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An Integrated Approach to Teaching Cell Staining

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INTRODUCTION

Research on various pedagogical strategies has shown that case studies (1, 2), active learning (3), and interdisciplinary instruction (4) have positive impacts on student engagement, understanding, and collaborative learning. Case studies have been shown to bridge theory and practice, promoting greater student engagement (1, 2), deeper understanding of concepts, enhanced communication, metacognitive skills, and an ability to make connections across various content areas (5, 6). Active learning enhances student engagement and enables higher-order thinking, leading to better understanding (3) and retention in science, technology, engineering, and math (STEM) disciplines (7). Interdisciplinary learning is an important pedagogical approach (4) to enhance problem-solving skills, promote collaborative learning, and develop a greater appreciation of interconnectedness of students' learning in different courses (8, 9), but it can be challenging to put into practice (8, 10).

Teaching with case studies has been extensively researched (https://ctl.columbia.edu/resources-and-technology/resources/case-method/), with resources freely available (e.g., https://www.nsta.org/case-studies, https://www.biologycorner.com/2016/12/28/hhmi-and-case-studies/). While educators have used the active learning approach with focus on interdisciplinary learning (11, 12) or interdisciplinary case studies (13, 14), combining all these teaching approaches has not been well researched. In this study, the implementation of a case study based upon cell staining, which is an important technique in STEM courses, is described. This case study enables active learning while emphasizing the interdisciplinary aspects of cell staining. This activity resulted in statistically significant improvement in student performance and long-term retention. The case study, active learning exercises, pre- and post-activity assessments, and instructor's notes, including implementation timeline, guidelines, keys to formative assessment questions, and the pre- and post-activity quiz are included in the supplemental material.

(The activity was presented in its nascent form in a microbrew session during ASMCUE 2022).

PROCEDURE AND RESULTS

An interdisciplinary case study was developed to introduce the chemistry of stains and cellular staining concepts to first-year undergraduates (see Appendix S1 in the supplemental material). The context for the case study was based upon two freshmen interested in learning about cell staining, and covered the basics of stains, including the principles of staining bacterial and eukaryotic cells with acidic, basic, and neutral stains. Formative assessments were embedded at pivotal points to assess student learning, and an active learning exercise (Appendix S2) was implemented at the end.

The activity (case study and active learning exercise) was implemented in three sections of microbiology (one face to face [F2F], with 11 students, and two hybrid sections [online lectures accompanied by F2F labs], with 10 and 14 students, respectively) during Spring 2022. Prior to implementation, a pre-activity quiz (Appendix S3) was assigned in the learning management system (LMS). Each class was divided into groups of 2 to 3 students each to conduct the activity. Though three active learning exercises were developed, only one (group PowerPoint presentation) was used in this study (Appendix S2). Feedback on the presentations was encouraged to promote students' science communication skills. Following the activity, the post-activity quiz, which was the same as the pre-activity quiz, was assigned in the LMS to assess student learning.

Two questions from the quiz, one at a lower Bloom's taxonomy level (remember; LLBQ) and the other at a higher level (analyze and evaluate; HLBQ), were included in the midterm exam (administered 35 days after the activity) to assess long-term retention.

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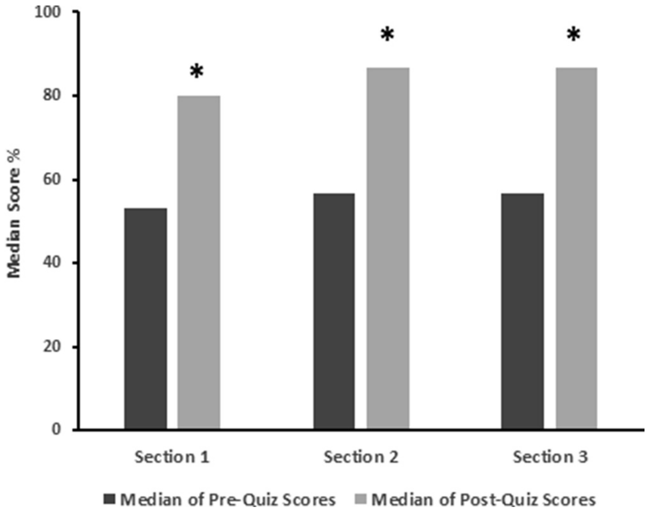

FIG 1. Median pre- and post-activity quiz scores in three sections of microbiology. Results from the Wilcoxon signed rank test with paired samples showed that post-activity quiz median scores were statistically significantly higher in all three sections of microbiology (*, α = 0.05). There were 11, 10, and 14 students in sections 1, 2, and 3, respectively.

Ethics statement

The study was conducted with institutional review board approval from the participating institution and participants' informed consent.

The median pre-activity quiz scores in sections 1, 2, and 3 were 53.3%, 56.67%, and 56.67%, respectively. The median post-activity quiz scores were 80%, 86.67%, and 86.67%, respectively (Fig. 1). Given the small sample size ($n < 15$), the Wilcoxon signed rank test (15) was used to test for statistical difference in the medians of paired samples (pre- and post-activity quiz scores) for each of the three sections. The results showed that the post-activity quiz scores were statistically higher at a 5% level ($\alpha = 0.05$), based on a one-sided test for positive difference in paired observations. The two-sided test also confirmed nonzero difference in paired samples at 5%. These results indicated improved student performance associated with the activity.

The Wilcoxon signed rank test could not be applied to the post-activity quiz and mid-term scores in LLBQ and HLBQ in each of the three sections separately, due to the low number of paired samples with nonzero difference in scores in two sections (only 2 nonzero difference in paired samples for both LLBQ and HLBQ in section 1 and only 2 nonzero difference in section 2 for LLBQ). Thus, the data for paired samples for all three sections were combined to test for the statistical difference in median scores between the post-activity quiz and mid-term scores (LLBQ and HLBQ, $n = 29$). The median post-activity quiz scores for LLBQ and HLBQ were 100% in all three sections combined. The median mid-term scores for LLBQ and HLBQ were 100% and 87.5%, respectively (Fig. 2). The Wilcoxon signed rank test showed no statistical difference in median values at a 5% level ($\alpha = 0.05$) for one-sided as well as two-sided tests. These results indicated retention (or no loss) after 35 days of learned concepts through activity.

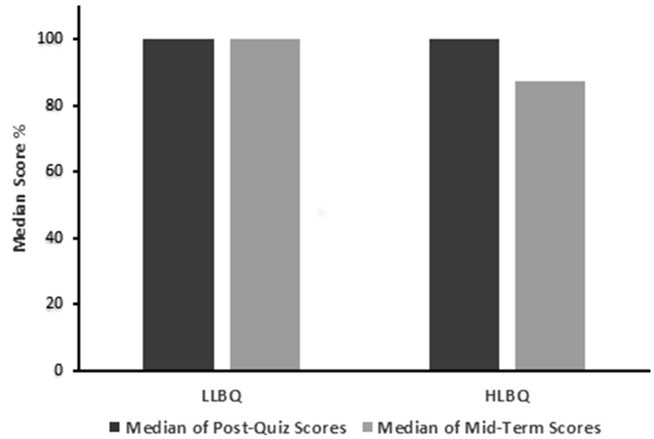

FIG 2. Median post-activity quiz and mid-term scores in one lower-level Bloom taxonomy question (LLBQ) and one higher-level Bloom taxonomy question (HLBQ) in three sections of microbiology combined ($n = 29$). Results from the Wilcoxon signed rank test with paired samples showed that LLBQ and HLBQ median scores in the mid-term were statistically not different ($\alpha = 0.05$) from post-activity quiz scores in all three sections combined.

CONCLUSIONS

Overall, the activity served as an effective pedagogical tool, resulting in statistically significant improvement in student performance in all sections (hybrid and F2F) and long-term retention of information. The activity showed the benefits of incorporating a case study with active learning and some interdisciplinary focus into content-heavy STEM courses.

The effectiveness of interdisciplinary active learning and case studies has been well established and used in disciplines such as chemistry (16). Despite this, interdisciplinary approaches in combination with case study and active learning to course and assessment design are not widely used in STEM classes in higher education. The cell staining activity introduced the interdisciplinary context between biology and chemistry to the students. A limitation of this study was the small sample size. In future studies, it would be beneficial to implement this activity in more classrooms and further build upon an interdisciplinary approach with involvement of faculty from other STEM disciplines (e.g., chemistry and biochemistry). There is also potential for using similar approaches to promote arts and science interdisciplinary learning (17).

SUPPLEMENTAL MATERIAL

Supplemental material is available online only.

SUPPLEMENTAL FILE 1, PDF file, 0.7 MB.

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