S #11

MODELING BEST PRACTICES: ACTIVE LEARNING VS. TRADITIONAL LECTURE APPROACH IN INTRODUCTORY COLLEGE BIOLOGY

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Introduction

This synopsis describes results of a study designed to determine biology students' understandings of key science concepts in an active learning environment and in traditional lecture settings. The study design was to compare student performance on identical exam questions given to students in the traditional lecture and active learning sections of Biology 100 (Concept in Biology) and to generate interest in students for K-12 science teaching. Interest in changing the format of introductory science courses is high as exemplified recently by the Undergraduate Advisory Committee to NSF in their report (1996), Shaping the Future: New Expectations for Undergraduate Education in Science, Mathematics and Technology.

After more than two decades of teaching Biology 100, the lead biology professor had become increasingly concerned about the apathy of the majority of the student taking the course. Few students appeared to begin or end the course feeling that science in general, or biology in particular, was exciting or relevant--although most students responded with high ratings for his teaching on the end-of-semester evaluation.

Methods

In this study the biology professor teamed up with other colleagues to implement a variety of active learning approaches based on Constructivist theory. He wanted to compare student performance on shared exam questions in his section to the other traditionally-taught sections of Biology 100.

Research Team

Researchers involved in this study represent a unique university research partnership linking the departments of Biological Sciences, Education, and Mathematics & Statistics. Two biology faculty members, a science educator, and a statistician worked to collect and analyze evidence related to determining the effectiveness of introductory biology teachings--active approaches versus traditional lecture format. One biology Professor, Professor A, the lead professor, was the sole instructor of Biology 100, the active learning section (section A). The assistant professor of science education was the on-sight classroom observer and instructional consultant. She served as evaluator and professional development mentor in section A, providing advice on implementing constructivist ideas, cooperative learning, and issue-oriented science teaching approaches with which she had extensive prior experience. A comparison section of Biology 100 (section B) was taught by Professor B using the traditional lecture approach. Professor B had five years of teaching experience with the course. Both Professors A and B had received highly favorable end-of-semester student evaluations. In addition to Sections A and B offered in the Fall, an additional comparison section (section C) was team taught by Professor A and two other faculty members in the Spring. The professor of mathematics/statistics provided expertise in analyzing the assessment findings.

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The research team asked two fundamental questions:

1) What could be done in a large lecture course to make the learning more active?

2) How would student performance compare on exams in the active learning and traditional lecture sections?

Not often do educational researchers find themselves in a situation where they can compare teaching approaches. The research team decided that this action research comparison should be done as a first step in exploring different ways of teaching and learning in undergraduate science courses.

Subjects

Biology 100 is a four-credit, one semester course designed primarily for beginning biology and biochemistry majors. Typically, two sections are offered during the fall semester (sections A and B) and one in the spring semester (section C). Section A contained 242 students, section B, 179 students, and section C, 236 students. Table 1 illustrates a comparison of the rank of students enrolled in each section (1A), percentage of biology and biochemistry majors in each section (1B), and the mean scholastic aptitude test scores and mean grade point averages for students (1C).

Procedures

A comparison of student performance on shared, multiple-choice exam items was conducted to determine if there were differences in performance between active learning and traditional lecture sections.

Research on active learning (Harwood, 1996, Hayard, 1993 Johnson & Johnson, 1991, Lord, 1994, Meyers & Jones, 1993, Orzechowski, 1995) guided the pedagogy for students enrolled in the active learning section (section A). These students were involved in a variety of individual and group discussions; hand-held microphones were used in section A to better facilitate whole-class discussion of research projects and cooperative learning tasks. In the active learning section value was placed on finding out what students knew through class discussion, what they wanted to know through analysis of their questions and conversations, and what they were learning through reasoning checks. Instruction in the active learning section was rooted in constructivist principles. The primary instructional goal was to have students actively participate in the learning process. Students were expected to question, think scientifically, and apply understandings of key biological concepts. Students in the traditional sections (sections B & C) were taught using the typical lecture method with very little discussion or interaction among students or between students and the professor.

Results and Discussion

Student populations in all three sections of Biology 100 were comparable with respect to rank, academic major, mean SAT, and mean GPA scores as shown in Table 1. The first research question was tackled in the procedures developed for the active learning class as noted above. Figures 1 through 3 show the results for the second research question by providing a comparison of student performances on common exam questions in the three sections.

Table 1 Three-Section Comparison Data for Students in Biology 100

A: Rank of Students Enrolled in Biology 100
Fall 1995 (Sects. A and B) and Spring 1996 (Sect. C)

	Section A (Active Learning)	Section B (Traditional)	Section C (Traditional)
Freshmen:	183 (75.6 %)	113 (63.1 %)	135 (57.2 %)
Sophomores:	33 (13.6 %)	30 (16.7 %)	54 (22.9 %)
Juniors:	13 (5.4 %)	19 (10.6 %)	25 (10.6 %)
Seniors:	6 (2.5 %)	6 (3.4 %)	12 (5.1 %)
Post-bac:	5 (2.1 %)	6 (3.4 %)	5 (2.1 %)
Spec- UG:	2 (0.8 %)	5 (2.8 %)	5 (2.1 %)
TOTAL:	242	179	236

B: Declared Majors in Biology 100, Fall 1995 and Spring 1996

BIOL [a]	76 (31.4 %)	50 (27.9 %)	57 (24.2 %)
BIOC [a]	16 (6.6 %)	14 (7.8 %)	19 (8.1 %)
Other	100 (41.3 %)	82 (45.8 %)	130 (55.0 %)
UNDC	50 (20.7 %)	33 (18.4 %)	30 (12.7 %)
TOTAL:	242	179	236

C: Mean SAT Scores and Grade Point Averages for Biology 100 Students. Fall 1995 and Spring 1996

Mean SAT scores (verbal + math)	1.045	1.035	1.087
Mean GPAs	2.69	2.58	2.68

Despite the similarity in student populations, section A showed better student learning as measured by achievement on common multiple choice questions. The mean percent correct score for the eight questions answered by section A students on their midterm was 20 points higher than the mean score earned by section B students on the same questions on their final ($p<0.001$ for A vs. B; Figure 1, left; error brackets indicate 95 percent confidence limits). In the following semester students in section C did somewhat better than section B students on the same questions, but were still 16 points lower then section A ($p<0.001$ for A vs. C; Figure 1). Similarly on a different set of eight questions that originated on the section B midterm, the mean score of section A for these questions on their final was slightly higher ($p<0.05$) than for Section B on their midterms, while the mean for section C on their final was significantly lower ($p<0.001$; Figure 1, right). The results show that Biology 100 students in the active learning section (section A) did at least as well as or much better than the students in either of the other two sections on answering identical multiple-choice questions for the first time.

To examine long-term learning the final exams in sections A and B included repeated common questions that students in each section had seen before on their respective midterms. Figure 2 shows the mean percent answering correctly on multiple-choice questions when they were given on midterm exams (open bars) and repeated on final exams (shaded bars). In the case of section A the students' performance on the final improved by 16 percentage points compared to the average for the same questions on the midterm exam, and the difference in means was significant ($p<0.001$). The mean percent for the scores on section B increased by only about three points on the final exam ($p<0.05$), but the mean for these questions was previously high on section B midterms so that, in fact, there was less room for improvement. Although we cannot conclude from these data that the learning of section A students improve *more* than that of students in section B, it is clear that on repeated questions section A students showed substantial and impressive improvement in achievement over the course of the semester.

Finally, section A students as a group performed significantly better overall on the full set of 16 common questions on the final exam than either of the traditionally-taught sections (Figure 3).

Figure 1

Comparison of Sections Through
First Time Performance on Common Questions

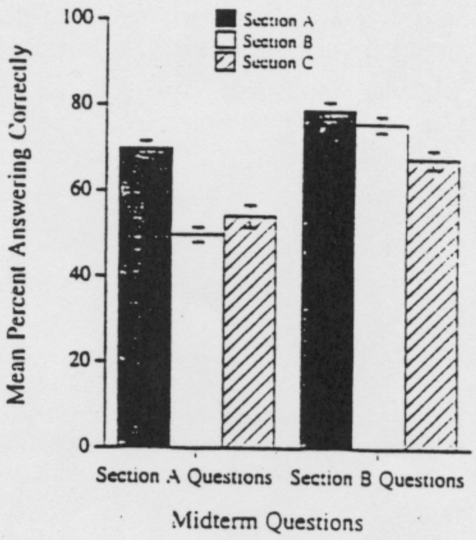


Figure 2

Comparison of Learning Within Sections
Through Performance on Repeated Questions
at Midterm and on Final Exam

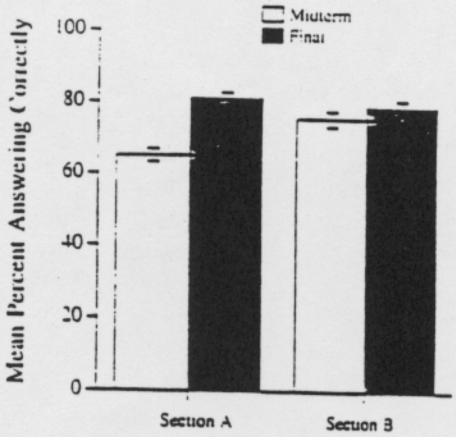
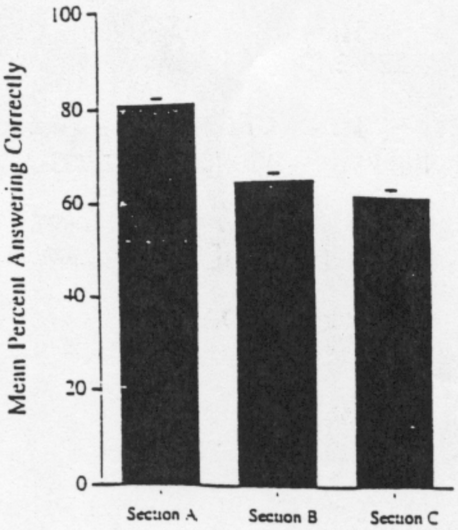


Figure 3

Overall Performance on Common Final Exam Questions



Conclusions

University science faculty have frequently voiced concern that active learning is fine in principle, but it takes too much class time to allow for student discussion and reflection and that the approach does not allow for enough time to "get through the material." In this study it is true that less time was available for "coverage" in the active learning section (Section A). Yet, the results revealed that students enrolled in the active learning section did as well or better than the students in the traditional lecture sections on a majority of the shared test items, and that the performance of students in the active learning section improved significantly across the semester. The results suggest that the principle of parsimony, "less is more," implicit in the National Science Education Standards (National Research Council, 1996) for K-12 students is also appropriate for large lecture introductory science courses at the post-secondary level.

The primary purpose for collecting this information was not to generalize the results for all students, but rather to begin to strengthen the researchers' professional voices through a more "scientific" approach to biology teaching. Our goal as both teachers and researchers is to obtain a clearer picture of what is happening with biology students and also to stimulate in other science faculty an interest in research related to improving undergraduate science teaching. The researcher-team members feel strongly that the process they have begun is research *in the service of teaching* as opposed to research about teaching.

These findings are being used to convince potential K-12 teacher candidates, other colleagues at UMBC and beyond to examine the merits of active learning. We believe in the power of modeling the most desirable and inclusive science teaching approaches for emerging K-12 teachers as well as any future professors who might be in the class as graduate teaching assistants.

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The Final Report of the Chautauqua ISTEP Research Project

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