Student- and Teacher-Centered Learning in a Supplemental Learning Biology Course

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Abstract: Students who chose to enroll in a supplemental course associated with a large biology lecture performed better on lecture exams than those students who chose not to enroll in the supplemental course. Sections of the supplemental course were taught with instructor-centered methods prior to some exams, student-centered methods prior to other exams, and a mixture of student- and instructor-centered methods prior to the first and final exams; the treatment (instructor- or student-centered learning) sequence varied between sections. This reciprocal repeated-measures design allowed for comparison of students' performance on exams following a series of instructor-centered, student-centered, and mixed sessions. The relative benefits of student- and instructor-centered instructional methods, or a mixture of the two methods, varied among supplemental sections. The section with the highest overall score showed the most improvement following mixed instructional methods, the two intermediate sections showed the most improvement in exam performance following student-centered instruction, and the section with the lowest overall score did not show consistent improvement. Those sections that improved in response to student-centered or mixed instruction methods maintained their improved exam performance throughout the remainder of the semester.

Keywords: introductory biology, student-centered learning, supplemental instruction.

Introduction

Whereas lectures and textbooks may be an efficient method of presenting knowledge, most students need additional activities to process the information presented in lecture. Small group cooperative learning sessions complement lectures by providing a social context in which a student constructs individual understanding of the content presented in lecture. Just as discourse is a central component of scientific process, students working with peers to explore their understanding of scientific content is a central component of learning science (Tien, *et al*. 2002). Many instructors have adopted student-centered teaching methods (Johnson and Malinowski, 2001) to engage students in their learning processes and by doing so increase content acquisition as well as metacognition, student understanding of the way that they learn. Such learning will hopefully provide students with a self-sustaining level of biological literacy.

Large science courses present a particularly challenging environment for the implementation of student-centered learning strategies. This problem is being addressed on many fronts: creative teaching strategies which promote student involvement in the lecture course (Klionsky, 2001), workshops (Udovic *et al.*, 2002) or studio sessions (Roy, 2003) in place of lecture sessions, inquiry-based laboratory exercises (Herrnkind and Bowling,1999; Moss, 1999; Preszler, 2004a; Turner *et al.*, 1988) and smaller interactive sessions, which supplement the larger lecture course (Ogden *et al*., 2003; Van Lanen and Lockie, 1997). In a previous study (Preszler, 2004b), I found that a single cooperative concept mapping session improved students' performance on biology lecture exams more than traditional assignments. In this current study, I evaluate the impacts of 12 weekly small group sessions of a Learning Biology workshop course on students' exam performance in the associated large lecture course. I also assess the effects on lecture exam performance of two approaches to teaching the workshop course: student-centered and teacher-centered sessions.

Supplemental Instruction (SI) is a popular model for associating small group learning sessions with larger lecture courses. It is a program used by over 900 institutions, which aims to help students learn the content of challenging courses, while at the same time improving their more general learning skills (Center for Academic Development, 2003). A central tenet of SI is that sessions are led by peer instructors. I chose initially to teach 4 sessions myself in order to develop a first-hand understanding of SI prior to training and supervising student peer instructors. I also required participants to enroll in a one credit Learning Biology course which was graded on attendance and participation, rather than using voluntary attendance typical of most SI programs. While it is not clear if these sessions should fall within the general category of SI, they were used to assess the effectiveness of small-group sessions and of student-centered learning activities, both of which are central components of this popular program.

Constructivist theory presents learning as a process of knowledge acquisition and assimilation into each individual's existing knowledge domains. This suggests that illuminating relationships between known and recently acquired knowledge is a key step in meaningful learning (Alters and Nelson, 2002). Student-centered teaching methods encourage discussion and consideration of course material relative to students' existing knowledge base and by doing so promote constructivist learning. Alternatively, instructors with a view of both students' initial understanding and a more complete understanding of the ultimate course goals may better illuminate connections using teacher-centered activities. I personally feel the greatest sense of accomplishment when my students take ownership of their learning process during successful student-centered activities. However, I did not want to propose a revision of our introductory biology curriculum without more objective measures of the benefits of supplemental seminars in general, and an assessment of these two contrasting pedagogical approaches: student- versus teacher-centered instructional methods.

In this experiment, I compare the performance on a sequence of lecture exams of students enrolled in only the lecture, in comparison to students enrolled in both the lecture and the Learning Biology seminar. I also applied a reciprocal sequence of student- and teacher-centered activities across the four sections of the Learning Biology seminar to compare the influence of these teaching strategies on student performance on lecture exams through the semester. As a result of focusing on differences in students' sequence of scores across the three groups, and varying the order of the treatments, any variation in the difficulty of exams did not bias our conclusions.

Methods

In an effort to improve students' performance on exams in a freshman biology lecture course, and to improve their more general learning skills, I developed a one credit Learning Biology course. The lecture course covered four major topics (genetics, evolution, diversity, and ecology) with an exam at the end of each topic and a miniexam half way through the first section, worth half as much as a full exam.

Recruitment

After the miniexam, I opened four sections of a one credit Learning Biology course to help students learn to study in the context of their biology course. The Learning Biology course started immediately, but students were given two weeks to enroll; absences during these first two weeks did not count against students' grades. During these two weeks, I repeatedly described the Learning Biology course in lecture, and invited students to enroll in it. Enrollment in the lecture course was 206 students. Each Learning Biology section was limited to no more than 12 students. The Learning Biology section identified in this paper as ST1 quickly recruited 12 students, TS2 then filled at 12 students, TS1 had 9 students, and ST2 initially only had 3 students. I encouraged students signing up at the end of the enrollment period to enter section ST2 which brought the enrollment up to 7.

Treatments

In order to determine the relationship between enrollment in Learning Biology and performance on lecture exams, students were categorized as attending lecture only or attending lecture as well as participating in the Learning Biology course. In order to determine the influence on lecture exam performance of student- in comparison to teacher-centered methods of teaching Learning Biology, I assigned students in Learning Biology to sequential treatments. I taught students in the teacher then student sections (TS1 and TS2) using teacher-centered methods between exams one and two, and student-centered methods between exams two and three. Students in sections ST1 and ST2 were given the reciprocal treatment of student-centered methods prior to exam two, and teacher-centered methods prior to exam three.

Both methods of teaching the Learning Biology course actively involved students in activities including concept mapping, reorganizing their notes, analyzing previous exams, and developing answers to review questions. The difference between the two treatments was that when using a teacher-centered approach, I was standing at the white board leading the lecture/discussion; when using a student-centered approach, I defined the general activity and then students worked in groups of two to four students while I circulated around the classroom keeping them on track with prompts. For example, when making a concept map using the teacher-centered method, students would contribute terms which I would list on a white board. I would then lead a discussion of the relationships among the terms and while doing so illustrate our discussion by making a concept map. Alternatively, when making a concept map using a student-centered approach, students would work within their small groups to generate concepts associated with a major topic and would write the name of each concept on a post-it note. Each group would then construct their own concept map on their group's white board by arranging the post-it notes on the white board and connecting them with arrows labeled to indicate the relationships. I would circulate and ask leading questions, but during these student-centered activities, I avoided telling students how to construct their maps.

Data Analyses

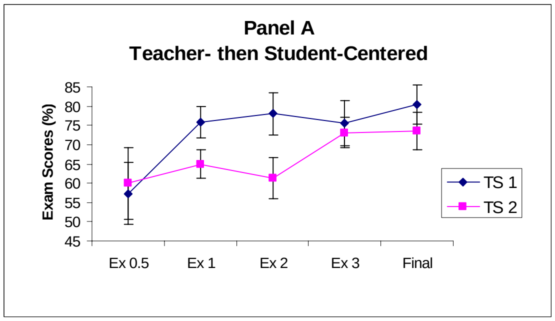
Students enrolled in Learning Biology who did not attend at least 67% of their sessions were excluded from the analyses of the impact of the Learning Biology course, and the two treatments applied to the Learning Biology sections, on exam performance. Students with poor lecture attendance were not removed from the analyses, as attendance was not recorded in the large lecture course. The analysis only included students who had taken all the lecture exams at the assigned times. These limitations on students included in the analyses were applied retroactively across all exams and reduced the number of Learning Biology students included in the analyses from the initial enrollment of 40 to 31 (subsample sizes: 14 students in Student-Teacher sequence, 11 in ST1 and 3 in ST2; 17 students in Teacher-Student sequence, 9 in TS1 and 8 in TS2), and reduced the number of lecture-only students from 166 to 132. The results were analyzed with a repeated-measures analysis (Systat, 2002). Exam scores in the miniexam and the 4 major exams were the dependent variable. Student category, the independent variable, had three levels: students in lecture only, Learning Biology students who were taught with teacher-centered method prior to exam two and student-centered methods prior to exam three (TS sections), and Learning Biology students who were taught with student-centered methods prior to exam two and teacher-centered methods prior to exam three (ST sections). The test statistic of interest was the analysis of the pattern of student test scores across the 5 exams (the repeated measure) associated with student category (the treatment variable).

In order to further understand differences in student performance associated with sections of the Learning Biology course, an analysis of variance was used to compare student attendance between the four sections of Learning Biology. This analysis used all 40 students enrolled in the Learning Biology course.

Results

The pattern of student performance across their five exams varied among the three groups shown in separate panels in Figure 1 (Exam by Treatment Interaction Term, Wilks' Lambda $F_{8,314}$ = 2.92, p = 0.004). This difference between groups was primarily due to differences between students who were only enrolled in the lecture in comparison to students who enrolled in the Learning Biology course in addition to the lecture. Students who were only enrolled in the lecture showed modest improvement between the initial mini-exam and exam one and then their performance gradually declined through the semester (Fig. 1, Panel C). These students showed no significant variation in performance across the three midterm exams (Wilk's Lambda $F_{2, 130}$ = 2.62, p=0.077). In contrast, three of the four sections of students in the Learning Biology course were able to sustain the improved exam performance they reached at different times during the course (Fig. 1, Panel A: TS1 prior to exam1, TS2 prior to exam3; Fig. 1 Panel B: ST1 prior to exam2). The results driving the significant exam by treatment interaction are most clearly seen by comparing the initial and final exam scores of the lecture only and the Learning Biology Workshop students. The scores of students who chose to only enroll in the lecture course were higher on the initial miniexam (lecture only 66.22%, workshop students 59.52%); however, students in the Learning Biology Workshop performed better on the final exam (lecture only students 66.88%, workshop students 73.27%).

Students in the two treatment groups applied in the Learning Biology course did not consistently differ in their performance across the five lecture exams (Wilks' Lambda $F_{4,26}$ = 1.43, p = 0.252). As illustrated within the panels A and B of Figure One, there were dramatic differences between sections of the Learning Biology Workshop that had been given the same treatment. The TS1 section improved most rapidly in response to mixed student- and teacher-centered strategies prior to exam one and the final (Fig. 1, Panel A). The TS2 (Fig. 1, Panel A) and ST1 (Fig. 1, Panel B) sections improved following their student-centered Learning Biology sessions. In contrast, ST2 (Fig. 1, Panel B) began the course prior to the Learning Biology sessions with a much lower average on the initial mini-exam, and responded more positively to teacher- rather than student-centered activities, although they never reached a passing level.



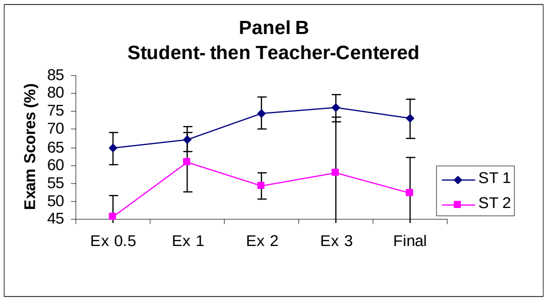


Figure 1. Student exam performance by treatment (panels) and section (lines in panels). Data points illustrate the mean exam scores, bracketed by the standard errors. The students illustrated in Panel A participated in workshops (TS1 & TS2) which were taught with teacher-centered methods prior to exam 2 (Ex 2), student-centered methods prior to exam 3 (Ex 3), and a mixture of teacher- and student-centered methods prior to the initial miniexam (Ex 0.5), exam 1 (Ex 1) and the final exam (Final). Students illustrated in Panel B participated in workshops (ST1 & ST2) which were taught with student-centered methods prior to exam 2, teacher-centered methods prior to exam 3, and mixed methods prior to the miniexam, exam 1, and the final exam. Students illustrated in Panel C were only enrolled in the lecture course and did not enroll in the Learning Biology Workshop.

Student attendance varied significantly among the four sections of the Learning Biology course ($p = 0.006$). The average number of student absences was surprisingly similar among three of the sections (ST1 = 1.50 absences per student, TS1 = 1.44, TS2 = 1.50). However, students in section ST2 missed an average of 4.0 of the weekly meetings during the semester.

Overall, students in the Learning Biology course performed better on lecture exams and were able to maintain increases in performance through the semester more effectively than students who did not participate in the Learning Biology course. The section of Learning Biology with the highest lecture exam performance (TS1 Fig. 1, Panel A) benefited more from a mixed learning approach, rather than strictly student- or teacher-centered activities; the section with the lowest exam performance and lowest attendance (ST2 Fig. 1, Panel B) showed an inconsistent response, possibly benefiting most from teacher-centered instruction, but did not reach a passing level; the two sections with intermediate performance on lecture exams (TS2 & ST1 Fig. 1 Panels A & B) benefited most from student-centered teaching techniques.

Discussion

This study revealed a significant association between participation in a weekly Learning Biology session and improved performance on lecture exams. Enrollment in the Learning Biology course was optional for students enrolled in the general biology lecture. As Ogden *et al.* (2003) note, studies which have revealed positive correlations between voluntary participation in Supplemental Instruction(SI) programs and outcomes such as improved grades (Grise' and Kenney, 2003; Ogden *et al*., 2003; Van Lanen and Lockie, 1997) and improved retention (Ogden *et al*., 2003) are limited in their ability to infer cause and effect due to selection bias. Students participating in SI programs, and students enrolled in my Learning Biology course, may perform better than non-participating students due to the effects of the supplemental courses, due to a difference in motivation (they cared enough to attend voluntary SI sessions or enroll in my LB course), or most likely, due to a combination of these two factors. I felt it would be inappropriate to assign randomly students to the supplemental course, and therefore exclude participation by students who didn't happen to be selected, because the balance of the evidence strongly suggests participation in such courses increases student learning. In this study, students enrolled in the Learning Biology Workshop had a lower average score on the initial miniexam (Lecture only 66.22, Workshop 59.52), but improved much more through the semester and had a higher average score on the final (Lecture only 66.88, Workshop 73.27). Studies, which have partially factored out the effects of differences in initial motivation from effects of SI, have found that the SI students have performed significantly better than students in a motivational control group who wanted to attend supplemental instruction, but had serious schedule conflicts (Arendale, 1997; Ramirez, 1997). A controlled experiment in which students in a developmental mathematics course were assigned to treatments of no supplemental instruction, traditional SI, or SI with participation of the SI leader in lecture activities demonstrated dramatic benefits of both versions of SI on student success rates (Wright *et al*., 2002). In an experiment conducted with the same general biology course described in this article, students were randomly assigned to different sequences of traditional homework assignments in comparison to cooperative concept mapping sessions (Preszler, 2004b). In that study, students performed three percentage points, a third of the way from a minimum score of one grade up to the next grade, better after a single cooperative concept mapping session. In this study, students enrolled in the Learning Biology course which met once a week for 12 weeks improved 13.48 percentage points between the first and last exams, and students who only attended lecture improved 0.66 percentage points.

Contrary to my expectations, there was not a consistent benefit of student-centered in comparison to teacher-centered approaches. There was interesting variation among sections in their responses to the treatments applied to the learning biology course suggesting that the choice of instructional methods should be informed by frequent formative assessments of individual classes and not rigidly tied to the instructor's favorite pedagogy. The section which never reached a passing level (ST2 Fig. 1, Panel B), also had significantly worse attendance, and not coincidently, was the section at a less popular time slot composed of students who enrolled late. We have seen this same pattern in an unpublished study, students who are talked into enrolling in a program during late enrollment tend to perform poorly. Students in this Learning Biology section showed the biggest drop in their performance following student-centered learning sessions. This result suggests that cooperative learning groups may need a minimum level of initial motivation to be able to benefit from student-centered activities. Our most typical students, those with intermediate grades (TS2 Fig. 1, Panel A; ST1 Fig. 1, Panel B), improved their performance the most following student-centered sessions. Perhaps the most interesting section was TS2 (Fig. 1, Panel A) which didn't respond to mixed teaching, nor to teacher-centered sessions, and then jumped approximately 10% in response to student-centered methods and maintained this higher performance through the final. The section with the highest overall grades (TS1) showed the strongest increases in their grades in response to mixed teaching of the Learning Biology course. While these students may have benefited from the more engaging student-centered sessions when it was a good match for the material, they also were able to stay focused during more teacher-centered sessions which reviewed more content just prior to exams and after content-rich lectures.

The most encouraging result of this study is that sections (ST1, TS2) whose performance on lecture exams increased more in response to student-centered learning enabled students to maintain their improved performance beyond the duration of the student-centered sessions. This suggests that these students have stepped above the specific content addressed in the student-centered sessions to gain a more general understanding of how they learn, which they have then applied during their studies for subsequent exams. One component of student-centered learning is that students organize, evaluate, and enhance their knowledge as they teach their peers. Tessier (2004) found that not only does teaching peers improve the student teachers' understanding of the material that they taught, but it also improved their performance on subsequent exams. As in my study, this indicates that student-centered activities result in meaningful learning at a meta-cognitive level.