted anytime during the year. The application

# Effectiveness of Elements of a Diversified Instructional Approach in an Introductory Biology Course

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**Abstract:** Students enrolled in a large-lecture, non-majors biology course employing a diversified instructional approach featuring both instructor-centered and student-centered techniques evaluated the effectiveness of each approach in fostering course goals. Students perceived both approaches to be effective to some extent. Students indicated that the instructor-centered approach was more effective than student-centered instruction in fostering knowledge of biological content and of the nature of science, making the course meaningful, and promoting interest in biology as a discipline. Student-centered instruction was perceived to be more effective in engaging students in the learning process, helping students construct their knowledge, and making the course interesting. Students indicated they preferred a diversified instructional approach, noting that the varied instructional environment helped to keep the classroom atmosphere engaging.

**Keywords:** instructor-centered, student-centered, active learning, introductory biology

## Introduction

Studies have revealed the effectiveness of student-centered, active learning strategies in promoting meaningful learning, retention of content, improved student attitude and the development of critical thinking skills (Klionsky, 1998; Lawson, 2001; Lord, 2001). In response to these findings, calls for reform in science education over the past decade cite the need for college science faculty to diversify their instructional approach by incorporating active learning strategies in their courses (McNeal and d'Avanzo, 1997; NRC, 2003; NSF, 1996; Seymour and Hewitt, 1997; Uno, 1999). Yet the shift from the traditional, passive, instructor-centered paradigm has been a slow one (Adams and Slater, 1998; Anderson, 1997, Rice, 1996). Faculty unfamiliar with student-centered instructional strategies, a lack of content specific curricular materials, and a lack of time have been identified as barriers to the implementation of a more diverse instructional approach (Laurer, 2003; Sunal, Bland and Sunal, 2001). For faculty to diversify their instructional approach, they must take a more scholarly approach to their instructional choices (Allen and Tanner, 2005; Powell, 2003).

A specific student-centered, active learning strategy that has shown to be effective in college science classrooms is the use of small-group cooperative learning activities (Astin, 1993; Tobin, Capie and Betterncourt, 1998). Such activities can "complement lectures by providing a social context in which a student constructs

individual understanding of the content presented in lecture" (Preszler, 2006), and actively engage students in science content. These activities may be particularly effective in large enrollment science courses where students may feel isolated and disengaged in the course (Anderson, 1997; Christensen, 2005; Michaelson, Knight and Fink, 2002; Suchman, Timpson, Linch, Ahermae and Smith, 2001). In response to calls for faculty to evaluate the effectiveness of their attempts to improve science education (Allen and Tanner, 2005), this study documents students' perceptions of the effectiveness of the implementation of a diversified instructional approach in a large enrollment introductory biology course. Findings detailed here may inform efforts to design instruction with the most effective balance of instructor-centered and student-centered approaches.

Middle Tennessee State University offers an introductory biology course specifically designed for non-majors. The course is designed to provide students with the understanding, experiences and skills that foster informed decisions on biological issues that affect their lives. In the course, efforts are made to promote meaningful learning of biological content by making the course relevant and engaging critical thinking skills through both instructor-centered and student-centered approaches. The lecture components of the course are generally large, often over 100 students.

## Methods



This study describes a course taught utilizing a diversified instructional approach that combined traditional, instructor-centered lecture/discussion elements along with instructor-designed, student-centered cooperative learning activities. In the instructor-centered approach students participated in lectures and discussions that were supplemented by PowerPoint™ presentations, and answered questions posed by the instructor. In the student-centered approach, students worked in cooperative teams of approximately four students, discussing and formulating group responses to questions concerning issues relevant to the biological content. The cooperative learning activities were structured so that each member of the group acted as the ‘discussant’ for one of four sets of questions, facilitating discussion and formulating the group’s response. For example, when covering the nature of science as a method of inquiry, students assembled into groups of four and were given a description of an advertisement for a herbal product that is promoted as having ‘scientific proof’ of its effectiveness as a weight loss supplement. Student groups analyzed the scientific validity of the claims by answering four sets of questions regarding the advertisement with each student acting as the discussant for one of the sets of questions (Appendix A). For some of the activities, the students were allowed to self-assemble in groups, while for others, the instructor formed the groups. For each of the topics in the course, both instructor and student-centered approaches were utilized. Overall, the balance of instructional approaches utilized was approximately 75% instructor-centered and 25% student-centered.

To assess students’ perceptions of the relative effectiveness of student-centered and instructor-centered approaches utilized in the course, students were administered an end-of-course survey (Appendix B) that was approved by the university’s ‘Institutional Review Board.’ Ninety-four students out of the 120 students completing the course completed the survey. The survey employed a 5-point Likert scale (with 1 indicating strong disagreement, and 5 indicating strong agreement) that students utilized to evaluate the effectiveness of each approach in achieving specific course goals. Students were also asked to indicate the balance of instructional approaches they felt would best achieve course goals, as well as their perceptions of the advantages and disadvantages of each

instructional approach. To determine if differences existed in student perceptions of the effectiveness of each approach in achieving course goals, the data were analyzed utilizing Student’s t-tests (n = 94).

## Results

Each approach was perceived as being effective in promoting course goals with each item achieving a mean response of greater than a ‘3’ on the five point Likert scale utilized, and most students indicating a degree of agreement for each item (Figure 1). The instructor-centered approach was perceived to be most effective in promoting aspects of student knowledge (biology and the nature of science), making the course meaningful and fostering critical thinking skills, while the student-centered approach was most effective at making the course relevant and interesting, and engaging students in their own learning. Both approaches were least effective in promoting student interest in biology as a discipline.

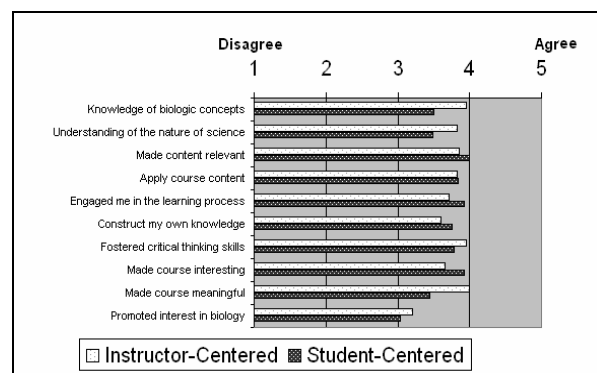


FIG. 1. Student ratings of effectiveness of instructional approach in achieving course goals (n = 94).

Differences in effectiveness in the approaches in

achieving course goals were found (Table 1).

Statement	Average Response		t-value	P-value
	Instructor-Centered	Student-Centered		
1. Developed my knowledge of biologic concepts.	3.96	3.50	4.69	< .001*
2. Developed my understanding of the nature of science.	3.83	3.49	3.74	< .001*
3. Made the content relevant.	3.86	4.00	1.00	< .320
4. Apply course content.	3.82	3.84	-0.10	< .850
5. Engaged me in the learning process.	3.71	3.92	-2.25	< .027*
6. Construct my own knowledge.	3.60	3.76	-1.39	< .017*
7. Fostered critical thinking skills.	3.95	3.79	-1.58	< .117
8. Made the course interesting.	3.66	3.92	2.13	< .038*
9. Made the course meaningful.	4.00	3.45	2.47	< .015*
10. Promoted interest in discipline of biology.	3.20	3.04	2.22	< .029*

n = 94

\* Statistically significant

TABLE 1. Survey results of student perceptions of electiveness of instructional approach.

**Knowledge of Biology:** A fundamental goal of the course is to promote student understanding of basic biological concepts. Students perceived the instructor-centered approach to be more effective than the student-centered approach ( $p < .001$ ) in this area. Students' comments indicate that one of the advantages of an instructor-centered approach is the perceived accuracy of the content and authoritativeness of the source, while a disadvantage of the student-centered approach is the perceived uncertainty of the accuracy of student responses.

**Understanding of the Nature of Science:** An accurate understanding of the nature of science as a method of inquiry is a vital aspect of scientific literacy. Students perceived the instructor-centered approach to be more effective than the student centered approach ( $p < .001$ ) in this dimension. As in 'Knowledge of Biology,' students noted the perceived advantage of the instructor as an authoritative source of accurate information over the

uncertainty of the work done by students in the collaborative groups.

**Relevance of Course Content:** In a course for non-majors the relevance of the content to students' everyday life can be an important aspect of student interest and learning. No significant difference in student perceptions of the effectiveness of instructor-centered vs. student-centered approaches in making the content relevant was found. Students' comments indicate that they found both approaches brought relevance to the content.

**Apply Course Content:** Fostering students' ability to apply course content to individual and societal issues is an important goal of the course. No significant difference in student perceptions of the effectiveness of instructor-centered vs. student centered approaches in this area was found. Comments indicate that students found this to be an attribute of both instructional approaches.

**Engaged in the Learning Process:** Engaging students in course content is a powerful method of promoting meaningful learning. Students perceived the student-centered approach to be more effective than the instructor-centered approach ( $p < 0.027$ ) in this dimension. Students noted that engagement was an important aspect to holding their attention and was an advantage of the student-centered approach over the instructor centered approach.

**Student Construction of Knowledge:** Students learn meaningfully when they can construct their own knowledge. No significant difference was found in student perceptions of the ability of the two approaches to foster student construction of knowledge.

**Fostered Critical Thinking Skills:** Meaningful learning of scientific/biologic content occurs as students apply, analyze, synthesize and evaluate information. No significant difference was found in student perceptions of the ability of the two approaches to foster critical thinking skills. Students noted that this was a distinguishing feature of the entire course and an attribute of both instructional approaches utilized.

**Course Interesting:** Maintaining student interest in the course can promote student attendance and engagement. Students perceived the student-centered approach to be more effective than the instructor-centered approach ( $p < .038$ ) in making the course interesting. Many students viewed this to be an advantage of the student-centered approach and a potential disadvantage of instructor-centered approaches when that approach is overemphasized.

**Course Meaningful:** Designing a non-majors course that students perceive as being personally meaningful is a departmental goal. Students perceived the instructor-centered approach to be more effective than the student-centered approach ( $p < .015$ ) in making the course meaningful. Students' comments indicate that they perceive this to be an attribute of both instructional approaches, but more so for the instructor-centered than the student-centered.

**Interest in Biology:** Promoting students' interest in biology as a discipline in a non-majors course may result in enrollment in additional biology courses and, potentially, a change of some students' major to biology or a related scientific field. Minimally, this can result in increased scientific literacy, promoting individuals' ability to make informed decisions about scientific/biologic issues facing society. Students perceived the instructor-centered approach to be

more effective than the student-centered approach ( $p < .029$ ) in making the course meaningful, but noted that both approaches were useful in this dimension.

Students were also asked to identify the balance of instructor-centered to student-centered instruction they thought was ideal for the course (Figure 2). All students preferred a mix of the two approaches, with the majority of students preferring a predominately instructor-centered approach complemented by student-centered instruction. Many students commented that a diversified approach helped to keep class sessions fresh and interesting.

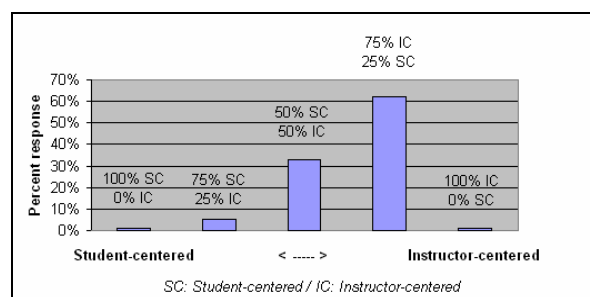


FIG 2. Student instructional balance preference (n = 94).

## Discussion and Conclusions

This study describes students' perceptions of the relative effectiveness of student-centered vs. instructor-centered approaches utilized in a one-semester, introductory biology course for non-majors taught by a single instructor. Generally, students indicated that they found both approaches to be effective in achieving course goals and prefer the course to be taught utilizing both approaches. Differences in student perceptions about the effectiveness along some dimensions were found. Students perceived the instructor-centered approach to be most effective in promoting knowledge (biology content and the nature of science as a method of inquiry) and in making the discipline interesting and the course meaningful, while the student-centered approach was perceived to be more effective at making the course interesting and engaging them in their own learning. Students indicated that varying the approach helped to maintain their interest in the course. They valued the ability of student-centered instruction to make the course interesting and the authoritativeness and accuracy of information presented in the instructor-centered approach. As the surveys were anonymous to encourage authentic and reliable responses, no mechanism was available to correlate student

responses with course grades—this is a potential avenue for subsequent research.

These findings provide students' views about instructional approaches and further support the calls for a more diversified instructional approach in university science courses. Developing and employing the content-specific, student-centered activities utilized in the study also highlights several barriers to implementing a diversified approach (Laurer, 2003). The amount of time required to develop, field test, implement and grade the student-centered activities is considerable. Some faculty might find the time and effort required prohibitive. However, one advantage to the use of cooperative learning activities is they can be developed over time and implemented gradually (Allen and Tanner, 2005). While some activities are published in relevant science education journals, or are available as textbook supplements, the limited availability of high-quality, content-specific activities remains limited, and this likely remains a primary reason for the over-reliance on passive, instructor-centered approaches utilized in university science courses. The development and dissemination of resources that support student-centered, active instructional strategies is a vital component of fostering a more diversified instructional approach in university biology courses.

### Acknowledgements

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# “Molecular Clock” Analogs: a Relative Rates Exercise

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**Abstract:** Although molecular clock theory is a commonly discussed facet of evolutionary biology, undergraduates are rarely presented with the underlying information of how this theory is examined relative to empirical data. Here a simple contextual exercise is presented that not only provides insight into molecular clocks, but is also a useful exercise for demonstrating how statistical processes are involved in modeling biological phenomena. The example given involves studying rate variation in traffic flow; a variety of other cases will be just as useful, and can provide founding material for further discussion of how molecular clock models are useful in basic and applied biology.

**Keywords:** molecular clock, relative rates test, Poisson distribution

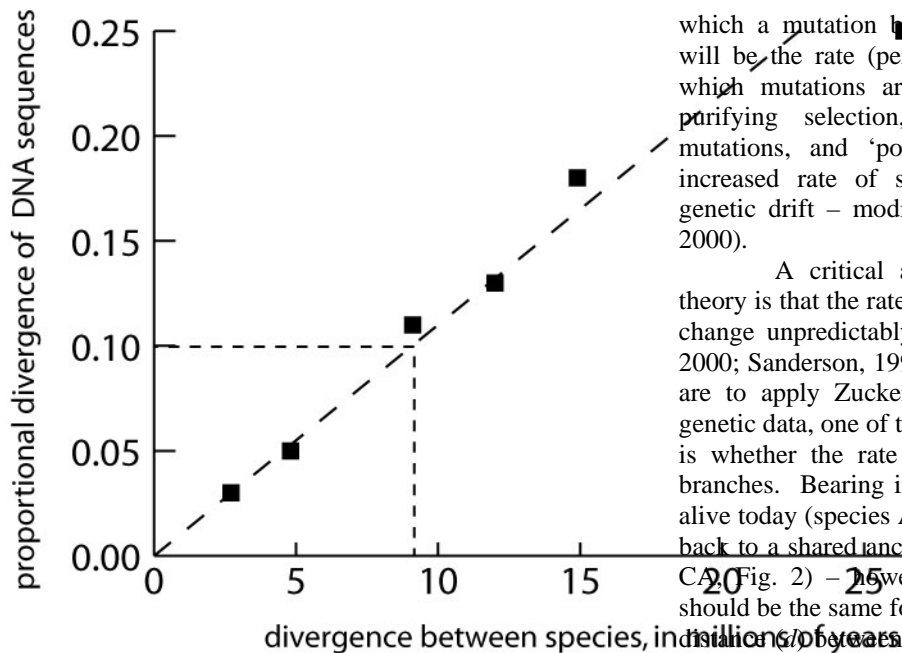
## Introduction

One of the more pervasive and often misunderstood aspects of evolutionary theory in popular science journalism is the “molecular clock”. This model, originally proposed by Zuckerkandl and Pauling (1965), revolved around a profound insight into how proteins differ among organisms: the more distantly related in time two organisms seem to be, the proteins they are composed of are also more distinct, suggesting that one process is an analog of the other. It is often discussed in science journalism, because it is a relevant and accessible feature of evolutionary biology: big discoveries often revolve around the age of a fossil, the time of separation of two lineages, and so on (Zimmer, 2003, 2005). This is also a point of contention in the debate between Creationists and evolutionary biologists. The former believe that clock estimates may represent circular logic (see Miller, 1999), requiring the inference of fossil dates to calibrate dates based on a molecular clock, while the latter are integrating information from diverse fields of science as well as testing the assumptions of clock models in a variety of ways (Pybus, 2006).

Thus, in undergraduate biology classes, it is often important to discuss the data and theory relevant to this model. A model is, after all, simply a testable way of describing what we see in nature. The broad implications of the molecular clock model are appealing – we can tell the age of an event by the molecular divergence of two lineages, assuming the clock has been ‘calibrated’ appropriately (Figure 1). Usually this involves information from breeding studies (Keightley and Lynch, 2003; O’Connell et al., 1997) or appropriate choice of calibration events –

often from the fossil record or based on biogeographic events such as the rise of the Panama isthmus (Hickerson et al., 2003; Marko, 2002) – for a given taxon and era of interest. It can be difficult to establish robust divergence times using molecular clocks if the calibration points are an order of magnitude older or younger than the divergence of interest. Even after establishing appropriate rates for a gene region, and having data to address a particular question, it is important to remember that a certain amount of error is to be expected. The prominent evolutionary biologist Joe Felsenstein (Felsenstein, 2004, p.6-7) comments: “With a molecular clock, it is only the *expected* amounts of change [in two diverging lineages] that are equal; the *observed* amounts may not be.”

FIG. 1. An example of using a molecular clock model to estimate the divergence time of two species. This is useful when there is fossil, biogeographic, radiometric, or other means of dating some species divergences in a group, but not all of them. First, the “known” divergences between species are collected, and DNA sequence data is collected and compared for each of these species pairs (shown as black squares). A rate of mutation and substitution is inferred from a linear regression of these points. Then a comparison can be made between two species that have no information regarding their divergence time: sequence data is collected, and the divergence between those species compared against the regression line (shown as dotted line box). In this example, the ‘unknown’ species differ at 10% of the nucleotides in a DNA sequence; the inferred time of speciation is then about 9 million years ago. The variance in these estimates can also be accounted for statistically. (next page).



It is not straightforward to illustrate a mutational process in a teaching or laboratory setting, much less to show how we test mutational data to see whether they are appropriate for timing divergences among species. A challenge for lab classes in general, when dealing with evolutionary topics, is that evolutionary processes often require much more actual time than can be managed in the constraints of a classroom setting. Thus, analytical and simulation-based tools (e.g. EVOBEAKER by Simbiotic Software) are increasingly popular ways to allow students to see idealized processes happen. However, illustrating clock-like divergence is difficult in a computational lab, because it is in many ways an opaque process – a computer tells the students what is put into it. The abstraction of phylogeny means that simply showing unequal branch lengths (that is, the inferred number of mutations along a branch of a gene tree) may not help students learn both the statistical and model-testing concepts underlying molecular clock theory. Here I present an inexpensive and short lab exercise that can be easily modified to represent numerous real-world scenarios, to give students the opportunity to observe Poisson-distributed processes and determine whether an “equal rates” hypothesis is violated.

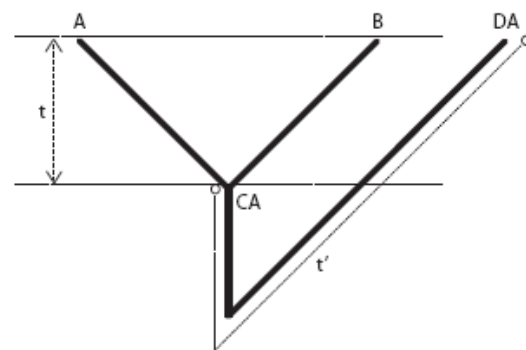
### Theory

Kimura (1968) argued that most genetic variation – represented by different mutational alleles of a given gene in a population – must be neutral with respect to natural selection, in order to explain there being so much variation in natural populations. One of the consequences of this model is that the rate at

which a mutation becomes ‘fixed’ in a population will be the rate (per gene copy, per generation) at which mutations arise,  $\mu$ . Selection – including purifying selection, which removes deleterious mutations, and ‘positive’ selection that leads to increased rate of substitution relative to random genetic drift – modifies this rate (Hartl and Clark, 2000).

A critical assumption of molecular clock theory is that the rate of molecular evolution does not change unpredictably, if at all (Huelsenbeck et al., 2000; Sanderson, 1997), among species. Thus, if we are to apply Zuckerkandl and Pauling’s theory to genetic data, one of the first things that must be tested is whether the rate is constant along evolutionary branches. Bearing in mind that for any two species alive today (species A and B in Figure 2), the time ( $t$ ) back to a shared ancestral species (common ancestor CA in Fig. 2) – however far back in time that is – should be the same for both species. Thus the genetic distance between two species is the mutation rate  $\mu$  multiplied by the time  $t$  that has passed along *both* branches, or  $d=2\mu t$ .

Figure 2. To examine whether the rate of evolution is constant in a group of species being compared, pairs of species (represented by DNA sequences, for example) are compared for divergence relative to a common ancestor (CA); by definition, the number of generations (time,  $t$ ) separating each species from the common ancestor is the same. Often there will be no available sequence data from a common ancestor; a true outgroup sequence from an extant species, which has been diverged from the focal species (and their common ancestor) for a longer period of time, can be used to test the same relative rates hypothesis. If the substitution rate deviates dramatically between the outgroup (DA) and each species (A and B, below), other processes such as selection or demographic change may make estimates of divergence time based on a molecular clock model unreliable.



Without knowing  $\mu$ , biologists can still evaluate the constancy of mutation using a relative-rates test. Since we often cannot sequence the DNA of an ancestral species (the common ancestor CA), we must compare the evolutionary divergence of each species to an ‘outgroup’ species. Although in general the molecular clock model performs very well for recent and ancient divergences alike, it is most common to only test the assumptions within a group that a researcher is interested in (say, turtles) and for a particular time scale (e.g. the phylogeny at the family level). Thus, DNA sequences can be separated into the ‘ingroup’ (the group that the researcher is considering) and the ‘outgroup’ species (those species that are known to be distinct from the ingroup – for example, a lizard could be an outgroup species for a phylogeny of turtles, as they are both in Reptilia but turtles share a more recent common ancestor with each other than with any lizard species; see Table 1).

TABLE 1. Researchers must often define outgroup species so that they understand the relationships within a group of species (the ‘ingroup’) better. These outgroup species must be from a distinct lineage of species, but preferably not so different that DNA substitution patterns are effectively random. Examples of outgroup species for several ingroups are given. The goal of choosing an outgroup for testing molecular clock theory is that for any two or more closely-related species, exactly the same amount of time must have passed since each of those species (which it is assumed – and can be tested – have a fairly recent common ancestor) had a more ancient common ancestor with a species that is from a distinct evolutionary lineage.

INGROUP	OUTGROUP
Genus <i>Quercus</i> (oak trees)	Maple tree, Poplar tree
Order Cirripedia (barnacles)	Crab, Shrimp
Genus <i>Oncorhynchus</i> (trout)	Atlantic Salmon (genus <i>Salmo</i> )
Family Ursidae (bears)	Dogs
Phylum Echinodermata (seastars)	Sea squirts

The basis of the relative rates test (Sarich and Wilson, 1973), and all of the more complex variants that are used in examining the time of species divergence based on genetic distance (Sanderson, 1997; Huelsenbeck et al., 2000; Pybus, 2006), is the underlying statistical distribution. The rate expectation is based on a very simple statistical distribution that is worth discussion in any science class or laboratory – the Poisson.

Mutations occur randomly over time and are often modeled by a Poisson distribution. The Poisson distribution is usually employed for modeling systems where the probability of an event occurring is very low, but the number of opportunities for such occurrence is very high. Generally, the probability of mutation in a single generation is low, but over evolutionary time there are many thousands of generations separating two species or even individuals within a species. The basic assumptions of a Poisson distribution are:

- (1) the length of observation period is fixed in advance
- (2) events occur at a constant average rate
- (3) the number of events occurring in different intervals is independent.

Thus typical examples that are given include the waiting time or frequency with which light bulbs burn out, because we know it will happen but the waiting time could be quite short or quite long, keeping usage and other conditions constant. A difficulty with making such a concept, and its statistical underpinnings, understandable to students is finding an example that is observable, quantifiable, and useful in the context of observing differential rates, as with the mutational changes on two distinct evolutionary lineages.

### Exercise

This exercise should begin with a short lecture explaining the underlying theory (previous section) and examination of typical applications of molecular clock data (such as Zimmer, 2003, 2005), including information from the fossil record and divergence data from DNA sequences. There is ample material available online and in the literature for this portion of the exercise (e.g. Kalinowski et al., 2006). The participatory focus of the exercise will be adapted to local surroundings, but the suggested opportunity involves finding a nearby area of high vehicle or pedestrian traffic in which people (vehicles, organisms, objects) are forced to turn either to the right or the left, as with a T-intersection at a traffic



light (Figure 3). The events should not be immediately predictable as to whether the turn will be left or right, and one reason that choosing an intersection with a stoplight is useful is because the light breaks the number of events into (semi-) discrete intervals, appropriate for examining a Poisson distributed process.

FIG. 3. Traffic scenario for illustrating Poisson processes and an analog to the molecular clock model. Here, the car at **a** is in the ancestral (prior) state; car **b** has turned to the right, indicating an independent mutation that distinguishes it from the ancestral state and from cars that turn to the left (c).

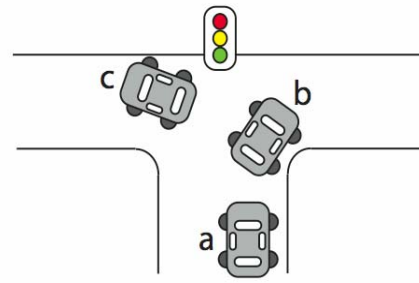
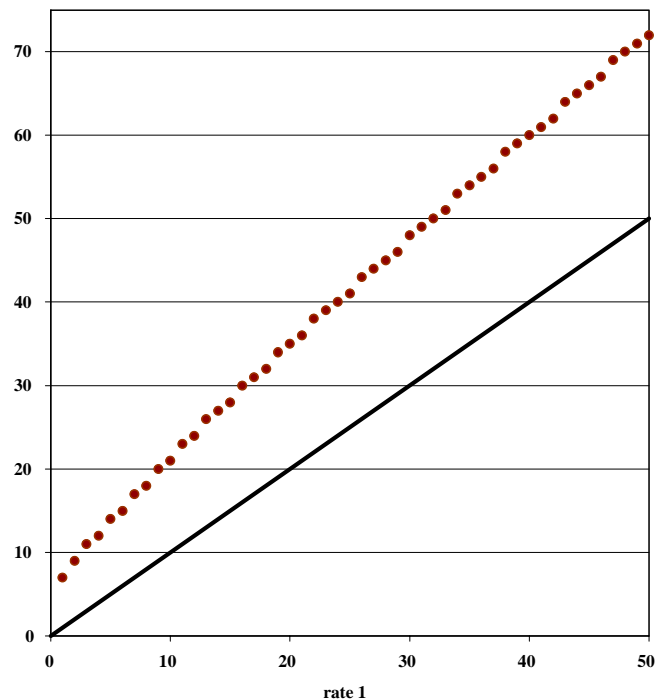


FIG 4. The  $\chi^2$  statistic used in relative rates tests becomes more sensitive as sample size increases. For very small numbers of observations, the excess of events for one of the rates being measured must be much larger than the other rate; as the sample size (number of observations) increases, the ratio between the rates can be smaller and still be statistically significant. Shown is a diagonal line illustrating equal rates, and dots indicate for a given number of observations for one rate estimate the number of discrete events in the other rate estimate that will be significant ( $\chi^2 = 3.84$ ) assuming 1 degree of freedom ( $p < 0.05$ ).

In the case of a T-intersection, students are given a portion of the lab time to safely observe and record the rate of turns in either direction. They are invited to subdivide the data into different partitions, such as ‘cars’ versus ‘trucks’ or ‘university vehicles’, which may have distinct rates from one another – much as different loci may evolve in different ways in the genome. After a series of time intervals appropriate for the rate of traffic flow (see Figure 4), in which all left and right turns for each partition (*i.e.*, vehicle type) are recorded in their lab notebooks, students return to the lab or a setting in which they can calculate the rate variation on each ‘branch’ being observed.

The students will use what is called a relative rates test to determine whether the rate is the same for both ‘branches’. Ordinarily, this would be done in the context of having genetic data for at least one additional species (the outgroup). However, with these data the test statistic can be calculated in exactly the same way, as though turns to either direction represent a branch from the ancestral position to each ingroup destination (species). Tajima (1993) showed that if there are three nucleotide sequences then we can define the number of sites in which nucleotides in sequence 1 (one of the two ingroup species) are different from the other two sequences by  $m_1$ . The number of sites in sequence 2 that are different from the other two sequences is defined as  $m_2$ . When sequence 3 is considered the outgroup, the expectation for equal rates is that  $m_1 = m_2$ .



This equality can be tested using the chi-squared distribution. Namely,

$$\chi^2 = \frac{(m_1 - m_2)^2}{m_1 + m_2}$$

approximately follows the chi-square distribution with one degree of freedom. This test is conservative, meaning that it will not always have the power to detect rate variation,

but it is a good first approach. The students will use their data, where left turns are equivalent to unique substitutions in sequence 1, and right turns are equivalent to unique substitutions in sequence 2, to determine if there is statistically significant rate variation (here, if the test statistic is  $> 3.84$  it would be considered significant at the  $p = 0.05$  level; this also offers an opportunity to discuss what is meant by 'significance' in scientific tests).

## Discussion

An important element of any teaching exercise is finding a way to make the subject matter memorable. It is very difficult to establish ways to educate students about statistical distributions, and particularly as related to rate variation, in a way that involves activity. While there is much to be gained from discussions and simulation-based exercises, abstract concepts are better conveyed through visual and participatory activities (Kalinowski et al., 2006). This exercise has been reviewed as one of the more memorable labs in my own teaching, and students did well on subsequent exam questions related to rate variation and the molecular clock. Students learn that some data partitions (*e.g.* University vehicles) may exhibit significant rate variation relative to other vehicle types, and that when there is significant rate variation the data in question may not be useful for examining questions that involve an *assumption* of constant rate, such as is used in molecular clock models. They also learn how scientists examine their own data in evaluating whether a particular model may be applied for further evaluation.

There are abundant instances in which researchers have found that the data they have collected are not consistent with a constant clock-like rate of evolution. In many cases, using relative-rates tests such as the one described and illustrated above is a way of examining why the data are inconsistent; for example, Posada (2001) showed that recombination within gene regions can often lead to larger variances in branch lengths among species and rejection of a molecular clock model. In these instances, other means of inference are required to determine the time of separation for species, or the rate at which other characters are changing in the course of evolution. However there are a great many cases in which DNA sequence data is able to accurately predict the divergence time among lineages, even on very short time scales if the rate of mutation is quite high. Nickle et al. (2002) found that the rate of sequence evolution in HIV samples fits a molecular clock model; this finding is clinically relevant as it may help infer sources of infection and

transmission in a patient's history. More work is being done to understand why some data sets deviate from the expectations of the model, and how to consider factors such as whether the rate can change over time (Huelsenbeck, 2000).

Unusual activities such as the one outlined here provide a more memorable experience when teaching abstract topics. As noted in Kalinowski et al. (2006), participatory exercises are often more effective and memorable than complementary approaches to teaching the same subject matter, particularly when the topic is relatively abstract in nature. Although the process described in this exercise is not a perfect analog to the process of mutation in independent lineages – for example, it is not possible for a car to turn left as well as right, but it is possible for a single nucleotide to mutate in two independent species lineages (a condition known as *homoplasy* or *parallel mutation*) – many alternative scenarios may be explored for such an exercise. This is presented primarily to illustrate ways in which educators can take advantage of local conditions to teach basic probability theory, to help explain a topic related to evolution and the molecular clock model, and to avoid the 'black box' problem of some computer-based simulation exercises.

## Acknowledgments

Thanks to Elizabeth Jockusch for sharing the molecular clock exercise that has been used in my own teaching lab along with the above exercise, and Scott Small for assisting with the Evolutionary Genetics teaching lab at the University of Georgia.

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## ***Editorial***

Putting together every issue of this journal is an extremely emotional experience. On the one hand, it's exciting to generate a document that will help colleagues in their efforts. It's also very gratifying to be in the middle of such creativity about biology teaching. On the other hand, *Bioscene* has been a quarterly publication. This involves considerable effort. In addition to putting together the journal, I've been the principle referee for submitted works and getting articles into a published-ready look. This is challenging with all the different types of computer codes out there. I had the four issues planned out for 2008 back in January. But ACUBE's current budget did not permit a quarterly hard copy document. Hence, you are looking at the first issue at the possible future form of our organization's journal.

At first I was extremely upset. In addition to having to scrap my plans for the upcoming year, I discovered that I had an old-fashioned preference for printed matter. There is so much gibberish on the internet, that I feared *Bioscene* would simply become another leaf on the pile. Also, I had worked extremely hard in the two years prior to standardize articles for publication so that there would be a distinct *Bioscene* look. Does this look work on the net? Our archived issues are fine ([www.ACUBE.org](http://www.ACUBE.org)), but is another format better for quality online publishing?

I can't deny some of those feelings persist. In order to alleviate some of my anxiety, I asked the Steering Committee for an adjustment in how often the journal is published. The current plan, subject to membership and Steering Committee discussions at the fall meeting in Hopkinsville, Kentucky (October 16-18), is to have two issues a year. One will be an on-line document, open to both members and non-members alike and available on our website. The other will be a printed document available solely to members. This issue will appear later in the year.

This arrangement has several benefits for all who care about *Bioscene*. First, two issues are much less labor-intensive than four. Moreover, two issues will allow the editorial board the opportunity to thoroughly review submissions for publication in order to ensure quality and focus. Finally, this plan will allow members an opportunity to help us move the journal into the future.

This is an extremely exciting time to be involved with undergraduate biology education. Technology as well as a growth in thinking about teaching, is rapidly changing how we carry out our work. I would like *Bioscene* and ACUBE to reflect this excitement. I encourage as many members as possible to come to this fall's meeting. I'm also asking that authors who submit to *Bioscene* to join ACUBE prior to my sending manuscripts out for review. This may help offset some of the costs of publishing *Bioscene*. I believe that our organization and journal could be leaders in the field of biology education, but we need a budget and active membership for this to occur. Please make sure your dues are up to date and encourage colleagues to join. Have an enjoyable summer and I look forward to seeing you in October.

Stephen S. Daggett, Ph.D.  
*Bioscene* Editor

## ***Letters to the Editor***

### **A Loss to ACUBE**

**Sister Rosemary Connell CSJ**, professor emeritus of Fontbonne University and longtime member of ACUBE, died today, May 20, 2008 at Nazareth Living Center in St. Louis MO. Sister Rosemary was an energetic member of ACUBE from very early times. Many of the ACUBE members will remember her faithfully attending AMCBT meetings.

Sister Jeanene Yackey CSJ



Association of College and University Biology Educators

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