# Impacts of Active Learning on Student Outcomes in Large-Lecture Biology Courses

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## Abstract

*Learning theorists have provided ample evidence supporting the use of active, student-centered, social learning environments. However, little action has been taken within U.S. university curricula to transform lecture courses so that they include such teaching methods. By adding cooperative and collaborative activities into large-lecture, introductory biology courses, I was able to measure the impacts of such active-learning strategies on student attendance and performance. I gathered data from two investigations involving 378 undergraduates from paired sections of biology, one section using active-learning activities and one not. In the first investigation, I used a mixed-methods approach to measure the effects of a cooperative pre-exam group discussion on student performance, confidence, and anxiety. In the second investigation, I used a quantitative approach to measure the effects on course attendance and performance of using scenario-based collaborative activities regularly throughout a semester. Students who engaged in cooperative pre-exam discussion did not show significant individual learning gains but did show an increase in confidence and a decrease in anxiety. Students who engaged in scenario-based collaborative activities showed significantly higher learning gains and course attendance. The identified gains are promising for course reform.*


**Key Words:** *Active learning; collaborative learning; cooperative learning; large-lecture; scenario-based learning; undergraduate education.*

## ○ Introduction

It is well known that students learn and retain the most information when they are actively taking part in their own learning (e.g., Michael, 2006). Active-learning practices place responsibility on the learner to build understandings. Additionally, social interactions are known to be an integral aspect of the learning process (e.g., Vygotsky, 1978; Bonk & Cunningham, 1998). Unfortunately, lecture courses tend to highlight instructors as the "sage on the stage," and students are left acting as passive participants. This is particularly problematic in courses with large enrollment, such as university introductory biology courses. Most of the reasons instructors give for not including active-learning components in instruction involve perceived time constraints regarding preparation and in-class commitment, preexisting ideas about the nature of the learning environment, concerns about classroom management, questions regarding efficacy of practice, and not knowing how to alter teaching strategies (Michael, 2007). The common prevalence of passive, teacher-focused learning has become such an issue that national guidelines have been published (i.e., New Media Consortium, 2008; AAAS, 2011) as a "call to action" encouraging the transformation of undergraduate education in biology toward student-centered learning. These guidelines encourage engaging students as active learners, using multiple modes of instruction, facilitating collaborative learning, integrating constant assessment, and providing ample feedback.

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Some instructors have committed to this call to action by flipping their classrooms (e.g., Bergmann & Sams, 2012). The process of flipping a classroom involves having students watch and read lecture materials at home (typically through lecture videos posted online and chapter readings) and then spending class time working through related problems and activities. Such a total course transformation is not appealing to all instructors. Still, even without fully flipping a class, there are multiple ways for instructors to integrate active-learning elements into their teaching. Such strategies include group exams (Hodges, 2004), concept maps (Novak, 2013), problem-based learning (Savin-Baden et al., 2004), case studies (National Center for Case Study Teaching in Science, 2015), Socratic discussion (Overholser, 1993), think-pair-share (Lyman, 1987), and many others.

These active-learning strategies can be grouped as cooperative or collaborative approaches. Cooperative learning involves students working together to accomplish a common goal while being assessed individually (Prince, 2004). The core of this

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experience is a focus on cooperative success rather than competition. Collaborative practices go a step further and mandate that students work collectively to accomplish tasks and build shared understandings. In collaborative activities, students must rely on group partners to explore course materials and all must contribute in order to complete the assigned task. There are four essential elements to implementing effective collaborative learning: (1) student groups must be properly formed and managed; (2) students must be held accountable for individual and group work; (3) students must receive frequent and immediate feedback; and (4) assignments must promote learning and team development (Michaelsen et al., 2009).

### Course Context

Stemming from the socio-constructivist perspective and following published guidelines (Michaelsen et al., 1997), I transformed two large-lecture, introductory biology course sections. I implemented a cooperative-learning strategy in one section and a collaborative active-learning strategy in the other. I compared these two transformed sections to two mirror counterparts that I taught using a more traditional approach. For this project, I used an online learning management system to provide students with access to lecture outlines and homework assignments. I did not "flip" my classrooms – no lecture videos were provided online. Instead, I used the standard, publisher-provided materials to assign students homework associated with textbook readings. In the case of my second investigation, I also used this online platform to upload scenarios (Brooker et al., 2015) that students were expected to read prior to regularly scheduled collaborative activities. Furthermore, I ensured that the time spent preparing for the transformed instruction matched that of the time committed to the traditional course instruction. In my study, the only difference between the mirrored classes was the in-class instructional treatments. Thus, I sought to measure the impacts of in-class active-learning strategies that required minimal time commitments by an instructor. This design allowed me to measure changes in student performance as a direct result of the active-learning interventions. My goal was to attain a more manageable model of active learning that hesitant instructors might be willing to adopt.

The purpose of this study was to measure impacts of active-learning strategies on student performance and attendance in large-lecture courses. Specifically, I focused on the following research questions: (1) In what ways do cooperative pre-exam, group discussions influence student performance? (2) What are the differences in student-reported confidence and anxiety when taking individual versus group exams? (3) How does incorporation of collaborative group work influence class attendance and performance?

## ○ Methods

**Research design.** This project took place in my introductory biology course over four sections and included 378 undergraduate students. Within each of my paired comparison groups, students received identical content, participation points, and instruction (other than the cooperative or collaborative treatments) for the duration of the semester. Classes met for 75 minutes twice each week during a 15-week semester. Course content focused largely on evolution, ecology, and organismal biology. Data were collected and analyzed within approved guidelines by the university institutional review board, ensuring ethical treatment of all participants. I conducted two separate investigations to address the research questions, each employing a quasi-experimental design (see Table 1).

**Investigation 1.** To measure the impacts of the cooperative-learning strategy of pre-exam discussions on student performance, I compared student exam grades in two sections of introductory biology during one semester. In section A (n = 133), I distributed unit exams and then allowed students 10 minutes to discuss any aspect of the exam with peers. During this time, students were not allowed to make any marks on the exam or take any notes. After the pre-exam discussion, students returned to their seats and I then provided scantron forms for them to record their individual responses to the exam questions. Section B (n = 133) acted as the control group for this investigation. In this section, I had students complete the unit exams individually in the traditional fashion, with no pre-exam discussion. I compared student performance on two of the unit exams, each composed of 50 multiple-choice questions and identical in content questions across treatments. Additionally, I gathered student-reported feedback on confidence and anxiety after exams through anonymous, open-ended questions asking how students felt about taking each exam. I used a single-factor analysis of variance (ANOVA) to test if there were any significant differences in mean scores or variance across treatments. Then I used a deductive approach to qualitatively code student-reported levels of confidence and anxiety to determine any potential differences between treatments.

**Investigation 2.** To measure the impacts of collaborative group work on class attendance and performance, I compared two sections of introductory biology during one semester. In section A (n = 56), students worked in groups of four to complete 12 collaborative activities throughout the semester, in addition to standard course content and lecture discussions. For each collaborative activity, students were given a scenario to read prior to class. During class, each group was provided one worksheet consisting of four open-ended questions related to the assigned scenario (see Figure 1). I had students complete each activity using a jigsaw method (Blaney et al., 1977; Halverson & Lankford, 2009), wherein each student within the group acted as a facilitator for one of the questions while the remaining members acted as discussants to develop an answer. Students switched roles until all the questions had been addressed. After that point, all question-1 facilitators met together (and likewise for question-2 facilitators, etc.) and discussed responses before rejoining their original group to share what they had learned, revising responses as the group saw fit. Section B (n = 56) was used as the control group for this investigation. These students were given identical content as the treatment group through a lecture format and did not complete the scenario-based collaborative activities. In each section, student attendance was gathered through formative iClicker assessments, and completion points were awarded for individual

**Table 1. Research design.**

| | Group A | Group B |
|---|---|---|
| Investigation 1 | Pre-exam Discussion (n = 133) | No Discussion (n = 133) |
| Investigation 2 | Group Collaboration (n = 56) | No Collaboration (n = 56) |

1. Find an example of a lichen on campus (take a picture of your team with it to verify with the instructor) and identify the growth type of the example you found. Explain the relationship in the lichen.
   Facilitator ________________ ID ___________

2. Describe the importance of fungi in ecosystems and why penicillin might cause bacteria not to grow in its presence.
   Facilitator ________________ ID ___________

3. Describe two economic benefits of fungi.
   Facilitator ________________ ID ___________

4. Describe an example of a parasitic fungus and how it causes detriment.
   Facilitator ________________ ID ___________

**Figure 1.** Example collaborative-activity questions that students completed in class.

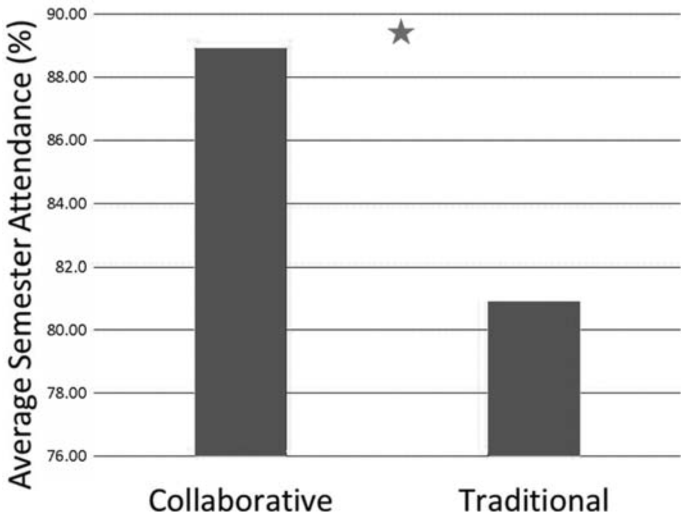


**Figure 2.** Average student attendance.

minute-paper assignments that asked students to summarize the day's content. Academic performance was evaluated through identical periodic content quizzes and summative, multiple-choice unit exams. I used a t-test to determine if there were significant differences among average daily attendance, and a two-factor ANOVA with replication to determine if there were significant differences between unit-exam and average overall scores between sections. Following this ANOVA, I ran a post hoc analysis to determine specific differences using a Bonferroni corrected alpha (0.025) for significance.

## ○ RESULTS

**Investigation 1.** There were no significant differences ($F = 1.94$, df = 3 and 905,$P = 0.121$) in mean exam scores between unit exams or treatment groups. However, students who participated in pre-exam group discussions reported higher self-confidence and less anxiety than their counterparts. Students in the cooperative section remarked: "I felt much more confident in the answers I was thinking about" and "Taking time to talk with my friends that I studied with before the test helped me feel like I could do it." By contrast, students in the other section made statements more similar to "I studied so hard for this test, but got so nervous, I made several stupid mistakes."

**Investigation 2.** The findings for the third research question indicate a significantly higher rate of average attendance ($t = 2.058$, $P = 0.0419$) when students were expected to engage in collaborative activities (88.90%) than when collaborative activities were not included in lecture (80.91%) (Figure 2). Students were awarded the same amount of participation points for attendance, regardless of the instructional treatment.

Likewise, when I ran an ANOVA test to compare exam scores across groups, I found a significant difference ($F = 20.336$, df = 1 and 660, $P < 0.000$) in mean exam scores between treatment groups across the entire semester. When I ran the post hoc analysis of mean differences for each exam and overall averages, I found significant differences between student scores on two exams (covering introductory biodiversity and ecology) and the overall exam averages (Exam 2: $t = 3.046$, $P = 0.003$; Exam 5: $t = 3.111$, $P = 0.002$; overall average exam scores: $t = 2.360$, $P = 0.020$). However, I found no significant differences on the remaining exams (Exam 1: $t = 0.529$, $P = 0.598$; Exam 3; $t = 1.258$, $P = 0.211$; Exam 4: $t = 0.478$, $P = 0.456$; see Figure 3) that covered evolution, animal biodiversity, and physiology.

## ○ Discussion

### Suggestions for Teacher Implementation

When first integrating active learning in the classroom, it is important to establish consistency in implementation. Given that both cooperative and collaborative activities deviate from traditional instructional approaches, students may not understand their roles and responsibilities initially. Once students understand what is expected of them in a given class, they are able to build a routine for how to act in that class. Additionally, it is important to provide students with a minimal amount of participation points to encourage consistent attendance. I found that once students understood the expectations, peer accountability was a much larger driving factor than any potential points they may have earned, as indicated by the significant increase in attendance in the collaborative section of my study. Still, the initial incentive of participation points promoted good practice of attendance by students until they developed their semester routine.

When considering implementing a group exam, it is important to consider the assessment goal. Group exams can be used to measure group understanding or individual understanding, depending on how they are implemented. In the method I described in this study, I chose to assess individual understanding through the cooperative task. As such, it was imperative that students were not allowed to take any notes or mark any responses during the group discussion. Also, because students were given only 10 minutes to discuss questions, they had to consider which parts of the test they wanted to discuss because there was not enough time to review every question. After the discussion period, students had time to consider the knowledge that was reviewed independently as scantrons were passed out.

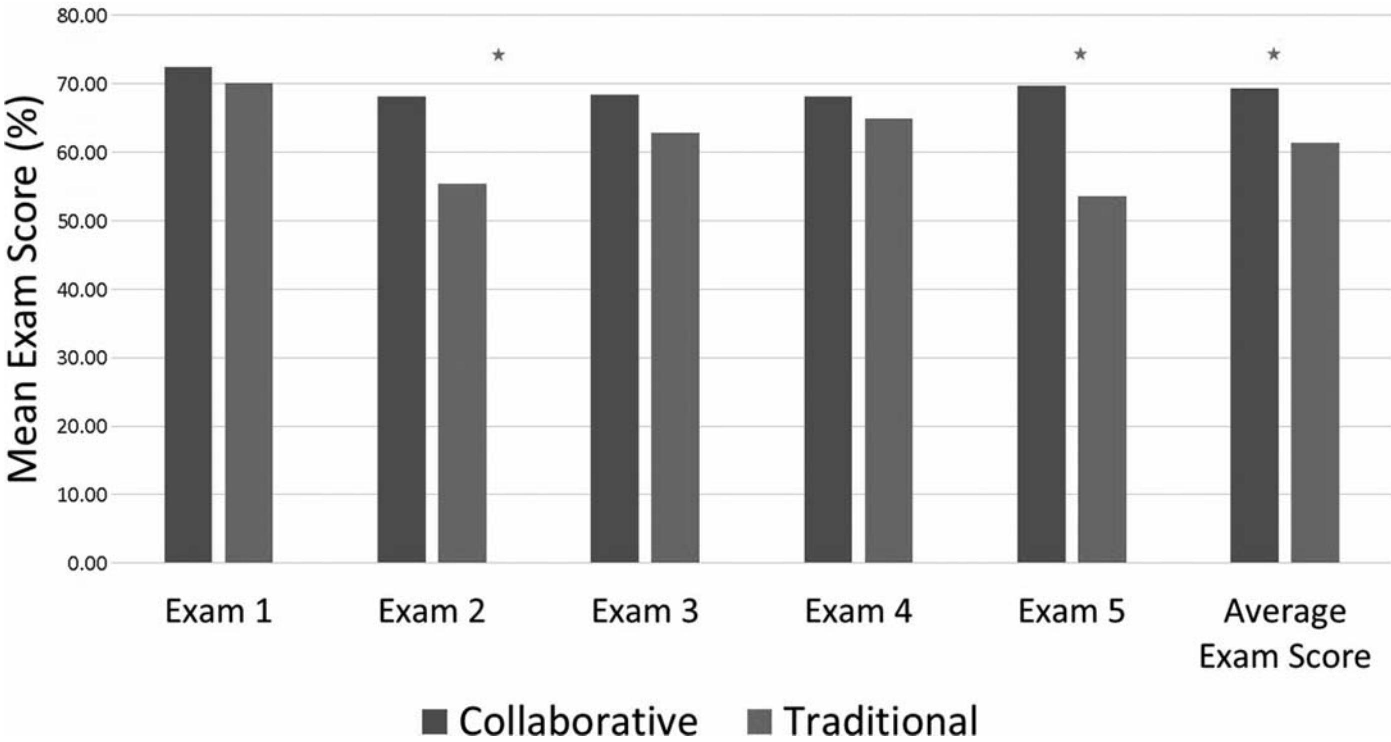


**Figure 3.** Differences in mean exam scores by treatment.

During this time and for the remaining duration of the exam, students had to decide for themselves what were accurate responses. Ideally, I would have liked to administer this task with open-ended questions on the exam, but time restrictions for grading the exams made that option too difficult to be a practical option.

When developing collaborative activities, a separate pre-scenario reading is an optional task. I found that students were equally prepared when they had read only the textbook assignment. When I decided to use this collaborative approach in my course, I used existing activity questions provided by the textbook. When resources were unavailable or inappropriate (e.g., for fungi diversity), I crafted four open-ended questions that were aligned with my learning objectives for that topic. For example, when I prepared to teach about fungal symbiosis, I selected the four main points of what I would have lectured on and transformed those ideas into questions for students to research and answer. For these activities, I had students self-assign themselves into groups of four before I handed out worksheets. This was effective for multiple reasons. First, with groups of four, I was able to assign four questions and each student was facilitator for a single question. Second, this group size allowed every student ample opportunity to voice their perspective. Third, through the self-selection process, students were able to adjust their groups as they deemed necessary. Fourth, having students select groups prior to receiving their handouts forced them to work in groups instead of trying to complete the assignment alone. And lastly, groups made the large lecture more manageable for providing real-time feedback.

## Conclusion

In order to push forward with the national call to action on transforming undergraduate biology education, it is critical that we find realistic ways to encourage instructors to integrate active learning in their classrooms. I propose that documenting evidence of "gains in academic success" from active instructional approaches and providing a "model for manageable transformations" are two ways to encourage action. Based on prior research, we know that the use of active-learning, student-centered activities facilitates improvements in student performance (Prince, 2004). However, much of the past research has been focused on studying the impacts of large-scale changes in instruction – and not all instructors are willing or able to accomplish such large-scale changes. My study provides evidence that even small-scale changes in classroom strategies can still have large impacts on student outcomes. Affective outcomes, such as increases in confidence and decreases in anxiety, may promote student retention and interest in the subject, which is a driving priority in STEM education (AAAS, 2011). And significant learning gains by students involved in collaborative group activities indicate that taking time away from lectures to allow active learning does not diminish learning opportunities. In fact, students engaged in collaborative work outperformed their mirror counterparts. Additionally, this investigation provides evidence that effective transformations can be accomplished with no added time commitments. In this case, I invested equal amounts of time preparing for each given class section and grading student work. By documenting these types of projects, we can begin to see evidence of positive changes in undergraduate education across classrooms.

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