Improving Student's Performance in a Challenging Biology Course: Assessing Specific Components of Supplemental Instruction

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Abstract

At NMSU, and at universities throughout the U.S., students far too often fail biology lecture exams; I have found that at NMSU, small group workshops, using some components of supplemental instruction, improve student performance on lecture exams. In the Fall of 2002, students performed better on biology lecture exams after a single cooperative concept-mapping workshop than after an essay homework assignment. Encouraged by the positive effects of a single small-group activity, the next time I taught a large biology lecture course (Spring 2004), I offered students the opportunity of enrolling in a workshop which met weekly throughout the semester. Students enrolled in this supplemental course associated with Biology 111 performed better on lecture exams than students not enrolled in the SI course. In order to investigate how to best teach such workshops, I taught some sessions using instructor-centered methods, and other sessions using student-centered methods. The relative merit of these two approaches, and a mixture of the two, varied between sections suggesting that when it comes to designing SI courses─one size does not fit all groups of students. Students in the SI section with the lowest overall performance on lecture exams generally were not successful in the lecture course, regardless of the method used during the SI sessions, although they may have benefited most from instructor-centered methods; the two intermediate SI sections benefited most from student-centered activities; and lastly, the section with the highest overall performance responded to a mixture of student- and instructor-centered instructional techniques.

Introduction

In this paper I will describe my efforts to address the immediate problem that a majority of NMSU students who enroll in Biology 111 fail to learn the course content and as a result earn a grade of W, F, or D. Addressing this problem requires the development of an understanding of how our students learn, or fail to learn, the content of challenging courses and how the students' learning process is impacted by various teaching strategies. Because this problem is nationwide, and is not limited to biology, a variety of promising solutions have been developed. However most of these solutions, if treated as hypotheses, have not been tested using evidence in a manner that is convincing to people teaching biology and other sciences at our universities. While those of us involved in science education often lament the slow implementation of educational reform by teaching scientists, scientists generally do not accept hypotheses supported primarily by testimonials, anecdotal evidence, and correlational data which can be explained by many alternative hypotheses. I have set out to not only increase my students' success rate in Biology 111, but also to evaluate educational hypotheses in a fashion which may be convincing to some scientists.

These lofty goals require a fundamental evaluation and restructuring of the way that we teach science. The central problems may be misconceptions students have developed about science prior to arriving at their first university-level science course, instructors' misconceptions about student perspectives and skills, students' limited literacy skills and inability to apply their skills to content courses, and a predominant course structure (didactic lectures) which is ill equipped to address these problems. Gardiner in an essay on higher education claims that the structure of teaching and learning at universities is producing students who are unable to apply their fundamental academic skills as they study scientific content, and graduates who are unable to think critically, communicate effectively, engage in life-long learning, and solve complex problems (1). As biological knowledge, and the range of societal issues tied to such knowledge, expands it becomes increasingly important that we provide students with the tools to enhance their biological literacy. The development of multidimensional biological literacy, characterized by the ability to apply biological knowledge to complex interdisciplinary issues, depends on the development of dynamic life-long learning skills (2). We are modifying the structure of our lectures, laboratories, and developing supplemental courses to enhance student learning in the lecture and laboratory in order to help our students learn to learn science at a meaningful, self-sustaining level. In this paper, I will discuss the development and assessment of activities for courses that supplement biology lectures and laboratories.

The concordance of my impression of my students' problems learning biology, constructivist learning theory, and educational research on the effects of concept mapping and cooperative learning led me to evaluate the impact of a cooperative concept-mapping activity on my students performance in Biology 111 during the Fall of 2003 (3). The constructivist perspective on teaching and learning suggests that meaningful knowledge acquisition occurs when students incorporate new knowledge into their existing conceptual frameworks, and when they modify and refine these frameworks to accommodate the consequences of this knowledge (4). Although biology textbooks and lectures emphasize unifying concepts, when my students respond to questions, they often appear to be randomly grasping at disconnected sound bites of biological knowledge. Concept mapping is an activity which explicitly targets the development of increasing effective conceptual frameworks (5). When students create concept maps in a cooperative learning setting, they more fully explain and develop their connections between concepts, and hopefully, develop a more meaningful understanding of the knowledge domain that their group is exploring and developing.

The results of this work led me to explore the possibility of incorporating such activities into a formal supplemental instruction course associated with Biology 111. Prior to the start of the Spring 2004 semester, I attended the Supplemental Instruction Supervisor's workshop, initiated by the University of Missouri in Kansas City. While the standard SI approach as a whole is often associated with positive short- and long-term effects on student learning(6), I was interested in obtaining some first-hand experience teaching in this format, and in beginning to explore the impacts of different SI activities on Biology 111 students, prior to attempting to initiate a full-fledged program. Although teaching sessions myself differs from the standard SI model of peer instruction, I felt it was a reasonable approach to gaining the experience and knowledge needed to effectively guide peer instructors. The student learning that occurred during cooperative concept-mapping session with a low student:teacher ratio in comparison to learning which occurred during the traditional essay homework assignment varied in so many respects that it was hard to determine whether differences in performance were due to interactions with the instructor, with peers, or due to concept mapping *per se*. In order to begin to dissect the factors associated with enhanced learning during these sessions, and to develop my knowledge of SI, I taught four sections of an SI course associated with Biology 111 in the Spring of 2004 and compared student learning in student-centered cooperative learning sessions to student learning during instructor-centered activities in the same course.

Methods

In the Fall of 2003 Biology 111 course, I compared students' lecture exam performance after a cooperative concept-mapping exercise to their performance after completing a homework assignment. In The Spring of 2004, I compared lecture exam performance of students who chose to enroll in a supplemental course to those who didn't; within the supplemental instruction course, I compared students' performance on lecture exams after a series of student-centered S.I. activities to their performance after a series of instructor-centered activities.

Cooperative Concept Mapping

In order to compare each student's exam performance after a cooperative-conceptive mapping workshop to their own performance after a traditional assignment, I assigned students to into three groups. Prior to Exam One, Group One students participated in one of nine cooperative concept-mapping workshop, while Groups Two and Three completed a more traditional assignment; prior to Exam Two, Group Two students constructed concept maps, while Groups one and Three completed a traditional assignment; prior to Exam Three, Group Three made concept maps, Groups One and Two completed an assignment. Workshops had up to a maximum of 16 students divided into 4 groups. After excluding students who missed their workshop, assignments, or took an exam at an alternative time, there were 152 students left in the analysis (Group One, 50 students; Group Two, 46 students; and Group Three 53 students).

I started each concept-mapping workshop with an explanation of the purpose of concept mapping. I explained that the method was meant to help students construct their own organization scheme in a manner that helps them understand the concepts presented in lecture. In order to illustrate the method, I led a discussion in which we listed the main concepts from a lecture topic, and then discussed the relationships among the topics. I illustrated our discussion on a white board by drawing a concept map with nodes representing major concepts and labeled arrows illustrating relationships among the topics. At this point, I assigned students to groups of 2 to 4 students, and they began to develop their concept map of another lecture topic that typically spanned 1 or 2 weeks worth of lecture. I circulated among groups, asking follow-up questions about their maps and prompting groups that were getting bogged down, but carefully avoiding telling them how to organize their concept map.

I compared the effects of concept mapping to those of viable alternative assignments. In the first assignment, students wrote short answers to questions about an application of Mendelian genetics; in the second assignment, students read an article(7) about the evolution of human skin color and related it to a series of questions about natural selection and evolution; in the last assignment, students wrote a short essay relating the laws of thermodynamics to human carrying capacity.

After the 3 treatment periods and their associated exams were completed I adjusted each exam score by the average course percent of all students divided by the student's course percent. This adjustment was made to avoid biasing the results with random differences between treatment groups in the students overall course performance. I used these weighted exam scores as the response variable in a repeated-measures analysis(8) of the interaction between the treatment and the exam. This analysis asked if their were significant differences between groups in their pattern of performance across exams. More specifically, I was interested to see if a groups' weighted exam scores jumped up after participating in a cooperative concept-mapping workshop prior to the exam. Since groups had these workshops prior to different exams, each treatment group should show improved performance on a different exam, if cooperative concept-mapping was more beneficial than the assignments. The exams were composed of multiple questions. A majority of the exam questions were at an intermediate level using Bloom's taxonomy (9), requiring integration of related concepts. A few questions were at the lower term-recognition level and a few were at higher application, synthesis, and evaluation levels.

Student- and instructor-centered learning

In the Spring of 2004, I compared the influence on lecture exam performance of student-centered methods in a supplemental Learning Biology course to instructor-centered methods. Students voluntarily signed up for this optional 1 credit course from a week before, to a week after, the first mini-exam. The course was divided into 4 sections, each of which met once a week. I taught two of the sections (TS1 and TS2) using teacher-centered methods prior to exam 1, and student-centered methods prior to exam 2; I reversed this sequence in the remaining two sections (ST1 and ST2). I used a mixture of student- and teacher-centered methods prior to the miniexam, exam 3, and the final in all sections. During instructor-centered sessions, I stood at the white board and led each activity by facilitating discussions of solutions to problems, organization of concept maps, or clarification of challenging topics from lecture. During student-centered sessions, I presented students with their task and then periodically circulated around the room asking follow-up and clarification questions, but generally not providing direct answers. Because of the small class size (7 to 12 students), both methods resulted in active student learning.

I only included students who attended at least two thirds of the Learning Biology sessions in the analyses of the effects of student- in comparison to instructor-centered learning. I also compared the lecture exam performance of the students who had chosen to enroll in Learning Biology with students who had not. In all of these comparisons, I only included students who took all exams at the assigned times. The results were analyzed with a repeated-measures analysis (8). The analysis compared the pattern of student test scores across the 5 exams with treatment category: Learning Biology ST sections, Learning Biology TS sections, and lecture only students.

Results

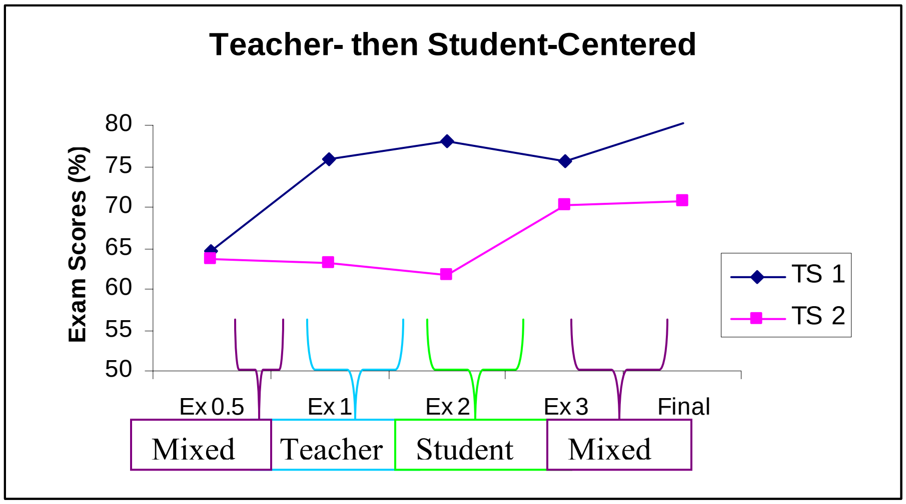
The results, from both studies, showed a positive impact of small group sessions on student exam performance in the large lecture course. The relative benefit of student- in comparison to instructor-centered methods of teaching these sessions appears to depend on the population of students in the session.

Cooperative Concept Mapping

In each of the three exams, students who had participated in the cooperative concept-mapping exercise had a higher weighted exam score than students who completed the traditional assignment (3). This interaction between the treatment and the pattern of exam scores through time was statistically significant ($F_{4,296}$=2.84, p=.024). Although, the effect of a single cooperative concept-mapping session was modest (approximately 3 points higher on a 100 point exam), it represents a jump of nearly one third of the way from the minimum score for one grade to the next highest letter grade as a result of a single cooperative concept-mapping session.

Student- and instructor-centered learning

Three of the four sections of students in the Learning Biology course were able to improve their exam performance at different times during the course, and sustain these improvements for the remainder of the course. Students who only were enrolled in the lecture course, and not the Learning Biology supplemental course, improved between the mini-exam and exam one, and then their exam scores gradually declined through the semester. By the end of the semester, students in the Learning Biology course scored 6.9% points higher on the final exam. The pattern of student performance across their five exams was strikingly different among the three groups (Wilks' Lambda $F_{8,316}$=2.78, p=0.006.). However, this pattern across the exams did not vary consistently between the student- and teacher-centered treatments (Wilks' Lambda $F_{4,26}$=1.43, p=0.252.). The Learning Biology section (TS1, Fig. 1) with the highest overall scores improved rapidly after mixed student- and teacher-centered sessions and maintained this improvement throughout the semester. The sections with intermediate overall performance (TS2 and ST1, Fig. 1), improved after student-centered sessions, even though these sessions occurred in a different sequence between these sections. The group with the weakest overall performance did not show sustained improvement, and did not perform at a passing level (ST 2,Fig. 1)



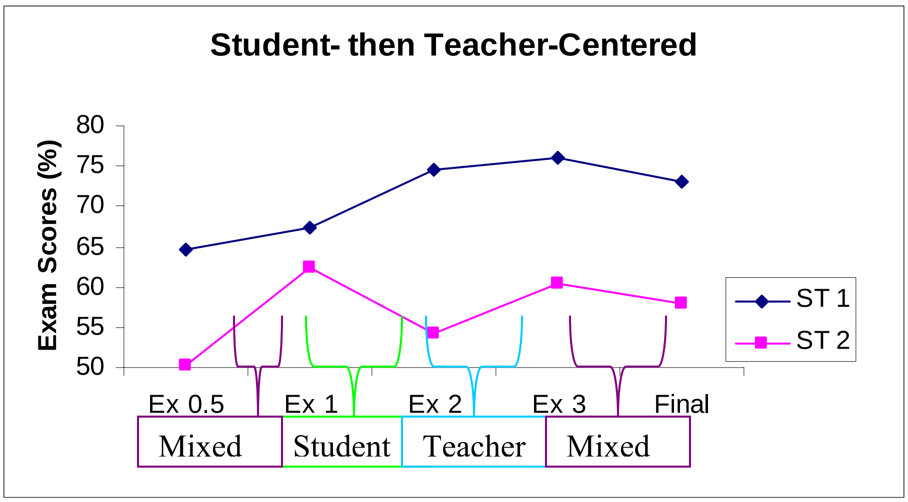


Figure One. Lecture exam performance of students in the four sections of Learning Biology.

Discussion

These studies have convinced me that small group sessions have the potential to improve students' success in general biology courses. They indicate that cooperative concept-mapping may have helped students put information from their biology course into a more lasting conceptual framework, but I cannot rule out the possibility that the beneficial impact of the cooperative concept-mapping sessions was due to the opportunity to work more closely with the instructor than is possible in the large lecture component of the course.

The results of the comparison of the effects of student- and instructor-centered activities suggests that for the typical group of students, student-centered activities are more effective. However, this may not be the case for some groups of students. While student-centered activities in theses supplemental sessions are more consistent with my preferred pedagogy, there are topics and groups of students who might be better served with instructor-centered activities. These results suggest that effectively leading a SI session requires the ability to rapidly assess and respond to the needs of each particular session. Most SI programs use peer instructors. These instructors need to be provided with frequent guidance in order to effectively assess the unique needs of each small group. The standard SI model claims that peer instructors need not be teachers, in fact need to be encouraged not to be teachers, but rather are simply successful students sharing their methods with their peers (5). It may be that peer instructors need to be introduced to a wide range of teaching techniques, and that they need to be guided to the technique which works best with their particular group of students.

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