Descriptive Account

Teaching the Nature of Biotechnology Using Service-Learning Instruction

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Abstract

A 2-credit service-learning biotechnology course designed as a general education elective for students of all majors and at all levels was offered as an 8-week, half-semester course. The course met for a total of 3 hours of lecture/discussion and 2 hours of service-learning workshop weekly, during which students participated in discussions about peer-reviewed articles, group problem-solving exercises and reflective journal writing. A service-learning project related to biotechnology and addressing the educational or programmatic initiatives of a local non-profit organization and a service-learning portfolio are required elements of the course. The service-learning project required completion of agency brochures or advocacy letters, or participation in the planning and presentation of a community round table discussion on biotechnology-related issues. Based upon comparative analysis of pre- and post-course surveys, students' knowledge of biotechnological methods and practical applications of biotechnology increased significantly. Furthermore, students report a greater understanding of the societal implications of the global utilization of biotechnology.

Keywords: biotechnology education, service learning, active learning

Introduction

Recent advances in the application(s) of molecular biology and biotechnology techniques to pressing social issues such as hunger and malnutrition, including attempts to increase food production levels and nutritional value, have been met with skepticism and grave concern by the public. Much of the debate surrounding the use of biotechnology has centered on genetically modified organisms (GMOs). Dissenting views about the benefits and drawbacks of the products of biotechnology are prevalent in all forms of media. To assess critically the widely discussed potential promises and perils of biotechnology applications, the public will need a greater understanding of the scientific bases and prospective applications of biotechnology. This increased knowledge will require the implementation of new, engaging educational paradigms by scientists and science educators (Alberts and Labov, 2003).

In a recent survey of undergraduate students, Sohan et al. (2002) found that a greater percentage of students rejected the use of biotechnology than those approving of its use. Notably, this survey revealed that increased knowledge about biotechnology was positively correlated with affirmative attitudes and

perceptions about the technology (Sohan *et al.*, 2002). There are a number of different pedagogical approaches that encourage active learning and critical thinking skills – the skills that will be necessary for students to arrive at an increased, intimate knowledge about biotechnology. Some approaches that have been employed to improve student knowledge about biotechnology include using case studies (Colavito, 2000, Dori *et al*., 2003), having students review primary literature writings (Flores and Tobin, 2003), assigning group research projects (Thomas *et al.*, 2001) and utilizing student debate (Lindell and Milczarek, 1997).

Service learning, an active-learning pedagogical approach, offers the unique advantage of dynamically engaging students in the personal application of newly acquired knowledge about a subject to real world problems. As formally described by the National Service-Learning Clearinghouse,

> *"Service-learning combines service objectives with learning objectives with the intent that the activity change both the recipient and the provider of the service. This is accomplished by combining service tasks with structured opportunities that link the task to self-reflection, self-discovery, and the acquisition and comprehension of values, skills, and knowledge content"*

(from http://www.servicelearning.org/article/archive/37/). Among the many advantages of experiential service-learning are that in addition to its recognized ability to provide increased critical thinking skills, it integrates community service learning with the gaining of factual knowledge (Howard, 1993) and serves as powerful motivation for learning (Eyler, 2002). Furthermore, service-learning specifically has been reported to better prepare students for making informed decisions about complex social issues (Batchelder and Root, 1994) and to understand the need to become active in policy decisions (Eyler *et al*., 1997), including those pertaining to biotechnology and its utilization.

In general, biology service-learning courses have been utilized successfully to involve students in attaining a working understanding of little understood biological principles (Kennell, 2000). This is clearly an important goal for biotechnology-based instruction. Thus, in addition to its documented general educational benefits, service-learning instruction should prove a particularly powerful tool for improving biotechnology education. Ultimately, however, one of the major advantages of utilizing service-learning for biotechnology courses is its ability to serve quite effectively to create a subject-centered classroom in which the instructor's primary role is to allow students to interact intimately with a subject (Palmer, 1998). Such subject-centered environments bring the subject matter at hand to the center of all interactions in a very tangible way and provide the subject with "a capacity to speak its truth quite apart from the teacher's voice in terms that students can hear and understand" (Palmer, 1998). This type of intimate knowledge of biotechnology transcends fact-based understanding. Such integrated knowledge about biotechnology will be needed to create a biotechnology-informed citizenry capable of critical evaluation of current technologies and of understanding the societal implication that arise from these technological advances.

To address the need for progressive educational endeavors in biotechnology and exploit the recognized benefits of community service learning, a service-learning course on biotechnology and biotechnological applications was developed. This course sought to introduce students to the biological principles and processes behind biotechnology and provide a forum for students to encounter the benefits and pitfalls associated with the global utilization of biotechnological advances. The service-learning course material addressed both agricultural and medical biotechnologies and their utilization in the United States and globally. The ultimate goal was for students to arrive at a greater active understanding of biotechnology and its implications for changing society.

Course Design

The impetus for and design of this course have been previously described (Montgomery, 2003). In brief, a service-learning course was designed to address the need for creating formal avenues to discuss public concerns about the development, use and global deployment of biotechnology in agricultural and medical arenas. This biotechnology service-learning course is offered as a half-semester (8 weeks), 2-credit graded course at a residential living-learning center. The center houses students from all academic levels and focuses on student-centered and experiential learning and a commitment to community service. The course accommodates 10 to 15 students. Students met with the instructor twice for 1 ½ hours for lecture and discussion weekly. Students met with the service-learning coordinator as a group in workshop format for a total of 2 hours each week.

Readings utilized as reference material and as a basis for generating discussion include the book “Biotechnology Unzipped: Promises & Realities” (Grace, 1997) and an instructor-compiled reader of current peer-reviewed journal articles and popular press pieces. As a range of students from freshman to seniors and a range of majors including non-science majors are included in the course, students are provided a guide to understanding scientific peer-reviewed literature during the first week of class and are guided through the reading of the first article. The course utilizes a number of teaching strategies and learning systems including brief lectures, in-class small group discussions, journal reflection writings, service-learning project and service-learning portfolio (see Table I for detailed descriptions).

Table I. Teaching Strategies and Learning Systems

Lectures	Brief lectures present new information and model critical thinking patterns.
In-class discussion	Discussions allow students to present personal views with each other and to collectively synthesis new perspectives on the topics present in class. Participation is expected to reflect careful prior thinking and to be offered in a way that contributes to the objectives and goals of the course.
Journal reflection	Reflective writing assignments allow students to demonstrate their mastery of concepts discussed in class and an opportunity to present questions about the lectures and/or discussion materials. Students include a summary and evaluation of reading assignments and lecture content, as well as open questions and/or remarks in this weekly writing.
Service-learning project	During the course, students work with a local non-profit organization for at least 2 hours weekly. Students assist with implementing programmatic or educational biotechnology-based projects. These include assisting in the writing and/or compilation of educational brochures and the planning of local biotechnology-related round table discussions.
Service-learning portfolio	This final project documents evidence of the processes utilized and products completed during this service-learning course. The portfolio includes a combination of the following items: a weekly log of service activity, copies of journal reflections, directed writings assigned during the class period, and/or copies of products completed during the service experience (e.g. agency brochure, advocacy letters, round table agenda, etc.). The portfolio also includes a required self-assessment essay that summarized the student's current view of biotechnology including the potential benefits and drawbacks of its development and deployment

Brief lectures (~15 minutes per class period) generally occur at the start of a class for the purpose of introducing general concepts and terminology, as well as to address any questions derived from readings or reflection. Lectures are generally followed by small group discussions that were preceded by preparatory minute writings or case studies. A guided approach is used for the completion of reflective journal writings. Students are prompted to tie issues from readings and discussions to themes encountered in service activities by a series of evaluative questions. Such structured writings have been shown useful for utilizing service learning as a tool for increasing cognitive development (Eyler, 2002).

The service-learning component of the class is initiated with a discussion forum on the target community. This includes an introduction to the community composition and the prevalent social issues, as well as a discussion on the current needs of the community as assessed by the service partner organization. The provision of such information about the target community has been recognized as one of the key components of successful service-learning endeavors (Eyler, 2002, Tai-Seale, 2001). Furthermore, discussions that address current beliefs held by students about the community and individuals to be served prepare students for maximal educational benefit from service-learning activities (Eyler, 2002).

Service-learning projects are completed in groups of 2 to 5 students. Groups are required to meet with the service-learning project coordinator to decide on a specific project. Project choices include compiling educational brochures or pamphlets describing biotechnology and the implications (both negative and positive) arising from its specific agricultural or medical uses. Alternatively, students can participate in the planning and hosting of a local community roundtable discussion on the role of biotechnology in sustainable, global development. Both of these projects are facilitated by a single local nonprofit organization, which seeks to provide well-rounded, unbiased educational biotechnology initiatives.

As a final reflection project, students compile service-learning portfolios. The documents incorporated into the portfolio include an overview or log of the activities completed during the service-learning component, copies of the products produced in partnership with the community service organization and a self-assessment essay detailing the student's current stance on biotechnology and technology transfer. Students are provided a rubric (see Table II) specifying how each section of the portfolio will be assessed.

Table II. Service-Learning Portfolio Rubric

	Excellent	Satisfactory	Absent or Needs Improvement
Organization/ Quality (10 points)	Overall appearance and format are of exceptional quality. There are almost no grammar, spelling or formatting errors [9 – 10 points]	Overall appearance and format are satisfactory. There are limited grammar, spelling and formatting errors [6 – 8 points]	Overall appearance and format are poor. There are numerous grammar, spelling and formatting errors [0 – 5 points]
Process (7 points)	Log of activities is complete and easily understood [6 – 7 points]	Activity log is present but not thorough or easy to decipher [3 – 5 points]	Activity log is incomplete or absent [0 – 2 points]
Self-Assessment (20 points)	Self-assessment essay is of exceptional quality and shows significant evidence of understanding learning principles. Also displays that the student engages in critical thinking and understands how self-reflection has impacted own learning/attitudes [17 – 20 points]	Self-assessment is satisfactory and shows some evidence of understanding major learning principles. Shows adequate use of critical thinking skills and understanding of how self-reflection has impacted learning/attitudes [12 – 16 points]	Self-assessment shows limited to no evidence of understanding major learning principles. Student does not show an engagement in critical thinking or understanding of how self-reflection has impacted learning/attitudes [0 – 11 points]
Variety (3 points)	Portfolio contains evidence of the range of different activities utilized in the course [3 points]	Portfolio contains some evidence of the range of different activities utilized in course [2 points]	Portfolio contains very limited or no evidence of the range of different activities utilized in course [0 – 1 point]

Course Evaluation

Students complete a pre-course and post-course, instructor-designed survey (See Table III).

Table III. Survey of students' knowledge of biotechnology and its utilization

Before and after the Spring 2003 course, students (n=11) were asked to answer the questions listed below using the following scale:	**1 = Unable to answer question** **2 = Partially able to answer question or know where to find the answer** **3 = Fully able to answer question**
1. What is biotechnology? 2. What is technology transfer? 3. What are the prevalent issues associated with technology transfer? 4. Are the current methods of technology transfer efficient? 5. Who is responsible for technology transfer? 6. What are the benefits of technology transfer? 7. What are the risks associated with technology transfer? 8. What are the costs associated with technology transfer? 9. Who pays for technology transfer? 10. Who is most impacted by technology transfer efforts?	

This survey probes students' self-reported knowledge base on specific issues related to biotechnology and technology transfer. Additionally, students complete two university-sanctioned surveys at the end of the course: one survey is required of all university courses, while the second is specific for service-learning courses (see Table IV).

Table IV. Student Service-Learning Course Assessment[a]

At the conclusion of the Spring 2003 service-learning (SL) course, students (n=11) were asked to respond to the following statements using the following scale: **A. Strongly Agree B. Agree C. Disagree D. Strongly Disagree E. N/A**
1. The service work I did in this class filled a real-life community need. 2. As a result of this course I feel more connected to the local community. 3. My time was well used by the agency. 4. The service work helped me better understand the basic concepts of this course. 5. The service work I performed made me more interested in the course content. 6. The service work I performed made me more motivated to attend class. 7. This class helped me become more interested in solving a community problem. 8. I brought lessons learned in the community back into the classroom. 9. As a result of this course I plan to continue working in the community. 10. As a result of my community experience I would take another SL course. 11. As a result of my SL experience I would recommend this course to others.
[a] *This survey is based on the "Student Service-Learning Course Asessment" from the Community Outreach & Partnerships in Service-Learning (COPSL) Guide to Partnerships in Service-Learning, August 2000, http://www.indiana.edu/~copsl/download/assessment.pdf.*

Course Outcomes

Students enrolled in the class were an approximately equal mixture of freshmen through seniors and included a variety of academic majors including business, sociology, environmental affairs, biology and general studies. The students in this service-learning course showed an average gain on all questions in the instructor-designed, post-course survey as compared to the level of knowledge reported on pre-course inquiries (Figure 1).

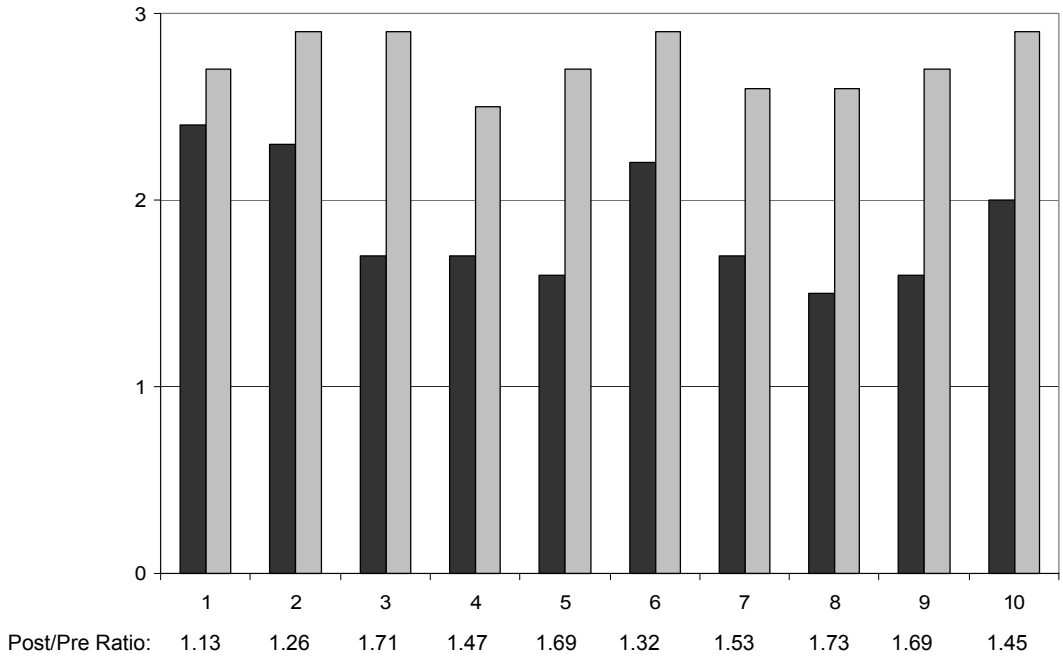

Figure 1. Pre- and post-course survey results of students' knowledge of biotechnology and its utilization

The largest gain in self-reported knowledge was observed in regards to students' confidence in identifying the prevalent issues associated with biotechnology transfer (see Question 3, Table III). By contrast, the smallest gain observed was for students' self-reported ability to define biotechnology (see Question 1, Table III). This unexpected, small gain in student's ability to define biotechnology is attributed to students moderately expanding an initially limited definition of biotechnology.

Notably, in a comparison of the change in level of self-reported knowledge for the 110 total individual responses received, an increase in self-reported knowledge was noted for 74.5% of responses. An additional 20% of responses showed no change in self-reported knowledge, whereas 5.5% of post-course responses were lower than pre-course levels of self-reported knowledge. Interestingly, 1/3 of those responses showing no change were rated at the highest possible level in pre-course surveys and thus had no fraction for improvement in post-course surveys. Using a wider range of responses (e.g. 1 – 5) may allow more specifics about the improvement of students' understanding of key issues. Altogether, these measures suggest that the service-learning course was highly effective for improving students'

self-perceptions about their personal knowledge of biotechnology and technology transfer concepts.

The results obtained from student self reports were further underscored by responses elicited using a university-sanctioned, service-learning course survey (see Table IV). Among the insight gained from this survey was the finding that 90% of students strongly agreed that involvement in the service activity increased their interest in the core subject matter (see Question 5, Table IV). Eighty percent of students agreed or strongly agreed that they would take another service-learning course as a direct result of the service experience gain in this course (see Question 10, Table IV). Additionally, all students agreed or strongly agreed that as a result of the service-learning experience they would recommend the course to others (see Question 11, Table IV).

In response to open-ended inquiries about outcomes of the course included in the instructor-designed survey, a majority of students indicated that two of the most important outcomes were understanding the importance of cultural norms, education and infrastructure building in the global deployment and utilization of biotechnology and recognizing that actual facilitation of biotechnology transfer methods is extremely complicated when one takes into consideration the cultural and political differences that exist between donors and recipients of the technology. I believe that this point of view was largely reinforced by the emphasis on the practical implications of public education about technology transfer in the service-learning component of the course.
In addition to the knowledge gained during the completion of the service-learning projects, students benefited from working in groups. It has been previously reported that including group project work in a biotechnology ethics course resulted in students acquiring new skills including improved critical thinking, problem solving, communication and collaboration in addition to increased factual knowledge (Thomas et al., 2001). As the instruction utilized in this report was not service-learning based instruction, it is expected that increased societal awareness would be acquired in addition to these gains in key skills in a service-learning environment such as that described here.

A truly encouraging outcome of this service-learning course was its ability to change the ways in which students think about biotechnology, its societal impacts and its global employment generally (See Table V). Student comments provided evidence that the students were thinking deeply not only about the processes involved in the development of biotechnology but also about the larger social, and indeed global, implications of using biotechnological applications. Notably, service-learning courses that focus on intense reflection have been reported to transcend factual knowledge and understanding to attain transformations of student thinking (Eyler, 2002) such as those indicated by the students' self reports and instructor analysis of the service-learning portfolios.

Table V. Selected student comments from open-ended survey questions

"It's interesting to know that not all genetically modified organisms are only to make things bigger and better, but that they have the potential to make things such as vaccinations."
"With regulations and guidelines, these technologies could prove to be the best discovery mankind has ever made, helping all living things, yet if left open and unregulated none of the common goals would be reached and more harm would be done than good."
"This type of technology should be kept in perspective. Think of when Neanderthals discovered fire. It was a major breakthrough but without keeping it under control, fire can be a very devastating thing."
"Agricultural biotechnology is and should be a needs-based technology and with the current private sector domination, highly industrialized countries such as the U.S. are making this an economic based technology."
"It seems to me that without labeling their products they are not confident with the messages they are sending out. Their actions speak louder than their words. If they are not willing to label their products, I am not willing to try their products."
"I believe the precautionary principle is the best approach to the current situation, we don't know the outcome of eating these products for 30 or 40 years because of the newness of the technology."

Conclusions

This biotechnology service-learning course engaged students in community service learning activities that served to provide real-word experience with the biotechnology principles and practices discussed in class. Students participated in numerous reflection activities to learn how to extract civic learning from their community service activities and to practice articulating personal views of complex, and often conflicting, issues related to the utilization and employment of biotechnology. Student self reports and an instructor assessment of end of the course student position papers indicated that the course was successful at increasing both factual knowledge about biotechnology and imparting a greater understanding of societal and policy issues arising from biotechnological innovations. Further insight might be gained in future iterations by having students provide written responses to the survey questions.

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