AC 2007-98: MULTI-CAMPUS DESIGN AND IMPLEMENTATION OF PROBLEM-BASED-LEARNING COURSES IN ENVIRONMENTAL BIOTECHNOLOGY WITH INTERDISCIPLINARY LEARNING

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Introduction

The project described here began with a civil engineering and biology laboratory research collaboration that ultimately led to educational research about course development and pedagogy. The laboratory research was centered on genetically engineered organisms for contaminant tracking, and it soon became apparent that neither students from civil engineering nor biology had the requisite backgrounds to work on this type of project without some supplementary tutoring. As a result, a team-taught environmental biotechnology (EB) course was piloted that was cross-listed between the two departments, and although it was satisfactory, it suffered some deficiencies because it was difficult to find the right content balance between the two disciplines.

At about the same time, two sister institutions were also expanding their biotechnology offerings. North Carolina State University had just hired a new civil engineer with expertise in molecular biology who was developing new courses; and at UNC-Pembroke, a variety of bioprocess equipment had been donated, leading to interest there in designing a new biotechnology curriculum track. As we tweaked our course design, there was a sense that efforts were being duplicated and that there was a missed opportunity to capitalize on the collective expertise of the faculty at each institution. Further, there was a realization that the phenomenon of simultaneous development of similar courses at sister campuses in response to emerging disciplines likely was being played out in many other multi-campus university systems.

Thus began a collaboration among civil engineering, biology, chemistry, chemical engineering, and education faculty at various University of North Carolina (UNC) campuses to design a single environmental biotechnology course template that would (a) incorporate the most current and effective learning paradigms; (b) be readily adaptable to a variety of settings within a single university system; and (c) would receive buy-in to both the curriculum and instructional methods from diverse faculty within those settings. The science educator recommended the use of student-centered learning methods (SCLM), which have received a great deal of focused promotion because of their perceived value among educators but are still not used widely or well among science and engineering faculty[1]. These methods typically involve student group information gathering and problem solving and have been shown to promote improved investigatory and critical thinking skills and to prepare students for the more team-based interdisciplinary nature of the work environment[2,3,4].

Upon obtaining support from the federal Fund for the Improvement of Post-Secondary Education (FIPSE), a three-year research program was mapped out. The specific research objectives, the results from Year 1 and some lessons learned are described below.

Research Objectives

The research objectives were to:

1. Use the combined expertise of education, biology, and engineering faculty and graduate students to implement open-ended inquiry through problem-based learning (PBL) as the instructional strategy in a series of environmental biotechnology courses;

2. Deliver course content to learners in a variety of settings and across disciplines within a single university system;
3. Assess student learning to substantiate that the instructional methods result in increased (a) student conceptual knowledge and understanding, (b) critical thinking skills, (c) ability to seek out new information, (d) ability to work collaboratively in teams; and (e) ability to engage in productive assessment (self-assessment, peer assessment, program assessment).
4. Provide faculty with the opportunity to critically assess and change their attitudes, perceptions, beliefs and practices with respect to the use of student-centered instructional strategies; and
5. Evaluate both the program and curricular development and implementation processes to optimize their transportability and adaptability to interdisciplinary courses at other institutions with respect to different department programs and diverse student populations.

Experimental Plan

Overview

In Year 1, a three-course sequence was begun at UNC Charlotte, the campus where a pilot course had been delivered. The courses were designed to offer introductory (EB I), advanced hands-on (EB II), and independent internship (EB III) opportunities. At the end of Year 1, assessment results from the first two courses and feedback from the instructors were used to design courses for the other campuses. At the start of Year 2, while the UNC Charlotte sequence was repeated and EB III was started, North Carolina State University began an environmental biotechnology capstone design course for senior undergraduates; North Carolina A&T began an environmental engineering laboratory course; and UNC Pembroke began a biochemistry course. The latter two had “units” of EB, while the senior design course maintained focus on EB methods throughout. At the start of Year 3, all courses were repeated at all institutions.

All of the instructors participated in a two-day workshop on SCLM that was led by an educational consultant who had used PBL in science courses and published on these methods. Assessment coordinators from each campus were also taught how to use the assessment tools created by a lead assessor at UNC Charlotte. All participants were given the opportunity to develop PBL course materials during the workshop.

UNC Charlotte Course Offerings

EB I was team-taught and designed to serve junior and senior biology and civil engineering majors. A PBL strategy was tested as a means to introduce biology and engineering students to some of the fundamental molecular biology techniques and their applications to environmental biotechnology. A typical PBL format would involve providing students with a scenario describing an open-ended problem to be solved. Working in groups, student would develop (but not implement) a solution strategy for the problem. The solution process would begin by instructors counseling students to formulate the questions that needed to be answered in order for the students to proceed toward a solution. Then students would be guided to gather the information needed to answer their questions, some of which might be obtained by asking the instructors for mini-lectures on a topic. Critical evaluation of the information gathered would lead a group to a new round of questions, investigation and evaluation until the findings were sufficient to synthesize them into a research plan.

However, in order to be able to compare student learning in lecture format to learning in PBL format, the two formats were alternated over the four problem scenarios presented in the course. That is, for the first unit, a problem scenario was presented and students were prepared through lectures to develop individual solutions to the scenario posed. The second unit was then presented in a PBL format, with students divided into teams and led through the process described above for PBL instruction. In PBL mode, the faculty team served as advisors and “sounding boards” to the teams as they worked, helping to coordinate the team research topics, and generally helping students learn some critical thinking skills as they worked. The third scenario was completed in lecture format, and the fourth used PBL.

The first unit was abbreviated so that students could learn the techniques of PBL and follow one scenario through quickly to get a sense of the overall process. The scenario topics included design of a biosensor for mercury contamination; an assessment of the effects of fats, oil and grease levels on foam-forming bacteria population size in activated sludge; and design of a fixed film nitrification reactor for a closed loop waste processing system in a space vessel. For the fourth scenario, students were invited to develop their own problem scenario, and the solutions were presented in class as well as in reports.

At the start, several relevant journal articles were used by the instructors to guide students into their research problem and into consulting primary sources for additional information. In other scenarios, students were offered only one or two journal articles along with the scenario, and they were expected to develop the proficiencies necessary to do more sophisticated literature searches. At the end of each unit, in addition to report submissions, students took a test on the scenario topic; submitted journals in which they had recorded questions and described their daily progress, and completed peer evaluation forms when appropriate.

In addition to grading assessments, research data was collected by the education graduate student before and after each of the four scenario units. The assessments included survey forms at the end of each scenario unit to ask students how much learning and skill acquisition they believed occurred as a result of the instruction and classroom experience. At the end of the course, students were also queried about the extent to which they believed that the course objectives had been met. Instructors were surveyed about their perceived knowledge about PBL teaching techniques and their expectations for student learning and skill development. In addition to these quantitative measures, interviews with randomly selected individual students were conducted at the end of each unit, and several student focus groups were conducted throughout the semester.

Twenty students enrolled in the course, eight of whom were biologists and 12 of whom were engineers. At the start of the semester, the instructors explained to the students that they were in a course being used for research. The education graduate student was introduced in the first class and attended all subsequent class meetings. It was explained to the students that the graduate student was available to them if they had concerns. Student frustration with (i) the open-endedness of the process (lack of a single “right answer”), (ii) the tendency of the instructor to answer a question with another question, and (iii) the ambiguity of grading were all concerns that were anticipated.

The second course of the first year, EBII, targeted two student populations- senior undergraduates who had completed EB I and first year graduate students who might not have taken EB I. The latter were expected to attend tutorial sessions to learn about the PBL approach and to make sure they were well-versed in the basic molecular biology topics covered in EB I. Two of the students from EB I enrolled and three new graduate students (all of whom were international students) enrolled, resulting in a wide range of student backgrounds and a majority of students with no experience in SCLM. Students completing EB II were eligible to enroll in the third course of the sequence, which was a guided research internship, where students who enrolled were paired with a local municipality or industry to conduct an environmental biotechnology research project.

EB II students were given a scenario about fecal source tracking related to hog lagoon wastes. The first portion of the semester was divided between two activities. The first was group meetings with and without the instructors to generate a solution strategy; and the second was to practice hands-on laboratory exercises to learn the basic molecular biology techniques they were likely to use when they implemented their solution strategy. Grade assessment included a conventional mid-term, team reports (written and verbal), and a final report that included results from laboratory work. As with EBI, students were asked about their perceptions of how much was learned and how much new skill acquisition occurred as a result of the sessions. Their learning styles were also assessed. However, due to the small sample size, statistical analyses were judged to be inappropriate, and descriptive statistics were used instead.

Year 1 Results

For the research assessment, at the end of each unit, students were queried about their perception of the benefit that various teaching modalities had on their learning (Table 1, Items 1-12) and skill acquisition (Table 1, Items 13-20). A five point scale was used with low values (e.g. 1) indicating strong agreement and high values indicating strong disagreement (e.g. 5). Ratings from similar instructional blocks were pooled and compared. Ratings where differences were statistically significant (at the $p<0.05$ level) are shaded.

Table 1. Survey Results: Students' Perceptions of Learning and Skill Acquisition

Item	End of Combined Blocks 1&3 (Lecture)	End of Combined Blocks 2&4 (PBL)
1. The use of problems	2.24	1.74
2. Working in groups	2.58	1.29
3. Communicating about environmental biotechnology with your group members	2.55	1.34
4. Peers as teachers	2.45	1.68
5. Working individually on assignments	2.00	1.74
6. Class discussions led by the professor	1.68	1.82
7. Class discussions led by classmates	2.63	2.32
8. Lectures by the professor	1.68	1.87
9. The course pack of readings	1.95	2.21
10. The use of electronic resources, primarily the Internet, to find information	1.63	1.13
11. Library resources, other than electronic ones	2.42	2.26
12. The use of computers as an investigative tool	1.68	1.16
13. Communicating literature and/or research results	2.08	1.50
14. Participating in discussions	2.03	1.63
15. Writing about environmental biotechnology	1.84	1.55
16. Working collaboratively with classmates	2.47	1.32
17. Finding relevant information	1.82	1.55
18. Analyzing and synthesizing information	1.84	1.45
19. Using computers for information retrieval and data analysis	1.79	1.43
20. Thinking critically about environmental biotechnology issues	1.58	1.48
1=strongly agree; 2=agree; 3=neutral; 4=disagree; 5=strongly disagree		

(shaded) Denotes statistical significance ($p<0.05$) relative to lecture format

Obviously, some of the differences were because one teaching method contained no opportunity for learning by a certain modality, such as Item 2, where in Blocks 1 and 3 no group meetings were offered. However, others, such as the use of problems, peer instruction, or the internet and computers could have occurred in any of the blocks but was a more salient contribution to learning in the PBL instructional units.

When EBI students were asked to estimate their perceived level of knowledge about a set of environmental biotechnology topics, there was significant improvement (shaded areas represent significant differences at the p<0.05 level) in all but one content area, which dealt with the ethical considerations of genetic engineering (Table 2). Student satisfaction with group experiences in the first PBL unit and with learning overall was generally supported in the student interviews (Table 3), although it was also clear that students had difficulty discriminating between student-directed learning and simply being asked to work in groups. Two of the four students interviewed at the end of the first PBL unit believed the unit was "lecture-based". Some engineers reported feeling overwhelmed by the biology course content at the end of the first two units, but it is also possible their assessment was colored by a certain temptation to default to the biology student(s) rather than assume responsibility for the new content. Quiz scores at the end of the second unit did not indicate that the majority of engineering students were not able to learn the material; the average engineer score was 80.1 (n=12), while the average biology score was 86.0 (n=8). By the end of the third unit, there was only a two point difference between the two groups, with engineers averaging 80.8 and biologists 82.3.

Table 2. Comparison of students' perception of knowledge at start and end of course

Item	Start	End
1. Name and describe the principles behind a variety of biotechnology methods	3.21	1.65
2. List examples of molecular biology applications	3.53	1.65
3. List examples of molecular biology applications specific to environmental engineering	3.32	1.59
4. Name some potential future applications of the methods	3.05	1.94
5. Explain the basics of bioprocess engineering	3.37	2.12
6. Describe the ethical issues and arguments associated with genetic engineering	2.42	2.29
7. Describe the advantages and disadvantages of biotechnology methods relative to conventional methods	3.44	1.82
1=Very Knowledgeable; 2=Somewhat Knowledgeable; 3=Not Sure; 4=Somewhat Unknowledgeable; 5=Very Unknowledgeable		

(shaded) Denotes statistical significance (p<0.05) relative to lecture format

Faculty assessment of the two instructors indicated that going into the new course, both were confident in their ability to apply the PBL instructional format, and their ratings remained stable at the end of the course (Table 4). Perceptions of the ability of PBL to enhance student learning declined for one instructor over the duration of the course but increased for the other. Neither instructor's view on how well PBL would improve students' critical thinking skills changed as a result of completing the first course trial.

As noted previously, the small sample size (n=5) in the second course of Year 1, EB II, precluded statistical analyses, and therefore, a constant comparative method was used to analyze the qualitative data transcribed from faculty interviews and student focus groups and the field notes.

This method involves an iterative process of constantly collecting data and comparing each piece of data with others[5].Coding was constantly compared with new data as the process

Table 3. Student interview comments at the completion of Unit 2 (first PBL unit of the semester)

In your opinion, what teaching strategies did the professors primarily use during the most recent three weeks of this course (e.g., lecture, problem-based groups, etc.)?	Socratic seminar, group learning, guided information
	group learning
	This block was more lecture and group based work
	Lecture/group work
How effective were these teaching strategies used by your professors? Explain.	Pretty effective
	Depends on the student—I don't do in-depth research but the bio students seem to understand group work and are used to doing the research—so it would help them.
	Fairly effective. I feel "left out in the cold" because I'm not a bio major and I feel I don't have a prayer in this class. I don't feel I can gain much from groupwork because bio students don't necessarily have the background to teach us what we don't know.
	Groups help to find out you can see the solution to problems better and you ask question more—group members help you figure out answers—but I don't think this was totally effective because we need more background information
What were some of the positive aspects of the teaching strategies used by your professors? What were some of the negative aspects?	Positives: in groups everybody brings something to the table, you aren't expected to know it all, collaborative work with peers. Negatives—often things are just overheard from group to group and you aren't sure if you are right—and you don't know what to expect for grades
	Positive: you can learn at your own pace and it's not boring. Neg.: students are not necessarily going to do the work and research it takes to grasp the concepts.
	Positive: Group work opens doors to see what other the other major does in the field. It's interesting to see how the two disciplines overlap. There is a need for a class like this because in the real world you have to do both the biology and engineering or at least understand both. Negative: Too many assumptions that we know the basics. The start of class should have had enough background to know what they (the professors) are talking about I've had to dig to figure it out.
	Positive: it encourages participation and support. Neg: groups spend a lot of time off topic but this class requires you to use what you know
Do you want the teaching strategies used by your professors to change during the next block (i.e., three weeks) of this course? In what ways?	I want the group to continue
	I don't know how they could change but lecture didn't help—I thought it was going to be hands-on/experimental labs not just "scenario crap"
	Maybe in-class exercises not necessarily group work—more like the professors modeling what we should do. A diagram of a waste water treatment plant and then give us a problem scenario and discuss in depth what should be done not just telling us about PCR
	Continue with groupwork
Overall, has this block of instruction been successful?	* I've gotten a lot out of it—it's reinforced a lot that I've learned in the past—look at suggestions from focus groups—would motivate people in the course has been lacking—needed guidance on how to work in groups—explanations being more basic etc.
	Yes—this is the best class in my career I've learned more from this than any other
	Oh yeah, I'd say so
	I think so I've def. learned a lot; don't know how much I'll use in the field, but it's been beneficial. I'd like interaction and group work. I think it would be beneficial sometimes but not every class; there is only so much your peers can teach you. Also I'd like some articles that are scientific but not in a research format—more for a lay person.

Table 4. Assessment of faculty confidence in PBL teaching competence and student learning

Item	Start		End	
	Inst. A	**Inst B**	**Inst A**	**Inst B**
1. At this point in time, how well do you think that you understand the principles of problem-based learning (PBL?	2	2	2	2
2. At this point in time, how well do you think that you will be able to develop a PBL model that helps you satisfy your course objectives?	2	2	2	2
3. At this point in time, how well do you think that PBL will allow the students to learn the course content?	3	2	2	3
4. At this point in time, how well do you think that PBL will enhance your students' critical thinking skills?	3	3	2	2
5. At this point in time, how well do you think that you will be able to develop a PBL model that can be used at other IHEs?	3	2	2	2
1=Very Well; 2=Fairly Well; 3=Not Sure; 4=Not Too Well; 5=Not Well				

of data collection proceeded. The program evaluator and the graduate education research assistant were vigilant about the consistency of the coding, and every effort was made to reduce personal coding bias.

In interviews with EB II students, they indicated that the activities in class assisted their learning, and the course helped them improve their critical thinking skills and collaborative team work skills. Their self-assessments of learning and skill development were consistently positive, and when asked whether they would sign up for the course if this kind of course was offered in the future, all of the students said “definitely yes.” They enjoyed the course because they “learned more by doing it instead of listening to the lecture.” The results from the interviews relative to each of the project goals are described below.

Goal 1: Student Conceptual Knowledge and Understanding. Although both instructors were “not sure” about how well PBL would allow the students to learn the course content, and students were concerned about their grades and the grading policy, all students perceived that they were either very knowledgeable or somewhat knowledgeable in six of seven content areas. One student reported feeling neutral on knowledge of one item, bioprocess engineering, which was not emphasized in the scenario used.

Goal 2: Critical Thinking Skills. All students agreed that they learned well by actually solving the problem with the guidance from the professors. The professors challenged their critical thinking skills by “not directly giving us the answer but letting us brainstorm on our own.” Another student commented, “It was collaborative with them (the professors) throwing questions back at us so we could answer them among ourselves.”

Goal 3: Ability to Work Collaboratively in Teams. Students encountered difficulties in working collaboratively at the beginning of the course. This lack of cooperation within the group and the failure of a leader to emerge was noticed by the instructors. Instructor A commented, “I don’t think a leader ever stepped forward to assume responsibility to make sure they’d arrange meeting times or to assume responsibility as they were preparing a report for the class, causing stress and frustration for students and for us as well.” Instructor B supported this view: “Each week there was a reason that their meeting had gotten garbled. They were very resistant to meeting. We struggled with that and so we probably spent half of the semester to get them to the point where they had a solution strategy that was viable." Instructor B described another situation when a student group member was stuck and could not answer the questions raised by Instructor A. Although Instructor B thought the student's group members would "jump in and help her come up with an answer. Instead, they just sat and waited; that kind of passivity makes me crazy."

Classroom observations showed decreased numbers of questions to professors over time and increased collaboration and discussion among students and with the professors toward the end of the semester. Near semester's end, all students were actively engaged in collaborative processes as evidence by eye contact and verbal exchange. These indicators were measured as frequency counts and interval-recordings. Interestingly, when professors were not present, students looked more relaxed, and more collaboration occurred.

Goal 4: Faculty Receptiveness to the Use of PBL Strategies. Both faculty members at UNC Charlotte reported that they understood the principles of PBL "fairly well" and were positive about the impact of PBL on students' critical thinking skills. The following excerpt is an example:

Assessor: How well does PBL enhance critical thinking skills?

Instructor B: Very well. Students didn't get much out of it (lecture). There's nothing else in the biology department even close. Biology instruction is filling in the blank questions, multiple choices, but nothing like this where they take more than one step in the critical thinking process. Let's see where it leads.

Goal 5: A PBL Model Useful in Other Settings and Disciplines. Both instructors of the course reported that they were not sure about how well they would be able to develop a PBL model that could be used at other institutions of higher education. Instructor A thought it was likely a personality issue. He would tend to be self effacing and not think he was expert enough to tell anybody else how to do it at this point. He noted that "it's an art, more than a science to teach this way." Instructor B thought that the module would be tailored to each instructor's expertise and the curriculums of each institution. He added, "The initial plan was to come up with problem scenarios that we can put it on the web that everybody could download and use at any institution, but I'm not sure that is going to work anymore."

Discussion

The assessment results suggest that by the end of each course students generally reported positive experiences and were satisfied with the learning and skill improvement that occurred. There were no survey or interview results indicating that any subset of students found the courses to be a waste of time or offered little opportunity for learning, while there were very positive responses that reflected students enjoyed the novel elements of the class, including team research and problem-solving.

The instructors remained only moderately convinced that sufficient content coverage was occurring or that meaningful critical thinking skills were developing. They willingly attributed this in part to their novice status as deliverers of content in a PBL format. The PBL teaching method requires about the same time input as a traditional course, but the time distribution is different. Much more pre-course preparation is needed to build the proper learning drivers into the scenarios and anticipate resources that will be needed by the students, while the day-to-day class meetings required minimal preparation (but good planning and leadership). The need to rely on more subjective measures for assessment such as written report grades, peer evaluations, and presentation scores makes grading a more lengthy process. Also,as the course proceeds, it is difficult for novice instructors to trust the process learning mechanisms, judge how much frustration to allow, or anticipate the need for course corrections. There was a tendency to want to lecture even in the absence of student requests for assistance, provide extra emphasis for important topics, or try to reduce expected student frustration by providing some lecture content.

Students surveyed after completion of the first two units in EB I could clearly identify that the first unit had been a lecture format, but several still perceived Unit 2 to be a combination of lecture and group work, indicating that a clear transition to student-centered learning had not occurred in their minds, although it was the instructors' intention to do so. Feedback from student interviews revealed that some students were frustrated by having to learn content from their peers or external resources and viewed this as a deficiency on the part of the instructors rather than an intended experiential element of the course. However, the data in Table 1 (items 4 and 14) suggest that most students believed good learning occurred from peer teaching and collaboration.

The data clearly indicate that students believed their proficiency at using the computer to collect information increased over the course of the semester. Further, both instructors noted that the high use of primary literature sources in EB I and II is not the norm in either of their departments, and students' skill levels at finding, comprehending, and using references in journal articles matured rapidly over the duration of each course. There was also evidence that the engineering students believed the scenarios required much more biology than engineering background and either sought more lectures from the biology instructor or defaulted to their biology teammates when sophisticated solutions were required. Ironically, one of the engineers complained that the biologists had an advantage because of their experience with group work, while in fact, just the opposite was true. Engineering students at UNC Charlotte have a minimum of one team-based course each year of the curriculum, while group projects are atypical in biology classes.

EB II course results indicate that although the week-to-week classroom experience suffered from lack of leadership and poor group dynamics, the students were generally satisfied with the class and judged it to be personally beneficial. The opportunity to perform the scenario solutions was appreciated by the students despite the fact that the class required two weekly laboratory sessions. The faculty interviews show that the instructors struggled with what they perceived to be a lack of leadership and cohesion in the group despite their best efforts to mentor and challenge the team.

At the end of Year 1, one student from EB II was interested in enrolling in the EB III internship course. Arrangements were made for her to work in the county water treatment plant laboratory assessing the feasibility of substituting real time polymerase chain reaction (PCR) technology for cryptosporidium spore detection instead of using the prescribed microscopy method. Also, a two-day summer workshop for all UNC faculty participants was conducted.

In addition to the obvious need to reduce the time devoted to formal lecture so that students can clearly recognize a distinctive student-centered classroom experience, some of the other lessons learned at the end of Year 1 courses and assessment were:

(1) the use of a small practice scenario was very valuable. Students appreciated the chance to gain some proficiency by muddling through a short unit for "practice" and were reassured when told that the grade would not be weighted as heavily. This prevented them from becoming overly frustrated or anxious about what they perceived to be ambiguous grading;

(2) more guidance on team dynamics and success was needed. The content of handouts about successful team management are salient at the time they are presented and discussed, but they are quickly forgotten in the heat of group problem-solving. Some intermittent metacognition exercises to self-assess their strengths, contributions, and weaknesses with respect to teamwork are probably needed to effect behavior change. Also, creation of team contracts at the start of each scenario might help groups anticipate problems and create mechanisms in advance for dealing with members who are less motivated or productive than the rest. Fidelity to contract stipulations might also be incorporated into the peer evaluations;

(3) discrete skill lessons on critical thinking and frequent rehearsal of its key elements was needed. Clarity, precision, and relevance need to be mentioned when mentoring in small group meetings and when grading;

(4) despite much prompting, students remained hesitant to give low peer evaluation ratings. Presentation of a short unit on the value of practicing giving and receiving constructive performance feedback will be considered for subsequent courses.

Conclusion

The design and presentation of a new PBL-based interdisciplinary course in environmental biotechnology was successful in terms of student satisfaction with the content and skills learned and in terms of the classroom experience. The two member team of instructors believed that there was some sacrifice of content, although the challenge of information gathering and organizing solutions to open-ended problems was a unique and valuable experience for the students. It also accomplished an original goal of the instructors to equip engineering and biology students with the backgrounds needed to allow them to conduct interdisciplinary environmental biotechnology research.

A second year of course presentations occurred subsequent to the classes described here, where inquiry and/or problem based learning was used to deliver biotechnology courses at three other UNC institutions: NCSU, NC A&T, and UNC Pembroke. It is anticipated that by providing the team of instructors from all campuses the opportunity to debrief together and share course content and experiences, student learning and instructor proficiency with and adoption of PBL teaching methods will be higher at the end of the three-year study period.

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