Title: Faculty and student perceptions of learning in an inquiry-based introductory biology course

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Abstract

Active learning and inquiry instructional strategies have been shown to increase student knowledge and interest in STEM disciplines, yet faculty resistance to large-scale adoption remains. We developed an inquiry-based mixed major introductory biology lecture curriculum with common instructional resources and assessments. Implementation of the new curriculum was met with faculty resistance at a small, liberal arts college. The chief obstacles to overcome were the faculty perceptions that student exam performance and course satisfaction are largely influenced by instructor personality, and that common curriculum and assessments would hamper the instructional efficacy of the faculty. In 2013, multiple instruments were administered throughout the semester to measure student attitude, conceptualization, and learning gains. Preliminary results from these surveys indicate that regardless of instructor, students report significant gains in their knowledge level and critical thinking skills. While there were differences in how students perceived the efficacy of individual faculty, this did not translate into differences in exam scores among different course sections (i.e., different faculty instructors). Additional instruments were implemented in the most recent iteration of the course to further examine and elucidate the role and influence of faculty on student learning gains in this inquiry-based biology course.

Introduction

Numerous barriers to the widespread adoption of active, learner-centered pedagogies exist, despite the repeated recommendations of national reports (e.g., Alberts 2008; Brewer and Smith 2011) and strong evidence for the effectiveness of these teaching practices (Freeman et al. 2014). Barriers that are beyond faculty control can include access to faculty professional development, lack of institutional support, and student resistance (Cohen 1988; Sunal et al. 2001, Michael 2007, Brownell and Tanner 2012). Obstacles that are within faculty control, such as professional identity (Brownell and Tanner 2012) and perceptions of efficacy (Sunal et al. 2001), may not only impede an instructor's adoption of new approaches, but also motivate an instructor's opposition to the new approaches adopted or recommended by others. Many national and regional workshops to address professional development and institutional support now exist, and are creating a population of instructors who implement evidence-based teaching practices (e.g., Postareff et al. 2008, Pfund et al. 2009; but see Ebert-May et al. 2011). However, these instructors may still face opposition to these teaching practices from their students and colleagues, preventing widespread adoption.

Understanding faculty and student perceptions can help identify the nature of the opposition that exists at a particular institution, and perhaps aid in designing interventions. For example, students may object to using critical thinking skills beyond memorization in an introductory course (Keeley et al. 1995). Or, faculty feel that their professional expertise is undervalued, unrecognized, or even attacked (Weiss et al. 2003; Henderson and Dancy 2008). To address faculty resistance to a recently reformed, multi-section introductory biology course at a small private liberal arts college, we evaluate student and faculty perceptions of the course, and compared these perceptions of learning with actual assessments of learning to identify if beliefs were verified. In this paper, we depict preliminary findings from 2013, the first of three years of our project.

Previous to the reform of our multi-section, introductory biology course, the only common components across lecture sections were the list of topics and the required textbook. Otherwise, instructors prepared their own lecture curriculum, including all major summative assessments (exams). In our revised introductory biology course, all sections of lecture share a set of common learning objectives and major summative assessments, along with customizable lecture slide shows (including example activities/formative assessments). The revision also includes an emphasis on application and other critical thinking skills.

We experienced faculty resistance to these changes; the most clearly articulated opposition was to the increased consistency among sections. In particular, some faculty were concerned with the common summative assessments, because they believed that students would perform best on questions written by their own instructors. Initially, we (the authors of this study) wrote many of the questions for the summative assessments, as one of the goals of our project is to help the other faculty develop their skills of writing multiple-choice questions that are properly aligned with the cognitive level of instruction received by students. All faculty met before each exam to review and revise these questions, and changed or rejected questions for being confusing or not aligned with instruction in one or more sections. For the final exam, however, the faculty divided up the task of writing questions, with each faculty member responsible for a particular set of learning objectives.

Another reason for faculty resistance is that students are dissatisfied, specifically with the emphasis on application skills in an introductory-level course. In particular, throughout the semester, students complained about how they performed on summative assessments. Prior to the implementation of this course, content knowledge was prioritized over application and inquiry in both the lecture and laboratory.

To address concerns related to faculty resistance, we focused on these following specific questions:

1. Do students perform better on questions written by their own instructors?
2. Do students have learning gains that are dependent on having a specific instructor?
3. Can students make learning gains with respect to both concepts and critical thinking skills?

Questions 1 and 2 address the hypothesis that students should perform best on questions written by their own instructors. Question 3 identifies whether or not students can benefit from an emphasis on application in an introductory level course.

Methods

We used data collected from three assessments during the fall semester of 2013, to examine our questions. The first assessment was the final exam. Each instructor was asked to write a set of questions to align with learning objectives from a single unit. We also used the Student Assessment of their Learning Gains (SALG, www.salgsite.org, Instrument #63255), which collects anonymous student responses to questions about their perceptions of learning gains with respect to concepts and skills. The third assessment was a concept survey that we developed, which was administered at the beginning of the semester, and again at the end, with student generated, anonymous identifiers to track responses. During the fall semester of 2013, there were 244 students across 8 lecture sections, and 233 students across 10 laboratory sections for a total of 245 students. Twelve students repeated the course by taking only the lecture portion, and one student repeated the course by taking only the laboratory portion. All lecture students took the final exam (n=244, no students dropped the course). The SALG was offered as an extra credit assignment, and 197 students voluntarily completed the SALG instrument (80% of the class). All students enrolled in a laboratory section (n=233) completed the pre-course concept survey; however, only 135 post-concept survey results could be matched to students' pre-course results because of errors in anonymous identifiers (55% of the class).

We analyzed our assessment data using R (R Core Team 2014), using ANOVA and generalized linear mixed effects models. We tested the effect of instructor on student perception of learning (SALG), and actual performance in the course, using one-way ANOVA. We used generalized linear mixed effects models to test if answering a question correctly (i.e., binary response) depended on the factors of interest. We used student as the random effect in both the final exam and concept survey analyses. The fixed effects on the final exam analysis were section instructor and question author. The fixed effects on the concept survey analysis were topic, Bloom level (Crowe et al. 2008), and test (pre vs. post). We analyzed topic and Bloom level separately (i.e., topic × test and Bloom level × test), as the replication was insufficient to analyze the statistical interaction amongst all three factors. We used Akaike's Information Criterion (AIC; Akaike 1974) to determine the most likely statistical model to explain the data.

Preliminary Results

Do students perform better on questions written by their own instructors?

Student performance in 2013 did not depend on whether questions were written by their own instructors (Figure 1), as the most likely statistical model included only the effect of author (AIC = 8090), which was a significant predictor of performance ($p < 0.0001$). This effect of author is confounded with the topic tested, because each author was asked to write a set of questions on a particular topic. In the full statistical model with both section instructor and author (AIC = 8104), the statistical interaction was significant ($p=0.02$), but because of different combinations of instructors and authors that were not the same, i.e., some sections performed significantly better or worse on questions written by an instructor of another section, and not necessarily their own. In our course, the consistency of learning objectives and other curricular materials may contribute to this lack of instructor effect.

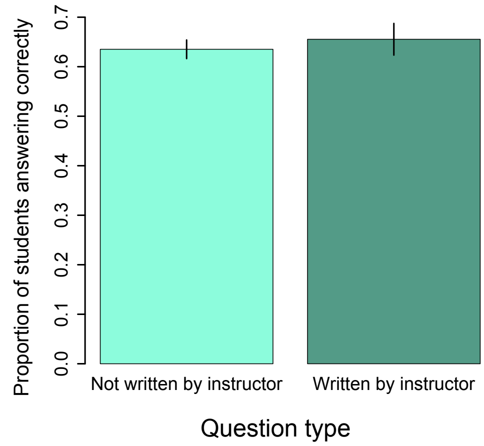

Figure 1. On a cumulative final exam (fall semester 2013), students did not perform better on questions written by their own instructor.

Do students attribute their learning gains to their own instructor?

When students were asked to rate their gains in the class based upon interactions with their lecture faculty there is a significant difference among instructors in 2013 ($p=0.002$); however, there is no difference with respect to performance among sections (Figure 2; lecture: $p=0.997$; lab: $p=0.991$). Further, there was no difference among instructors when students were asked in a separate question to rate their gains in developing and using critical thinking and analytical skills ($p=0.196$). Indeed, for both items, instructors were rated 3 (moderate gain) or higher on average. Although there are significant differences in how students perceived their instructors' efficacy, no instructor was rated at the "no gains" end of the scale on average.

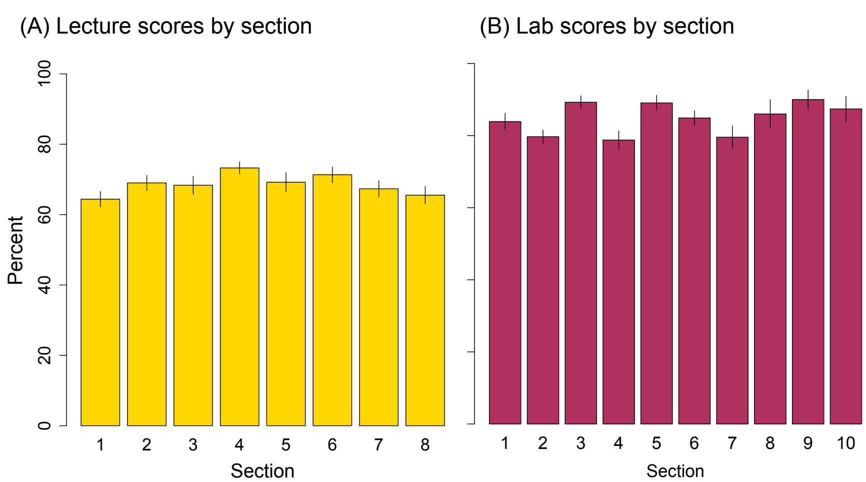

Figure 2. In 2013, there was no difference in performance across (A) lecture sections ($p=0.997$) or (B) laboratory sections ($p=0.991$), although there was a significant difference in how students attributed their learning gains to professors (data not shown).

Do students make learning gains with respect to concepts and critical thinking skills?
According to the 2013 pre- and post-course concept survey, students improved their performance with respect to concepts ($p< 0.0001$) and critical thinking skills ($p= 0.0002$), though the amount of gain varied with specific topic or skill. The greatest gains were made in application and knowledge (Figure 3), as calculated by the single-student normalized learning gain, or the real gain relative to the possible gain (Fagan et al. 2002).

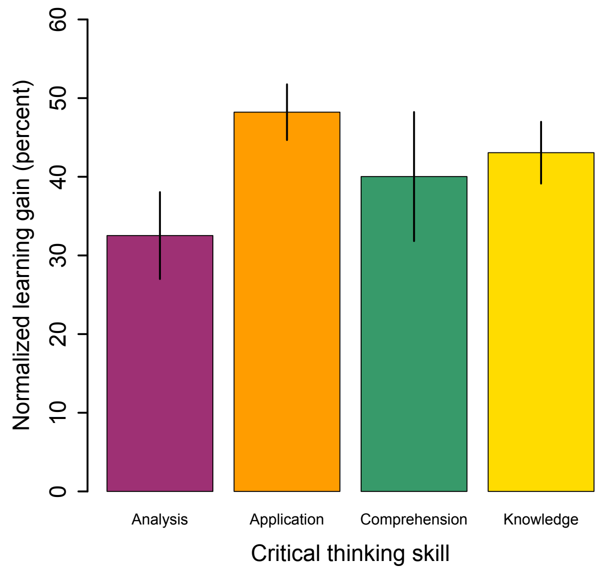

Figure 3. In 2013, students improved their critical thinking skills ($p= 0.0002$), with the greatest gains of application and knowledge, shown here as the single-student normalized learning gain, or the real gain relative to the possible gain.

Discussion

In our introductory biology course, the students perceived differences among instructors' classrooms, though there were no effects on what students learned, or perceived that they had learned. We did not find support for the belief that using common summative assessments creates an unfair bias. The cause of the perceived differences among instructors' classrooms is yet unidentified, though the existence of differences is not unexpected given the importance attributed to interactions between faculty and students (Umbach and Wawrzynski 2005). Discovering the cause of perceived differences may help in addressing the barriers to adoption of evidence-based approaches, particularly those related to instructor efficacy. We also attempted to counter the perceived unfairness of common summative assessments in the next iteration of the course (fall semester 2014) by dividing up the question writing for all of the exams, with multiple meetings to peer review and approve questions for each exam.

Students gained conceptual knowledge and improved critical thinking skills, and recognized these as growth with respect to self-efficacy by the end of the semester, but some faculty instructors and students still feel dissatisfied with their experience in the course. Adopting strategies to promote student acceptance of active learning and developing critical thinking skills may alleviate initial student resistance (Keeley 1995; Felder and Brent 1996; Kate 2004; Weaver and Qi 2005). By surveying students at the beginning of the current iteration of the course (fall semester 2014), we found that many students were not prepared for an active, learner-centered environment. We are currently designing and implementing formative assessments that include metacognitive components, with the intent of bridging the gap between student and faculty expectations both early and often. We have introduced activities to foster the development of problem solving skills, such as modeling good problem solving strategies, documented problem solving assignments (Angelo and Cross 1993), and identifying errors in problem solving.

Resistance to adopting evidence-based teaching approaches can come from many sources. Identifying and addressing faculty and student perceptions of active, learner-centered approaches, along with institutional support and faculty development, can be critical for the widespread adoption of these teaching practices. Obstacles originating from colleagues and students can be addressed by evaluating the validity of negative or differing perceptions, and using evidence to show mismatches between perception and reality. As our efforts to implement our new course is ongoing, we expect to uncover new challenges, even as we work to address current ones.

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