Bioscene

Journal of College Biology Teaching

Volume 31(3) August 2005

A Peer-Reviewed Journal of the

Association of College and University Biology Educators

Editor:

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Avila University

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Bioscene is normally published in March, May, August and December. Please submit manuscripts by November 1, 2005 for consideration in the next issue.

Cover image:
This image of perennial Bleeding Hearts (*Dicentra sp*.) was provided by Tim Mulkey.

Articles:

News & Views:

Bioscene: Journal of College Biology Teaching

I. Call for Submissions to *Bioscene*

Bioscene: Journal of College Biology Teaching is a refereed quarterly publication of the Association of College and University Biology Educators (ACUBE). Suggestions for manuscripts include: announcements, web site and book reviews, labs/field studies that work, course development, technological advice, software reviews, curricular innovation, history of biology, letters to the editor, undergraduate research opportunities, professional school, funding sources, current issues, etc.

II. Submission Requirements

Manuscripts may be sent to the current editor, Stephen S. Daggett. Submissions can vary in length, but articles should be between 1500 and 4000 words in length. All submissions should be double-spaced, including figure and table legends, any footnotes, and references. All submissions should come with a cover letter. If the submission is sent attached to an email, please address the subject line as BIOSCENE. The cover letter should contain the complete mailing address (including the street), email address, telephone number, and fax number of the corresponding author.

The manuscript itself should contain the following:

- Manuscript in RTF (Rich Text File) to facilitate distribution of the manuscript to reviewers and to make revisions.
- Tables, graphs, and images should be submitted as individual electronic files. If it is not possible to provide an image in an electronic format such as TIFF for Macintosh or BMP for Windows, please include a clean, sharp paper copy for our use.
- Double space all text including references and figure legends
- Title
- Author(s)
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- A brief abstract (200 words or less), followed by keywords
- Number all pages

III. Editorial Review and Acceptance

The manuscript will be sent to two reviewers as coordinated through the Editorial Board. Reviews 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 suggestions and comments from the reviewers. Acknowledgement of 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.

IV. Editorial Policy and Copyright

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Editorial Board

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Deadlines for Submissions

November 1, 2005 December, 2005 Issue **February 1, 2006 March, 2006 Issue**

A Classroom Demonstration of Garlic Extract and Conventional Antibiotics' Antimicrobial Activity

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Abstract: The Kirby-Bauer method is regularly used to test bacterial susceptibility to antibiotics, and is often employed in the classroom for teaching this concept. In this exercise, additional materials and instructions were given to students for the preparation of garlic extract and loading on blank BBL paper discs. They were further instructed to test the efficacy of the extract as compared with conventional antibiotics against *Escherichia coli, Staphylococcus aureus and Klebsiella pneumoniae.* The conventional antibiotics used were kanamycin, novobiocin, neomycin, erythromycin and tetracycline on BBL paper discs.After 48 hours of incubation, students measured the diameters of inhibition zones. Garlic was rated as being equal to, or less in inhibition than the antibiotics. A survey administered after the exercise showed that students gained a better awareness of garlic extract's potency as an antimicrobial agent. Students also became enthusiastic about searching for additional sources of antimicrobial substances to in light of antibiotic resistance.

Key Words: garlic extract, antibiotics, inhibition, allicin

Introduction:

The concept of antibiotic sensitivity is very important in the study of microbiology, especially to those in the health-related disciplines. Various modifications of the Kirby-Bauer diffusion technique have commonly been used to demonstrate bacterial sensitivity to antibiotics (Madigan *et al*., 2006). Other demonstration techniques include the well method and tube dilution techniques (Alderson, 2004; Kleyn & Bicknell 2004). However, these methods have usually been applied only to testing conventional antibiotics and disinfectants or antiseptics for classroom demonstrations (Alderson, 2004).

Students, just like other members of the scientific and general community, are being re-introduced to the potentials of the use of phytochemicals for various purposes. Although, many claims about the medicinal properties of phytochemicals are not supported by reproducible scientific experiments, much of the literature provides convincing evidences for some of them. One such phytochemical is allicin, which is released when garlic (*Allium sativum)* is crushed (Rees *et al.,* 1993; Sivam, 2001; Iwallkum *et al.,* 2004,).

Garlic has been used as a medicinal herb for centuries (Donkers *et al.,* 1999), and Louis Pasteur was reputed to be the first to demonstrate the antibacterial effects of garlic and onion extracts (Sivam, 2001). Garlic extract's reported activities include reducing cholesterol, tumor suppressing, and acting as an antifungal, antibacterial, antiviral and anti-parasitic agent (Reuter et al., 1996).

Garlic is widely consumed and is known to be safe. It has been reported that a human would need to eat 20 grams of garlic per kilogram body weight to reach toxic levels. Additionally, there is no known report in the literature regarding resistance of bacteria to allicin, the main active ingredient in garlic, whenever it has been found to be effective (Paszewski & Jarosz, 1978; Singh & Shukla,1984).

One problem with the practical use of allicin as a commercial antimicrobial agent is its instability. Its rate of deterioration increases with increasing temperature. In addition to allicin, other products of garlic that are more stable than allicin have been found to have antifungal properties (Harris *et al*., 2001). As a

wide spectrum antimicrobial agent, one concern is that garlic could be detrimental to beneficial gut bacteria. However, no reports of negative effects on gut bacteria occur in the literature (Dankert *et al.*, 1979).

In this laboratory exercise, students received additional materials and instructions to include garlic extract as one of the antimicrobial substances being tested as outlined below under "*Materials and Methods*". This is in addition to the instructions in their lab manual (Kleyn & Bicknell, 2004). The goal of this exercise was to supplement standard antibiotic testing by including a natural product whose source is familiar to students.

This exercise may help students to develop an appreciation for the potential for new antibiotic discovery in the future and from diverse sources. Furthermore, this exercise may aid botany students to realize the importance of plant products to humans, as well as the concepts and uses of plant secondary metabolites.

Materials and Methods

Preliminary Class Discussion

Prior to this exercise, students were assigned readings and class discussions on antimicrobial agents, including antibiotics. In addition, a class discussion was generated by supplying students with additional reading materials about Fleming's discovery of penicillin and other materials related to the early discovery of phytochemicals (Prescott *et al.*, 2002; Madigan *et al.*, 2006)

Materials for the whole class

(Estimated class size of 24 students)

- Kitchen blender
- Sterile paper discs ¼'' BBL (about 100)
- Balance
- Five average-sized garlic bulbs

Materials per students group

Students worked in groups of three or four. Each group was provided with the following:

- Ampoules of antibiotic discs of kanamycin, novobiocin, neomycin, erythromycin, tetracycline.
- Balance
- Forceps (one per student)
- Filter paper and funnel (previously sterilized by autoclaving)
- Agar plates of Mueller-Hinton medium (*5 per group*)
- Sterile swabs (one per student)
- Sterile Erlenmeyer flasks (250ml)
- Twenty four hour old cultures (in Tryptic Soy Broth) of *Escherichia coli, Staphylococcus aureus* and *Klebsiella pneumonia* (One set per group)
- Bunsen burner and lighter.

Preparation of garlic extract paper discs

Instructions on the preparation of garlic extract discs were provided for each student. Student volunteers from the groups prepared the extract based on the following procedure:

- Blend 10 grams of garlic cloves in 100ml of sterile de-ionized water at high speed for one minute.
- Strain the slurry through sterile cheesecloth, and then filter through sterile filter paper into a sterile 250ml Erlenmeyer flask.
- Pipette about 15ml into a sterile Petri-dish
- Use a sterile forceps to dip paper discs into the extract and allow for brief drain age on sterile filter paper.

Plate inoculation, antibiotics and garlic extract application

Each group member was given the opportunity to inoculate a different bacterial species to a Mueller-Hinton agar plate. Plates were seeded using sterile BBL cotton swabs. The tips of swabs were dipped into 24 - hour-old cultures of each species and spread over the surface of the agar plate. After a demonstration, each group member used the BBL multi-disc dispenser to apply discs of the different antibiotics from the ampoules onto the seeded plates. (Where a dispenser is not available, discs may either be ejected directly from each ampoule, or may be pushed out using a dissecting needle or any other pointed instrument). The plates were placed in a refrigerator for about 10 minutes after the application of the antibiotic discs to facilitate the diffusion of the antibiotics into the medium while bacterial growth is delayed.

The students then prepared the garlic extract disc as described above and placed it at the center of the plate with the conventional antibiotic discs. The plates were then incubated at 35^{o}C until the following class meeting (approximately 48-hours). Thereafter, students measured the zones of inhibition with a ruler and recorded their measurements. For each antibiotic or garlic extract discs, class averages of inhibition diameter were calculated for each species. They then compared the inhibition zones of the garlic extract with those of the other antibiotics used.

Results

The table on the following page represents the results of student measurements of the inhibition zones.

CLASS AVERAGES OF DIAMETER OF INHIBITION ZONES BY GARLIC EXTRACTS AND CONVENTIONAL ANTIBIOTICS. (millimeters)						
	Erythromycin	Kanamycin	Neomycin	Novobiocin	Tetracycline	Garlic Extract
Escherichia coli	11.0	19.0	19.0	14.0	23.5	17.0
Klebsiella pneumoniae	8.6	20.0	16.6	13.0	17.6	12.6
Staphylococcus aureus	21.6	21.3	21.3	27.5	29.0	21.6

Table 1. Summary of class report for comparative zones of inhibition of bacterial growth by conventional antibiotics and garlic extract.

The photographs in **Figure 1. (a-c)** show sample plates of garlic extract inhibition (center) as compared to the inhibition of conventional antibiotics.

Figure 1. (a) *Escherichia coli*

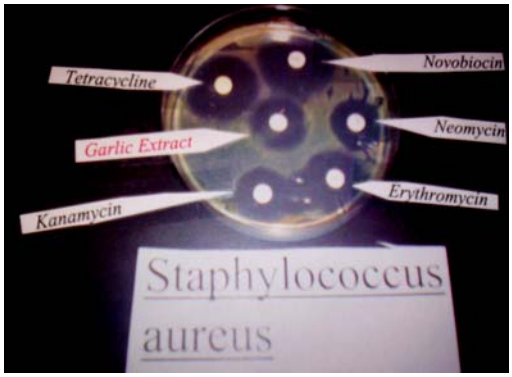

Figure 1. (b) *Staphylococcus aureus*

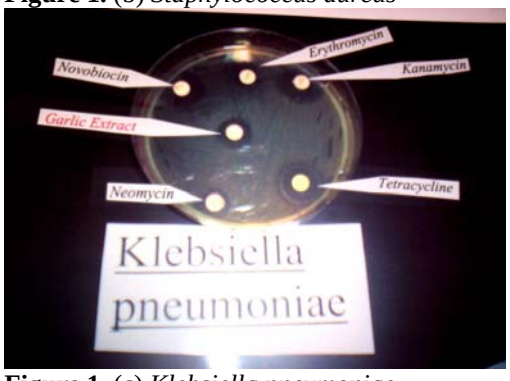

Figure 1. (c) *Klebsiella pneumoniae*

Evaluation Tool

The tool for evaluation was designed to test the students' general awareness of antimicrobial phytochemicals before and after the exercise, making simple water extraction from plants, and concrete awareness of possibilities of using plant extracts for therapeutic purposes. An open ended question about their experience with the exercise allowed them to make comparison between garlic extract and the antibiotics and to freely make other comments about the exercise.

Other questions tested a variety of reactions from the students about the exercise in general and the concept of plants as source of antimicrobial agents.

Students were also asked to indicate their future interest in searching for additional antimicrobial substances of plant origin.

The following evaluation questions were given to the students.

Key:

5= Strongly agree;

4= Agree

3= Agree with reservation

2= Disagree

1= Strongly disagree

1. After the exercise, I had acquired the skill of making extract from plants	[1] [2] [3] [4] [5]
2. The possibility of obtaining medicine from plants became more apparent to me	[1] [2] [3] [4] [5]
3. I am now more curious about other uses of plant extracts for medicinal purposes	[1] [2] [3] [4] [5]
4. I think this is a useful supplement to the lab on antibiotics	[1] [2] [3] [4] [5]

Result of Students' Responses

This exercise was first given during a previous year without data collection. However, the data below were collected from 30 students, in Introductory Microbiology and Botany courses in the following year. The students were either first or second year nursing, science or liberal arts students.

Question	Mean score	SD
Acquired the skill of extraction	3.1	2.4
Possibility of more plant antimicrobial became more apparent	4.2	0.4
More curious about other medical uses of plant extracts	4.4	0.7
Added exercise a useful supplement to existing one.	4.4	0.2

Table 2. Summary of students' response to the exercise on antimicrobial action of garlic extract

Overview of Students' Comments

Pre-lab, students were asked if they thought it was necessary to search for additional antimicrobial agents. All the students were positive about this. Reasons given include the need to use them to complement existing ones, and the widespread development of resistance to many of the existing antibiotics by pathogenic organisms.

After the results of the experiment had been read, students were asked what they considered their most significant learning experience in the exercise. Most of the responses showed that a practical demonstration of microbial inhibition by plants was their most significant learning experience. For example, one student commented that "*I had no idea you could make antibiotics from plants.*" Other comments conveyed the same general idea. An interesting point of view of one student was that if plant antimicrobial substances were used in medicine and microorganisms acquired resistance to them, plants could "get overrun and killed" Some students also saw the opportunity for obtaining antimicrobial substances from plants that could help combat the prevalence of antibiotic resistance.

Note to Instructors

The part of this exercise involving the conventional antibiotics is usually performed in most introductory Microbiology classes. The addition introduced here could enhance students' interest in the subject matter. The exercise could be extended to many other plant extracts, with the precaution that the extraction method, as well as treatment of the extract before loading to the disc may differ considerably. For example, licorice root has been found to be effective only in moderate amounts against only *Staphylococcus aureus*, among the bacteria tested (Not reported as part of this exercise).

Also, fresh samples of garlic should be purchased for each experiment. This does not imply that garlic samples could lose their allicin content, as long as they are not crushed, but this is a precautionary measure to ensure the success of the experiment. Moreover, garlic extract should be loaded on the blank paper discs as soon as possible after blending, since the active ingredient is well known to lose most of its potency with time after extraction, especially at higher temperatures. Commercially prepared blank discs should be used instead of using regular filter paper discs cut with a hole-puncher to carry the garlic extract. Based on preliminary trials, commercially prepared blank BBL discs worked better. Attention should be paid to the garlic to water ratio so that there is an adequate amount of the active ingredient. Sterile BBL discs of the same diameter, soaked in sterile distilled water could be included as a negative control in each plate.

Emphasis should be placed on care in handling microorganisms. This exercise is suitable for students of Introductory Microbiology who have acquired basic skills in handling microorganisms. It has also been used, mostly as a demonstration, for students of

Introductory Botany to reinforce the concepts of secondary plant metabolites and their possible uses.

Conclusion

Overall, students' responses were quite favorable. Most students did not participate directly in the extraction. Consequently, they responded to the question on the extraction aspect more negatively. This exercise stimulated the students' interest in the search for antimicrobial substances of plant origin. They were also optimistic about combating antibiotic resistance through such discoveries. The addition of plant extract to the exercise was considered useful by 100% of the students.

There is a strong indication that the added aspect could positively affect students' attitude and interest in screening for phytochemicals for therapeutic, especially antimicrobial purposes. The exercise is recommended as a useful addition to what is currently demonstrated, especially for students in the health-related sciences, as well as all students of Microbiology and Botany.

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The Autopsy of Squirrel Doe

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Abstract: Introductory biology laboratory experiences frequently rely on preserved chordates for anatomical study. Unfortunately, these preserved organisms rarely reflect the appearance of a living creature. Since community colleges are generally prohibited the use of live chordates, this paper describes the autopsy of a "road kill" squirrel to facilitate the learning experience of biology majors. In addition to the improvement in basic anatomy test scores, the students also learned teamwork, microbiology assays, and hazardous material protection.

Key words: animal dissection, dissection alternative, road kill

Introduction

The Owensboro Community and Technical College offers a two-semester course for biology and pre-professional majors. The first semester covers cell biology, metabolism, genetics, embryology, and immunology; whereas, the second semester examines evolution, botany, and zoology. Each course has a three-semester hour lecture component and a two-semester hour laboratory experience. This series has been used for twelve years and has never had more than one section of each. The class average is 15 students. The chordate section of the zoology portion of the laboratory consists of traditional methods such as the use of models and the dissection of preserved chordates. The rationale for the use of preserved chordates centers on the perceived need for future scientists and health care professionals to be familiar with the anatomy and physiology of such organisms.

Unfortunately, preserved chordate dissection exercises frequently fail to provide desired education outcomes as preserved animals show little evidence that they were once living organisms. Such preserved animals show no signs of disease, effects of aging, do not bleed,
feel like plastic, and smell like disinfectant. For a true experience of chordate anatomy and physiology, students might participate in the necropsy of a laboratory-euthanized chordate such as a rodent, cat, or dog. However, legal restrictions prevent such experiences in introductory laboratories in a community college setting. Community colleges generally do not have the appropriate facilities for the housing and care of chordates and are therefore prohibited such use. This paper introduces the idea that fresh road kills certainly may serve as an effective and desirable pedagogical alternatives to chemically preserved chordates.

Methods

In an effort to explore alternatives to the traditional use of preserved animals for dissection, science majors in biology lab were provided the opportunity to conduct an autopsy of a wild squirrel found in the college's parking lot. Based upon the lack of rigidity of the corpse, Squirrel Doe was found within two hours of death.

Students should be given a brief presentation on the collecting and use of road-killed animals. This should include information about the collecting procedures from the State Department of Natural Resources (DNR). An individual collecting road kills is required to have a Salvage Permit. The DNR will also indicate which animals cannot be collected. Collected animals should be placed in plastic bags and upon arrival at the school placed in a refrigerator or freezer depending on the period of time between collecting and use. Students should wear plastic gloves when collecting an dissecting organisms. The

organism and its parts should be disposed of in the proper manner after examination.

The carcass was immediately placed on ice and rushed to the lab where the OCTC radiography instructor took x-rays. Students were permitted four laboratory meetings to conduct the autopsy of Squirrel Doe. To pique interest and give the students focus, students were asked to find the cause of death. Using a photographic atlas of squirrel anatomy for reference, students were instructed to identify all major organs and bones. Students were instructed in appropriate biohazard safety precautions and additionally instructed to perform a microbiology exam of the body cavity, conduct a parasite search, and then from all the information gathered, determine the cause of death.

X-rays showed a young male with no major broken bones except for two caudal vertebrae and a slight splintering of the right scapula. Careful external examination of the squirrel showed a bulging of the nose, left eye, left ear, and mouth (both incisors were broken). A large tear extended from the anus to the scrotum. The testes were full of blood and the bladder was ruptured having released urine into the abdominal cavity. The lower right appendage appeared to have been broken and the right ear lobe torn (probably due to an old injury as the tear was healed). The last sacral vertebra directly above the tail protruded through the skin and appeared damaged.

Starting at the tear from the anus to scrotum, an incision was made vertically to the juncture of the trunk and leg allowing the skin to be spread apart along the inside of each leg. By making subsequent incisions around each ankle, the skin was easily removed from each hind limb. Upon removal of the skin, internal injuries were apparent: the abdominal cavity was torn, the large intestines protruded through the muscular wall of the abdomen and the gall bladder was ruptured. Careful examination of the squirrel's internal organs revealed that the large intestines had ruptured causing massive amounts of internal bleeding. The internal organs were then carefully removed, weighed, and dissected to rule out further injuries. As the fragments of the skull were removed, a massive amount of blood was revealed in the left cerebral hemisphere which indicated a severe hemorrhage.

Results

From the autopsy, it was concluded that the cause of death was due to massive internal and cerebral hemorrhaging. Although Squirrel Doe's organs were examined for parasites and bacterial infection, nothing unusual was discovered. Anonymous comments from five of the student participants follow.

"During the autopsy on the squirrel, I learned about different perspectives of looking at death. I may have already known that it was the end, but some of the time it depends on how you reach it. We can always say 'I hit some squirrel or rabbit today' and move on with our lives. Do you ever wonder how that animal actually died? Did the impact kill it instantly or did it suffer first and then die? I learned that it takes a lot of work to do an autopsy on a small animal; therefore, it must take longer to do an autopsy on a human being. Probably because of the squirrel's diet of nuts and berries, the squirrel was pretty clean of parasites. I believe it would be hard to catch a parasite from a nut or a berry."

"I thought that the whole process was extremely interesting. Actually learning the step-by-step procedure from taking length and weight measurements, to having x-rays, to the weighing of all the organs, and all of the gross anatomy was instructive. I found it really interesting that just from a few abdominal swabs, we could determine that *E.coli* was spread throughout the entire abdomen. Also, I gained more respect for animals. They are so very similar to us (we are animals after all). I felt sympathy for Squirrel Doe and have reduced my driving speeds and haven't eaten meat since."

"While doing the autopsy on Squirrel Doe, I learned that sometimes an x-ray is not enough to reach conclusions as the cause of death. Once we cut open Squirrel Doe, we noticed that there had been considerable bleeding. He also had a fractured skull that wasn't noticeable on the x-ray. I came to the conclusion that looking for flukes and parasites is an extremely tedious job because I searched long and hard for one but never did find one."

"I learned exactly what does happen to an animal after it has been hit. You will see a dead animal on the side of the road and think, 'Oh, there's more road kill' but you do not really stop and think about the trauma the animal had to go through. By opening up Squirrel Doe, I saw first hand the extent of the damage. It made me feel very sorry (more so than before) for road kills. I also learned how various organs work. When the stomach was opened and the contents inspected, I could see how the food looked once it enters the stomach and had begun the digestion process. Looking at the organs, I experienced the process for myself. This was different from looking at a prepared slide since I got to see the contents naturally without any dyes or preservatives."

"I learned many new and interesting things from our autopsy of Squirrel Doe. I learned that many animals from the order rodentia have similar structures and can be used in comparison to each other. I learned

that when something is dead it may look okay on the outside but it might be very messed up on the inside. I learned that a squirrel is very complex inside and that it has similarities to humans. I learned how autopsies require more than just dissection; they include x-rays and use of microscopes to see what is inside the organs. It was an adventure to be able to explore the insides of a once living creature to see what could have caused its death."

Conclusion

From an instructor's perspective, this autopsy was a success. The participating students conducted the autopsy, parasitic exam, bacterial cultures, and drew conclusions from the x-rays. They also studied the squirrel for more time than the scheduled lab requirement. Students spending extra time in lab are a rare occurrence. Clearly students who were willing to go beyond the amount of time required for lab indicates the students felt engaged with the assignment.

The autopsy of a fresh specimen is of more educational value than the dissection of a purchased and preserved organism. The internal organs are natural in appearance, blood clots are present, culture studies can be performed, and the students are intrigued by the novelty of the project.

Finally, the chordate exam scores were higher than any obtained previously with the usual dissection methods, indicating a better understanding of anatomy. For example, the chordate laboratory practical exam requires that students identify all major organs and bones. A ten-year review of scores revealed an average of 73% on this exam but the class, which conducted the autopsy of Squirrel Doe averaged 86%.

Introductory biology laboratory exercises frequently rely on rote memory and do not always spur students to think critically. But, the students accomplished more than just memorization of body parts. The exercise required teamwork, careful dissection, microbiological assays, and a creative interpretation of the data to reconstruct the cause of death. Yes, the students were able to effectively identify internal organs and bones, but the cumulative effect was a true educational experience.

Honorary Life Award

The **ACUBE Honorary Life Award** is presented to ACUBE members who have made significant contributions and/or service to ACUBE and the advancement of the society's mission. The award is presented at the annual fall meeting of the society.

If you wish to nominate a member of ACUBE for this award, send a Letter of Nomination citing the accomplishments/contributions of the nominee and a *Curriculum Vita* of the nominee to the chair of the Honorary Life Award committee:

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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. The John Carlock Award provides partial support for graduate students in the field of Biology to attend the Fall Meeting of ACUBE.

The applicant must be actively pursuing graduate work in Biology. He/she must have the support of an active member 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.

Applications, in the form of a letter, can be submitted anytime during the year. The application letter should include a statement indicating how attendance at the ACUBE meeting will further her/his professional growth and be accompanied by a letter of recommendation from a member of ACUBE. Send application information to Dr. William J. Brett above.

Dye Degradation by Fungi: An Exercise in Applied Science for Biology Students

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***Abstract*:** An easily implemented practical exercise in applied science for biology students is presented that uses fungi to degrade an azo-dye. This is an example of bioremediation, the employment of living organisms to detoxify or contain pollutants. Its interdisciplinary nature widens students' perspectives of biology by exposing them to a chemical engineering process. It also demonstrates the use of biological organisms to degrade a relatively complex chemical, Amaranth. This azo-dye, which is vibrant red across a broad pH range, is safe to employ in the student laboratory. Various species of white rot fungi of the genus *Trametes* are able to degrade Amaranth to differing degrees, permitting comparative studies. This laboratory exercise involves observations that occur over the course of 3 days, but may be shortened or lengthened, as desired. Results involving decreases in color intensity may be obtained by making comparisons to color standards or by using a spectrophotometer. In our example, we suggest using species of white rot fungi, including *Trametes versicolor* and *Trametes pubescens*. The complexity of the lab is easily modified to challenge students of diverse backgrounds because the degree of difficulty of the exercise is adjustable to suite biology non-majors or majors in introductory through advanced courses.

Keywords: Bioremediation, applied science, interdisciplinary exercise, biology non-majors, biology majors, mycology, white rot fungi, fungal culturing, azo-dye

Introduction

Major areas of concern when instructing college and university biology students include how to effectively demonstrate that basic information leads to applications (Clarkeburn et al., 2000) and how interdisciplinary approaches (Barisonzi and Thorn, 2003; Zoller and Scholz, 2004) improve the understanding of biology (Fields, 2001; McCarthy, 2004). Students should be engaged in interesting exercises that teach them the value of basic knowledge (Hughes, 2001; DebBurman, 2002) in society (Key and Nurcombe, 2003). This laboratory exercise was originally designed for a course in bioremediation, the use of organisms to dispose of environmental contaminants, but is equally adaptable to introductory courses involving aspects of environmental biology.

The theme of the lab exercise is the investigation of how white rot fungi can be used to degrade a dye similar to those used in the textile industry, where the dye waste problem is estimated at over eight hundred thousand tons annually (Wesenberg et al., 2003). The exercise follows the course of dye decoloration by species of the genus *Trametes* involving the degradation of the azo-dye, Amaranth. A degradation pathway has been proposed by Champagne and Ramsay (2005) in which the azo bond may be cleaved first (Martins et al. 2003). Because these fungi grow into spheres in liquid culture, they can be counted to provide an estimate of biomass. Dye is added to the cultures and the loss of color is monitored over a period of days; thereby, color change is an indicator of the rapidity of the process while making comparisons between species. Details of the laboratory preparation for instructors are provided. The students' part of the exercise requires less than one hour for initial setup, and measurements at each time point take about 15 minutes. Required materials and organisms are readily available from scientific suppliers. Conventional laboratory glassware in the form of flasks, liquid measurement and transfer apparatus, and a platform shaker are required. Instructors need some training in microbial culturing techniques, although the student laboratory exercise may be performed without the use of sterile technique.

Materials and Methods

Recommended Protocol

The following is a protocol that we have been using in our course. These may be modified as suggested in the Discussion section.

Fungal Species

Species of the genus *Trametes* can be obtained from the American Tissue Culture Collection (http://www.atcc.org/) *e.g. Trametes versicolor*

ATCC Number: 64311 (turkey tail fungus), and by searching the catalogues at CABRI (Common Access to Biological Resources and Information) website (http://www.cabri.org/CABRI/home/index.html) *e.g.* *Trametes pubescens* Strain Number: CBS 396.90 from CBS (Centraalbureau voor Schimmelcultures) Utrecht, The Netherlands. We recommend obtaining strains of *Trametes versicolor* and *Trametes pubescens* which decolor Amaranth relatively quickly, whereas other species, such as *Trametes hirsuta*, are less active. A lab exercise involving two or more species enables the students to rank the species' effectiveness in bioremediation.

Storage and Culture of Fungi

Preparation of fungi by the instructors for the practical exercise requires the use of sterile technique. Plastic Petri plates and 50 mL screw capped tubes can be purchased sterilized in plastic sleeves. Glassware and other implements such as metal spatulas need to be sterilized prior to their use by autoclaving, or by washing in 70% ethanol:water and rinsing with sterile water, ideally in a sterile air laminar flow cabinet. Common means of sterilizing fungal culture media and water include boiling, pressure cooking, and autoclaving. In the latter case, culture media may be autoclaved in glass flasks capped with aluminum foil lids.

Fungal strains are grown on semi-solid Kirk's 1.2 AT medium containing Malt agar (30 g/ L) in 150 mm Petri plates, each containing 10-15 mL. The Kirk's 1.2 AT medium contains 1.2 g/ L ammonium tartrate (see Table 1; Kirk et al. 1978). Seal the plates' lids with Parafilm™ (Fisher Scientific) or plastic wrap. Allow the fungi to grow for 3-7 days at 25-30 °C after which these plates can be kept in a refrigerator for up to two months.

To prepare fungi for the student laboratory, small amounts are removed with a sterilized spatula from these storage plates as pieces of agar approximately 5 mm in diameter. These are placed in the center of fresh plates containing the same medium and incubated at 25 to 30°C.

Mycelial growth should be evident within one or two days and it will reach the edge of the plate in a few days. Before it does, take hollow tubes such as plastic drinking straws (sterilized in 70% ethanol:water) and press into and extract round agar plugs from the growing edge of each fungal species. Use different tubes for each species to place 20 to 25 plugs as inoculum into 100 mL liquid cultures of Kirk's 1.2 AT medium (no Malt agar) in 250 mL Erlenmeyer flasks (or similar containers) capped with aluminum foil lids down to at least 5 cm below the lip. Flame the lids with an alcohol or Bunsen burner and then place into a rotary shaker at 30 rpm or an oscillating shaker at 15 rpm for 4 days at 25-30 °C. The plugs will grow into spheres and should not break up under gentle agitation. The number of spheres is used to determine the amount of fungus in all subsequent samples.

Using a spatula or small spoon remove the fungal spheres from the flasks and place them into an open sterile Petri plate and use this as a source to inoculate the decoloration chambers.

Setup of Student Samples

Clear plastic fifty mL sterile screw-cap tubes (Fisher Scientific) are used as decoloration chambers. One to six fungal spheres are transferred into each chamber containing 15 mL of liquid Kirk's 0.2 AT medium (containing 0.2 g/ L ammonium tartrate) to which 20 ppm Amaranth dye is then added from a 100 X stock of Amaranth (0.2% in water), *i.e.* 150 µL in 15 mL. These tubes are tightly capped and placed on their sides in groups of four to six, held together with elastic bands. Incubation is at 25-30ºC with gentle shaking (15 rpm). In 1-5 days, the dye will decolor because low nitrogen and the azo-dye, itself, act to induce the lignin-degrading enzymes, peroxidase and laccase. When all species have decolored the Amaranth dye, they are ready for the student practical exercise.

Amaranth Decoloration Experiments

Each group of students is provided with a pair of samples for each species of *Trametes* in fifty mL tubes. Three or four groups may be permitted to pool their results if statistically valid comparisons are desirable. One tube of each pair is heat treated in a boiling water bath for one hour, allowed to cool, and employed as a negative control to see if any subsequent decoloration could be attributed to the non-biological composition of the media or the physical conditions of the experiment. These heat-treated controls may be prepared ahead of time. All tubes are then treated as follows. Amaranth was added as a 100 times stock (0.2%) to bring the concentration to 20 ppm, *i.e.* 150 µL in 15 mL, and the samples are returned to the shaker incubator at 25-30 °C.

Decoloration, *i.e.* degradation, can be monitored in a simple fashion by comparing the color of the tubes to a series of tubes of Kirk's media containing 2, 4, 6, 8, 10, 12, 14, 16, 18, and 20 ppm Amaranth dye using the same volume of 15 mL in the fifty mL tubes. This provides the advantage of not needing to remove a sample for measurement by spectrophotometer (see below), which means that sterile technique is not a concern, although it is recommended to open the tubes to provide fresh air to the cultures once a day. The sample times should include an immediate reading which assures that a proper amount of dye was added, and as many hourly readings over a 2 to 3 day period as is reasonably possible. When complete decoloration has occurred

in the fastest decoloring species after 1-2 days, a second addition of Amaranth may be added to the tubes and another set of data collected, if desired.

Alternative Spectrophotometric Method

Spectrophotometry can be employed as an alternative method to estimate Amaranth concentrations at an optical density of 523 nm and using Kirk's medium as a blank. Ensure that the volumes removed are small (less than 50 µL) to permit sampling, which may require more than ten time points over a three day period. Precision pipetting is critical for these small volumes. Also, avoid any flocculent material. Hamilton syringes sterilized with 70% ethanol or automatic micropipetters using sterilized disposable tips are recommended.

Discussion

We employ this lab in our course on bioremediation. It requires minimal resources and is easily set up. For example, in the absence of a shaking incubator, manual agitation of the cultures can be performed at room temperature. This can be as simple as a gentle rocking every 1-2 hours during the working day. In our course, all of the students attend the initial exercise period that involves the addition of dye to the fungal cultures and the first two readings, *i.e.* zero and one hour time points. After this, members of each group share the time-point readings, which they coordinate with the instructors.

The complexity of this lab can be modified to suit biology non-majors and majors at introductory to advanced levels. It can be simplified by reducing the number of fungal species. Conversely, the exercise can be made more complex by increasing species number, varying media composition, and modifying growth conditions such as using different pHs and temperatures. For example, the media may contain different levels of nitrogen (Swamy and Ramsay, 1999a) and metals such as copper and manganese (Swamy and Ramsay, 1999a; Galhaup and Haltrich, 2001). Other dyes may also be employed such as Tropaeolin O and Reactive Blue 15 (Ramsay and Nguyen, 2002), although precautions will be needed to avoid potential toxicity. In this way the laboratory exercise can be adapted to suit the experience level of the students.

Measuring enzyme activities over time can also be added to this lab. The relatively simple assays for laccase and peroxidase are described in Johannes and Majcherczyk (2000) and Wariishi et al. (1992), respectively.

The students may be required to tabulate the results (see Table 2), plot them and answer questions such as: What is the rate of dye degradation? or Which species is the most effective at dye degradation? Statistical analysis with more replicates can provide additional complexity. In an advanced course the student may be requested to submit a formal laboratory report containing the following sections: introduction, methods and material, results, and discussion.

Students appreciated seeing a useful bioremediation process that utilized recognizable wood fungi such as the turkey tail fungus (*Trametes versicolor*). They are exposed to a simple form of microbial batch culture in a biological engineering application and the effects of powerful degradation enzymes. This lab also highlights the enormity of the global dye-waste problem. The students indicated interest in implementation of this dye degradation at a larger scale and the biochemistry associated with the process. This exercise is interdisciplinary in nature and can be employed in biology, botany, environmental science and chemical engineering for majors and non-majors as well as in more focused bioremediation courses.

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The Biomes of Homewood: Interactive Map Software

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Abstract: To build a learning community, the General Biology faculty at Johns Hopkins University conducted collaborative, problem-based learning assignments outside of class in which students are assigned to specific areas on campus, and gather and report data about their area. To overcome the logistics challenges presented by conducting such assignments in a class of 300+ students, we developed a software environment in which faculty write and distribute assignments and student teams record and store observational data. Further, the software uses a map of the campus to assign teams to a specific area and to manage the data relevant to that area. Since students can view data submitted by all teams, the faculty have devised assignments requiring students to examine and compare data from one area to another, thereby promoting interaction among the student groups. Faculty and mentors review, provide comments, and grade the assignments. The mapping feature enables faculty to develop questions that build from previous years' data. General Biology student teams in AY 2005-2006, for example, will compare reported data gathered in 2004-2005 with their current observations. Further, data can be pooled from all of the Biomes to conduct a survey across the campus.

Introduction

The General Biology Course Design Project seeks to transform the undergraduate educational experience in the 300+ student General Biology course by invoking a number of pedagogical and technological changes (reviewed in Fambrough *et al.*, 2005). This course redesign project, funded by the Howard Hughes Medical Institute (HHMI) and supported by talented Hopkins University faculty and staff, supports the development of educational resources to be made available to the broader science community. To reach sound design solutions to foster such an environment, the team conducted a yearlong analysis of the course. The analysis process involved gathering qualitative and quantitative data from a number of different sources: students, General Biology course, course faculty, Biology department, other universities and courses, and current and/or emerging technologies and resources. Qualitative data were gathered through interviews, focus groups, surveys, and reviews while quantitative data were gathered through tests, surveys, and other formal reporting mechanisms (such as registration data, etc). Based on the findings of the analysis, the faculty and project team decided to tackle the following goals:

1. Increase student preparedness, knowledge acquisition and retention, and participation in the course (without increasing student or faculty load), in part through computer and web-based instructional resources.
2) Increase student motivation and engagement with the course material (in sum, get students to *enjoy* the course).
3) Enrich the learning experience for students by adopting rich, meaningful problem-based team assignments.
4) Enriching the teaching experience for faculty.
5) Develop a teaching framework and best practices for course redesign projects that could be applied to other large enrollment biology lecture courses.

The last goal addresses issues faced at many academic institutions: implementing and sustaining solutions after the initial grant funds are exhausted. Not being able to build new buildings for labs or to hire TA's to lead discussion groups; the team was faced with achieving the goals using existing resources.

Methods

To achieve the goals, the team developed the *Biomes of Homewood* software, a web-based, team collaboration tool used by faculty and students in the general biology course. Based on assignments the faculty piloted in smaller classes, the project team used the software to introduce active learning assignments. These assignments enrich student learning by requiring students to apply biology lecture and textbook material to actual areas on campus. Because of the logistics involved in managing a 300+ student course, students were placed in teams using the course management tool,

WebCT, team generator and randomly assigned to a particular region on campus (termed a biome), as represented on the map.

Assignments require students to apply concepts learned in class and from textbook material to complete simple weekly or biweekly tasks. Fall semester 2004 tasks included identifying producers, herbivores, carnivores, etc; examining effects of our recently emerged cicada brood; studying phylotaxy and leaf structure, and generally surveying the diversity of organisms within their "biome." Some of the activities are loosely based upon the book "Investigating Terrestrial Ecosystems" by Andrews & Moore (1986).

Much more than a homework tool, the *Biomes of Homewood* software enables faculty and students to accomplish a number of other tasks, including associating content and findings to a specific area on a map (in this case, a map of campus that has been divided into sections). Data can be collected at regular intervals throughout the semester and subsequent years to document changes occurring over time. With this feature, the biology faculty who currently use the map software plan to develop questions that build from previous years' data. General Biology student teams in AY 2005-2006, for example, will be asked to report changes about an area using reported data from 2004-2005 and the team's current observations. Data can also be pooled from all of the Biomes to conduct a survey across the campus. Since students can view data submitted by all teams, faculty devise assignments that require students to compare and contrast collected data from multiple biomes, thereby promoting interaction between the student groups.

The Biomes of Homewood Software

The *Biomes of Homewood* was written using a Rich Internet Application (Flash) that combines desktop functionality with the broad reach and low cost deployment of the web. Recognizing the need for ease-of-use, the development team programmed the *Biomes of Homewood* software to check the user's system for the necessary components: platform (Mac or PC), browser type and version, and Flash version. Users who do not have compatible systems are guided to online resources for downloading necessary files. To ensure security yet provide ease-of-use, the program uses the university authentication system; faculty and students login to the program using their university ID's and university-associated password. Navigation within the program occurs by using breadcrumbs found at the top of the active window (Figure 1).

Figure 1. The Biomes of Homewood Map

Student Functions.

Once students login, *The Biomes of Homewood* homepage displays the Course Name, Actions, Current Assignments, a Campus Map, a list of team members and their email addresses, and an aerial photograph taken from Arc-GIS (www.esri.com) displaying their assigned biome area (Figure 2).

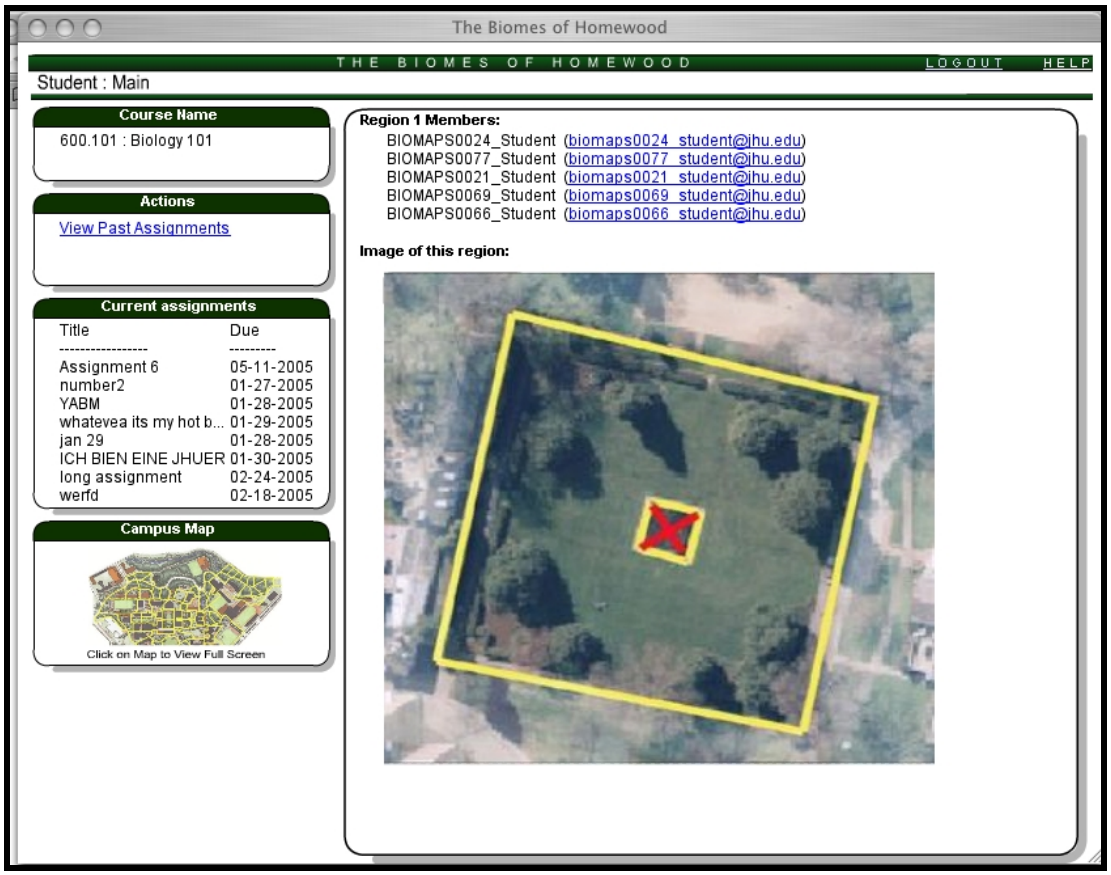


Figure 2. The Student Homepage Within the Interactive Map.

Actionable items on this screen include viewing current and past assignments, seeing a detailed map of all the biomes within the campus, and emailing their teammates by clicking directly on the email links. Selecting "Current Assignments" allows students to see all posted assignments that are due. Selecting one of the current assignments takes students to a page where they can view the assignment and media files (jpeg, swf, fla, mpeg) attached to the assignment by the faculty (see below). To enable students to print the assignment (thus enabling them to reference the assignment when in their biome or when away from their computer), they can view the assignment in a web browser. Viewing "Past Assignments" allows students within their assigned biome to see all their past assignments as well as their related scores. Selecting individual assignments allows students to see the completed assignments, comments and scores for each question in the assignment.

By selecting the Campus map, students can select any biome within the map and can view students' responses to past assignments. This functionality combined with comparative assignments written by faculty encourages interactivity between the students; the collection of students' responses in effect creates a "bioblog" of data related to the biome areas.

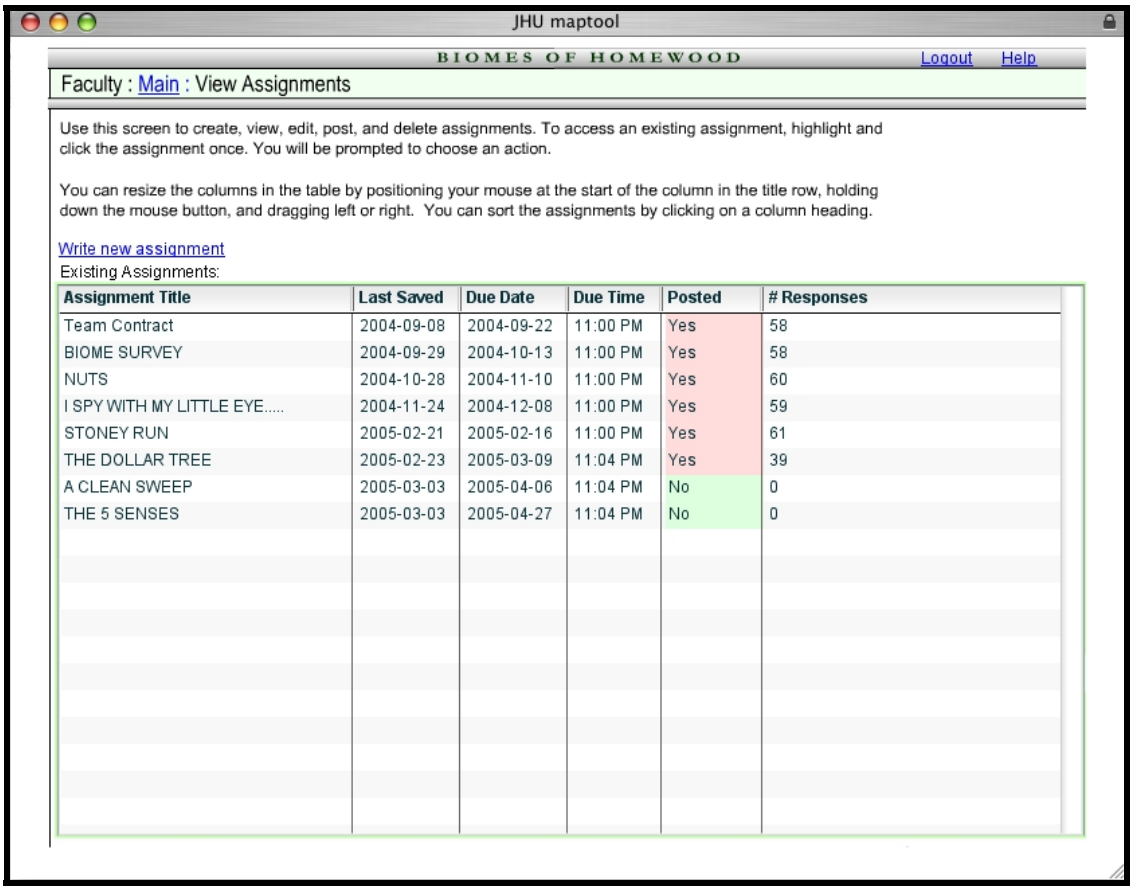
Faculty Functions.

After logging in to *The Biomes of Homewood*, faculty have three choices: View Assignments, Grade Assignments, and Management. "View Assignments" allows faculty to write new assignments, edit assignments, view existing assignments and post assignments. Creating new assignments is simple and straightforward: faculty enter assignment titles, directions, and questions in textboxes (adding additional textboxes as necessary via an "add question" button). Questions are added

one at a time with points allocated for each question by the faculty member. These scores can be weighted if necessary and the program will automatically display the weighted percentages.

To guide graders and student mentors, the program allows faculty to enter comments or correct answers to the questions in associated text fields that appear beneath each question. Faculty can augment questions by uploading media such as pictures, flash movies and sound files via a media uploader. This media is maintained in a faculty library that can be used in other assignments.

Finally, faculty set a due date and time for assignment submissions; the program will not accept entries posted after the deadline. Assignments can be saved (to allow revisions before posting them) or posted to students. Saved assignments can be edited by selecting an assignment from the list (Figure 3) and then selecting the "edit assignments" function. Faculty can edit posted assignments but will receive a warning that they are editing a live assignment that students may have already made entries to. By selecting an assignment and then viewing the assignment, the faculty member will preview the assignment exactly as it will appear to students.



Assignment Title	Last Saved	Due Date	Due Time	Posted	# Responses
Team Contract	2004-09-08	2004-09-22	11:00 PM	Yes	58
BIOME SURVEY	2004-09-29	2004-10-13	11:00 PM	Yes	58
NUTS	2004-10-28	2004-11-10	11:00 PM	Yes	60
I SPY WITH MY LITTLE EYE.....	2004-11-24	2004-12-08	11:00 PM	Yes	59
STONEY RUN	2005-02-21	2005-02-16	11:00 PM	Yes	61
THE DOLLAR TREE	2005-02-23	2005-03-09	11:04 PM	Yes	39
A CLEAN SWEEP	2005-03-03	2005-04-06	11:04 PM	No	0
THE 5 SENSES	2005-03-03	2005-04-27	11:04 PM	No	0

Figure 3. The Faculty View Assignments Screen.

In the "Grade Assignments" section, faculty select an assignment to grade from a list of assignments. With a specific assignment selected, a display of all student entries appears. After selecting a student submission to grade, faculty can provide feedback to each question and can assign a score to the answer. The program automatically tabulates the final score for the assignment, and faculty can release the grades if desired. While students can see other teams' assignments and faculty feedback, they cannot see the grades earned by other teams.

For courses with large enrollments or where students may be organized into teams faculty members may want to search for a particular student by name or ID. This is accomplished in the "Management" section of the faculty functions. Faculty can also download grades as an excel file for incorporation into an online gradebook, such as that in a course management system.

Teams.

Grouping the 300+ students into teams and using the *Biomes of Homewood* software enable the general biology faculty to conduct rich, substantive active learning assignments without imposing onerous grading and administrative tasks on themselves. Further, mentors - upperclassmen who

previously completed the General Biology course - assist in managing student needs and assignments. In particular, mentors act as facilitators to manage issues pertaining to interpersonal skills and team dynamics (Remocker & Storch 1992), help students understand team assignments and content, and provide substantive, constructive feedback to student assignments. Mentors have limited faculty access to the *Biomes of Homewood* software. While they cannot compose or edit assignments, they can view student teams' answers and can provide feedback and guidance. If appropriate and desirable, mentors can even grade student submissions. Mentors do have access to the "Management" section to view individual student records but cannot access the grades since the grade generator is password-protected.

Evaluations

Team Self Evaluation

As part of one of the assignments, students were asked about the following questions regarding teamwork and team dynamics. (Figure 4.) The questions were based upon Team Checkpoint (2001) from Boston University.

By having the student teams address these questions it helped them to identify areas in which their teams were weak. Goal setting, listening, trust, feedback and handling conflicts were not identified as being major issues for the teams. Decisions were sometimes problematic partly due to a lack of communication between team members and several teams indicated that they would change their method of communication to address this problem.

1. Outlining team goals and working as a team to achieve those goals.
2. Listening: Do team members listen to one another
3. Trust in teammates.
4. Giving feedback to teammates.
5. Handling conflicts.
6. Making decisions.
7. What procedures would you change for next semester i.e. decide on a fixed meeting time, change method of communicating with team members, reassign tasks to team members etc.

Figure 4. Topics on Teamwork and Team Dynamics

Pre- and Post-Surveys

Students were asked to complete an online survey using Zoomerang (www.zoomerang.com/, MarketTools, Inc.). Questions were designed as Personal Perception Indicators (PPI), a tool often used to assess the impact educational technologies have in instruction. The tool measures changes in growth, as reported by students. Given twice during the semester, the PPI compares students' perceptions about their knowledge, skills, and abilities pertaining to a specific topic at different points in time.

For the general biology course, the faculty used a five-point Lichert Scale PPI questionnaire regarding general biological concepts and environmental principles at the beginning and end of the semester. A sample question and the students' response are shown on the following page. (See Figure 5.)

Identify and explain examples of symbiosis within a biome.

	Low				High
Knowledge	1	2	3	4	5
Experience	1	2	3	4	5
Confidence	1	2	3	4	5

This would mean that

- I have a great deal of knowledge (response of 5) about identifying and explaining examples of symbiosis.
- I have an average amount of experience (response of 3) with identifying and explaining examples of symbiosis.
- I am not confident (response of 1) in my ability to identify and explain examples of symbiosis.

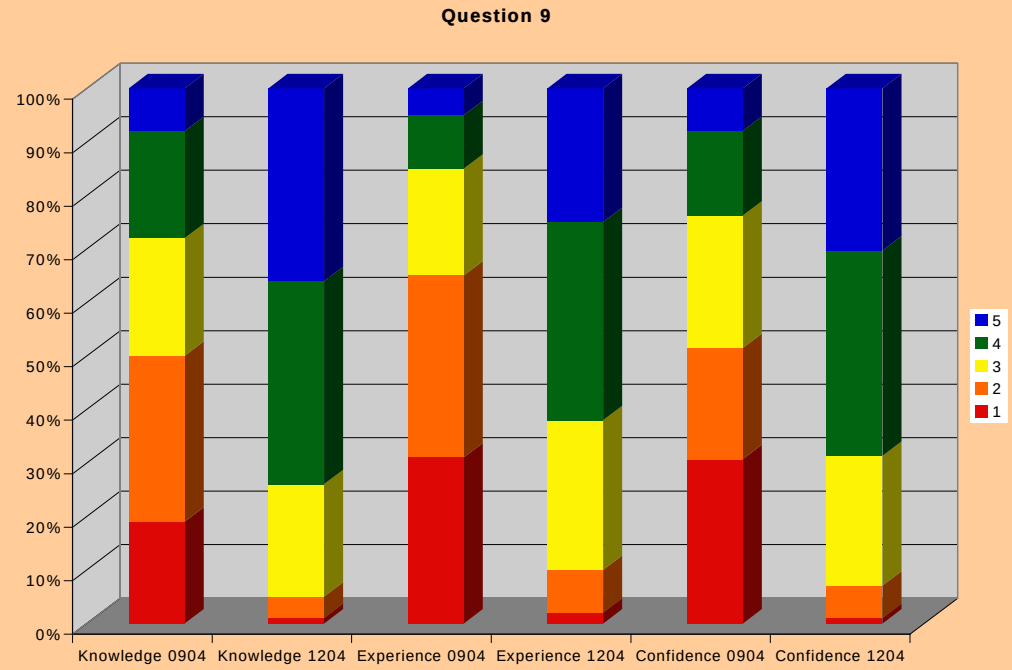


Figure 5. Student Pre- and Post-survey Question

In the pre-survey (0904) approximately 50% of students responses scored low (1's and 2's) on the Lichert scale and less than 30% scored themselves high (4's and 5's) on the Lichert scale. At the end of the semester, the post-survey (12-04) reveals less than 10% of students scored themselves low while over 50% of students scored themselves high in knowledge, experience and confidence regarding the biological principles they were asked to investigate within their assigned biome. Additional questions from this survey are available on request. Some biomes assignments were on topics *not* covered in class, and survey results were similar, thus indicating that the improvement was a result of performing the assignments themselves.

Focus Group

The JHU Center for Educational Resources, which supports faculty in the development of methodologies for the assessment of student learning in undergraduate education programs and initiatives, convened a focus group of 10 students at the end of the semester.

Students were interviewed about the Biomes of Homewood software and the assignments associated with it. Examples of the questions included in these interviews follow.

1. Do you like the Biomes assignments? Why or why not?
2. What do you think about the team aspect? How has it been working in a team and having to rely on other people?
3. Have the Biomes assignments helped you to form friendships, study groups or study partnerships?
4. How would you compare the Biomes of Homewood assignments with the regular weekly individual assignments?

Response: They take longer to complete:
- coordination 50% of time involved
- meeting 10%
- doing assignment 20%
- submitting 20%

Figure 6. Interview Questions.

The initial goal of the faculty members for this project was to create a vehicle by which students applied material from classroom lecture and the textbook to explore and appreciate the biological world around them. One student enthusiastically commented that she enjoyed getting outside of the classroom and appreciating the biology of the campus:

> "I can see what Dr. Fambrough was talking about when he said we should appreciate nature. These assignments actually get me out in the world, looking at trees, and enjoying the environment. I like them [the assignments]."

However, other students did not see the immediate relevance of the assignments to the content in class. Instead, they wanted faculty to state explicit connections between course material and assignments, even to be tested on the biomes material in class exams. For these students, the assignment grades were not sufficient in and of themselves.

The team aspect of the assignments was difficult for the students. In general the PPI questionnaire results indicate neutral to good ratings pertaining to team dynamics. Some teams were very well organized. These teams appear to have older and/or more seasoned students in them who help mitigate team difficulties. A solid contract developed by the teams as part of the first assignment helped these teams operate well. Some people formed friendships as a result of the Biomes project: one group, composed of 5 members all born in a different country who had never met before, forged strong friendships that would have been unlikely had they not worked together. Students do sit with group members in class but they generally study with their own friends. Noted difficulties for all teams include trying to find a common time to meet and communicating with other members. These issues, pertinent in all walks of professional life, took up most of the groups' time. Further, team assignments often have several non-participants (Walsh et al., 2005). In the general biology class, between 4-10 students did not participate in each assignment. The mentors, who were assigned 3 teams each, helped teams manage problem members, organize meeting times, and obtain equipment needed to complete assignments.

Results and Discussion

Students' learning has been deepened and enriched as a result of using the *Biomes of Homewood* tool. The *Biomes of Homewood* software has been effective in organizing students into teams, relaying contact information to the teams, and allowing students to complete assignments via the tool. All teams have been able to successfully complete all assignments in a timely manner. Unexpected, yet logical, results of using the tool are (1) improvements in students' ability to work in teams, and (2) improvements in students' time management skills. Working in teams necessarily requires students to grapple with issues of equity in contributing to and managing workloads. Students must collaborate closely in meeting deadlines, as the software prohibits submissions past the assignment deadline.

From the faculty perspective the *Biomes of Homewood* increased student motivation and engagement with course material; in sum, it allowed students to enjoy the course more and to develop a better appreciation of biology and their environment. Assignments that actually make students go out into the real world to look and find examples of organisms and topics covered in class provide an invaluable experience.

Overall the faculty thought that the tool enriched the teaching experience of the course while not placing any undue load on the faculty to prepare and submit assignments. The low number of students who actually missed a biome assignment indicates that student participation was high in this project, which helps student preparedness and knowledge acquisition. This tool helped us develop a teaching framework and best practices approach for course redesign projects that could be applied to other large enrollment lecture courses.

Initially built specifically for biology, the *Biomes of Homewood* tool currently applies to biology and environmental sciences. The team is developing the tool to accommodate content from any discipline. Medical faculty, for instance, could use an anatomical drawing of the circulatory system and have students or researchers enter data about specific points in the human body. Or, Astronomy and Physics faculty could use a map of the solar system and enter data about specific points on the map. Further information about the *Biomes of Homewood* and an online demo are available at http://www.cer.jhu.edu.

Acknowledgements

This project funded by a Howard Hughes Medical Institutes grant to Johns Hopkins University for enhancements to undergraduate science education.

We would like to thank the work of student graphic designer Mike Huerta and student programmer Lee McDaniel. We also would like to thank Rebecca Pearlman, Allen Shearn, Richard E. McCarty and Doug Fambrough, the faculty involved in teaching the General Biology course.

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