Introducing Active Learning Strategies into an Undergraduate Engineering Physiology Course

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Abstract

Active learning strategies have been shown to increase both academic performance and student engagement. Such strategies were recently incorporated into the first semester of a two-semester engineering physiology course. Interteaching, in which student groups discussed instructor-provided learning objectives, followed by ranking of difficulty of the learning objectives via a text polling system allowed students to direct the level of coverage of the lecture material. Results indicate that student attitudes are mixed about the active learning strategies, with students favoring the group discussions over the ranking of the learning objectives. When accounting for the academic credentials of the students prior to taking the course, these interventions did not appear to increase or decrease academic performance as a whole from previous offerings of the course.

Introduction

Active learning has been shown to improve retention of material across a wide variety of disciplines [1]. The use of active learning strategies in engineering courses continues to be a popular topic in education literature [2]. A review of active learning strategies relevant to engineering educators demonstrated that these strategies can improve student engagement and performance [3].

Other STEM fields have also found success implementing these techniques. Of particular interest to biomedical engineering programs is the use of active learning in physiology. ABET program outcomes for biomedical engineering programs require a knowledge of physiology [4], which can be gained through courses taught by either biology/physiology or biomedical engineering departments. A survey of ABET-accredited biomedical engineering programs showed that a majority of programs teach physiology within the department rather than outsourcing the course to their life science colleagues [5].

Various active learning strategies have been incorporated into physiology courses in undergraduate courses as well as in dental and medical schools. For example, a group of medical students participated in active learning activities such as puzzles, debates, board games, and videos during four semesters of their medical school curriculum [6]. These active learning strategies led to better performance on a cognitive monitoring test compared to that of their colleagues who did not participate in the active learning strategies. In another study involving medical students in a large lecture format (approximately 150 students), group discussions followed by individual formative assessment was employed in a renal physiology module [7]. While no formal assessment of the success of these interventions was performed, the authors reported a maintenance of student performance and an increase in student satisfaction. In a study of undergraduates involved in team-based active learning workshops [8], student performance on exams increased over those not involved in active learning. In addition, students with lower academic profiles entering the course as evidenced by college entrance scores could be aided in their performance by working with teammates having higher scores. These studies, among others, demonstrate that active learning strategies can be used to improve student performance in physiology courses.

In an effort to facilitate learning of difficult physiology concepts, the first author introduced active learning strategies into an engineering physiology course taught within a biomedical engineering program.

Methods

Incorporation of Active Learning Strategies

Biomedical engineering students at Western New England University have provided feedback that the first semester of a two-semester junior-level engineering physiology sequence is particularly challenging, based on data from end of semester course evaluations. Students were asked to respond to the statement "Please rate this course based on the level of challenge you felt it delivered" using a five-choice Likert scale. With a response of "least challenging" corresponding to a 1 and "most challenging" corresponding to a 5, the average responses for the fall 2015 and fall 2016 offerings of the course were 4.67 and 4.6, respectively, demonstrating the perceived difficulty of the course. Open-ended feedback on these evaluations showed that students wished the course was "more interactive" and that the instructor should "focus on learning objectives that we are struggling with during lecture."

Traditionally, the course has been taught three times per week for 50 minutes per class period, covering both physiology topics as well as engineering models of physiological phenomena. In course offerings prior to the semester where the intervention described herein was introduced, learning objectives (10 - 15 per lecture) were provided to students before the lecture. Students were required to read specified pages in the text and complete an online quiz prior to class. Lectures would then focus on the material from the reading, with equal emphasis across the lecture topics. This coverage of the material was unsatisfactory for the instructor and students as class time was spent reviewing material that students found easy while more challenging topics may not have received enough class time as noted in the student comment above. Lectures were recorded for student review outside of class.

To address student concerns, in fall 2017, active learning was added to the course to make the course more interactive and to provide the instructor feedback on what specific material students found the most challenging. The active learning strategies employed were related to the interteaching methods as described by Boyce and Hineline [9] in which pairs of students work through instructor-supplied questions and cooperatively develop solutions and identify topics which they find challenging. These lists of challenging topics would be collected at the end of the class and reviewed by the instructor to discuss in the subsequent lecture. For the offering of the engineering physiology course in fall 2017, as with previous years, students were provided learning objectives and assigned reading and an online quiz prior to the lecture. The active learning experience (interteaching) took place in the first 10-15 minutes of the class period where groups of four students each discussed the learning objectives, which served as the instructor-supplied questions of Boyce and Hineline. After the interteaching sessions, feedback from each group was provided immediately to the instructor and classmates via the Poll Everywhere response system. Each group rated the difficulty of each learning objective using a 5-choice Likert scale (easy, sort of easy, not easy or difficult, sort of difficult, difficult). The instructor then used the remaining class time, rather than a subsequent class period as with Boyce and Hineline, discussing lecture topics. These lectures were similar to the lectures in previous years, but highlighted and spent more time on those learning objectives the groups identified as more difficult. In general, those topics with a majority of groups choosing sort of difficult or difficult on the Likert-scale, were discussed in more depth. Lectures were again recorded. In the event that all topics were not covered in class, students were also provided with videos of lectures from the previous year. Note that the interteaching sessions did not take place for class sessions where engineering modeling topics were introduced since there were no pre-class readings and quizzes for this material.

Because the success of the interteaching depends on students' preparation prior to the class session, the instructor provided incentive for this preparation by assigning a portion of the final course grade (5%) as a teaming score based on teammates' evaluation of each group member's contributions. This evaluation was performed via a CATME peer evaluation survey [10], a validated team member evaluation tool that uses descriptions of student teaming behaviors to rate an individual's performance as a teammate [11]. The survey focused on a group member's contributions to the group and interaction with teammates, whether the group member helped keep the team on track, and whether the group member had the knowledge necessary to help the team, presumably gained via the pre-session reading assignment. Students were evaluated by their teammates twice during the semester. The CATME adjustment factors (without self) from each evaluation were used to generate a teaming score at the end of the semester.

Assessment of Active Learning Experiences

The assessment methods were approved by the Institutional Review Board of Western New England University.

To evaluate the success of active learning in improving academic performance, the scores on the comprehensive final exam from the fall 2016 semester where there was no active learning were compared to the fall 2017 semester where active learning strategies were employed. The final exams for both semesters were identical, allowing a direct comparison of student performance between semesters. A two-sample, one-tail t-test, with a significance level of $\alpha = 0.05$, was performed comparing the final exam scores from the fall 2016 offering ($n = 16$) to that from the fall 2017 offering ($n = 24$), with the hypothesis that the active learning would lead to an increase in academic performance. From Figure 1, it can be seen that the average final exam score for the 2016 offering (78.7) was significantly higher than that of the 2017 offering (69.5), with $p = 0.013$. Thus, it appears that the active learning experiences may have led to a decrease in academic performance.

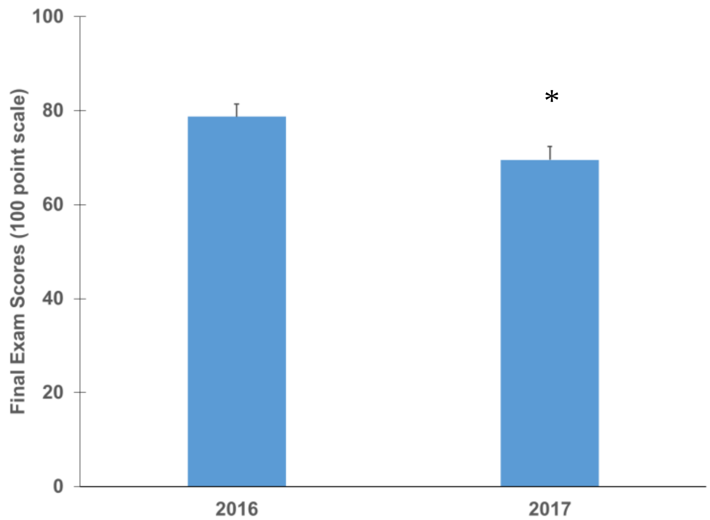

Figure 1: Final exam scores for the fall 2016 (no active learning) and fall 2017 (active learning) semesters. Results are shown as mean + standard error of the mean. *p = 0.013

Because of observations that student academic performance in courses taken prior to the junior year appears to correlate with the final grade in the first engineering physiology course, further analysis was performed to determine if the decrease in final exam grades from the fall 2016 to the fall 2017 was due to different academic profiles of the students in the courses, rather than the effect of the active learning experiences.

To investigate this possibility, course grades for students (n = 78) from four previous course offerings of the engineering physiology course without the active learning experiences taught by the first author in fall 2012, 2013, 2015, and 2016 were evaluated using an analysis of variance (ANOVA) to determine which lower level course grades are statistically significantly related to the course grade in the engineering physiology course. An analysis of the degree audits for these students yielded letter grades for lower level courses which were then were converted to their corresponding numerical grade using the institution's standard grading scale. AP and CLEP test scores were converted to letter grades using guidance from the The College Board [12] and The American Council on Education (ACE) [13] prior to conversion to a numerical value. Factors in the ANOVA included grades in math courses (Calculus I, Calculus II, Calculus III, and Differential Equations), General Biology, two courses in English composition, and two sophomore-level biomedical engineering courses (Foundations of Biomedical Engineering and Biomedical Systems) as well as grade point average (GPA) entering the junior year and gender. Results of the ANOVA demonstrated that the factors related to the final grade in engineering physiology were grades in all four math courses, Foundations of Biomedical Engineering, and General Biology, with p values no greater than 0.008 for any of these factors.

Identification of these factors allowed the authors to develop a regression model to predict the engineering physiology grade (EP grade) based on the grades in the courses identified above. The resulting regression equation (R = 0.82) is

$$EP\ grade = 17.87 - 1.04\ Calc\ I\ grade + 2.67\ Calc\ II\ grade + 0.77\ Calc\ II\ grade + 3.05\ Diff\ Eq\ grade + 8.47\ Found\ of\ BME\ grade + 4.27\ Gen\ Bio\ grade$$

This regression equation was then used to predict the engineering physiology grade for students in the fall 2017 offering who had taken part in the active learning experiences based on their academic background entering the course. These predicted grades were compared to students' actual grades using a two-sample, two-tail t-test with a level of significance of $\alpha = 0.05$. The results are shown in Figure 2. The mean actual grade (75.4) was higher than the mean predicted grade (71.4), but the difference is not statistically significant ($p = 0.186$). This suggests that the active learning experiences did not enhance overall student performance in the course. This analysis, however, provides evidence that the results shown in Figure 1 may be attributable to the academic preparation of the students in the 2016 and 2017 offerings, rather than a negative impact of the active learning strategies.

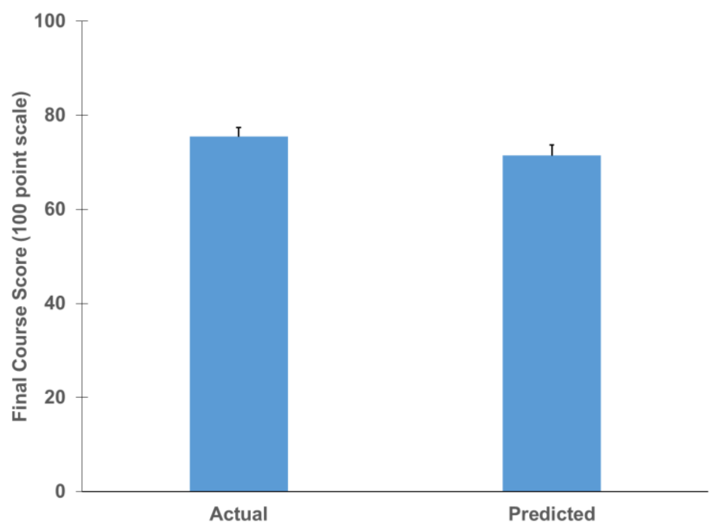

Figure 2: Actual and predicted grades (via regression analysis) for students exposed to the active learning experiences. Results are shown as mean + standard error of the mean. p = 0.186

Student attitudes about the active learning experiences were captured with an anonymous survey which can be found in the Appendix. The questions covered three main topics: attitudes toward the interteaching (group discussion), effectiveness of ratings of learning objectives (text response system), and overall thoughts on the active learning experiences. A total of 13 out of 24 students enrolled in the course in fall 2017 completed the survey, yielding a response rate of 54%.

The first set of survey questions involved the in-class discussions and the results are shown in Figure 3. Approximately 77% of the respondents thought the discussions contributed meaningfully to their learning by responding somewhat, significantly, or a lot. Thus, there appears to be value in the interteaching process employed. In addition, one of the primary motivations for the instructor to implement these active learning strategies was to encourage students to read the assignments before class. Again, approximately 77% of respondents found the in-class discussions to be a motivator by answering somewhat, significantly, or a lot to this question.

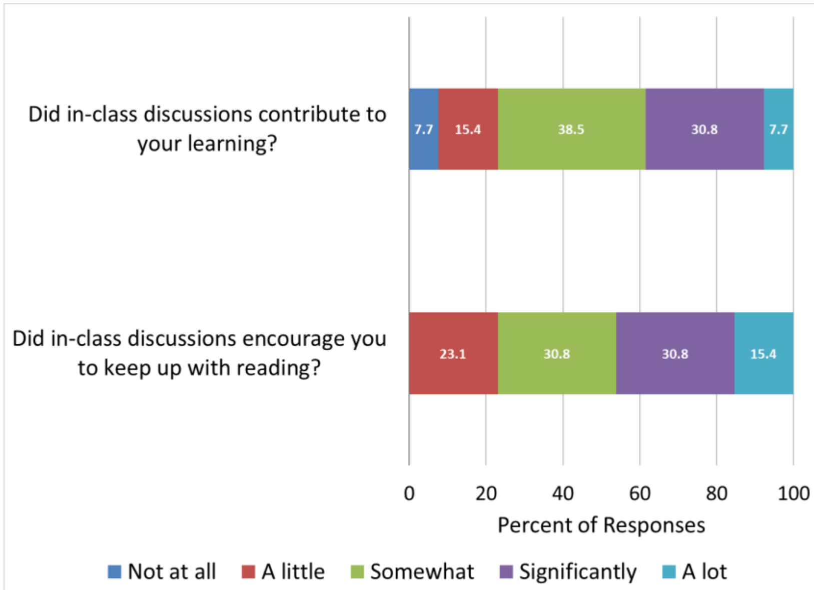

Figure 3: Student responses to survey questions on in-class discussions. Note that percents do not add to 100 due to rounding.

The next set of survey questions involved effectiveness of rating the difficulty of the learning objectives via a group response via the text response system. The results are shown in Figure 4. Respondents appear to be less enthusiastic about this learning strategy. For example, 77% of respondents, by answering not at all, a little, or somewhat, felt that the rating of learning objectives did not significantly help guide the lecture topics and approximately 85% of respondents felt that the rating of the learning objectives did not contribute to their learning of the material by answering not at all, a little, or somewhat. Only approximately 8% used the ratings of the learning objectives to identify challenging material to study for exams.

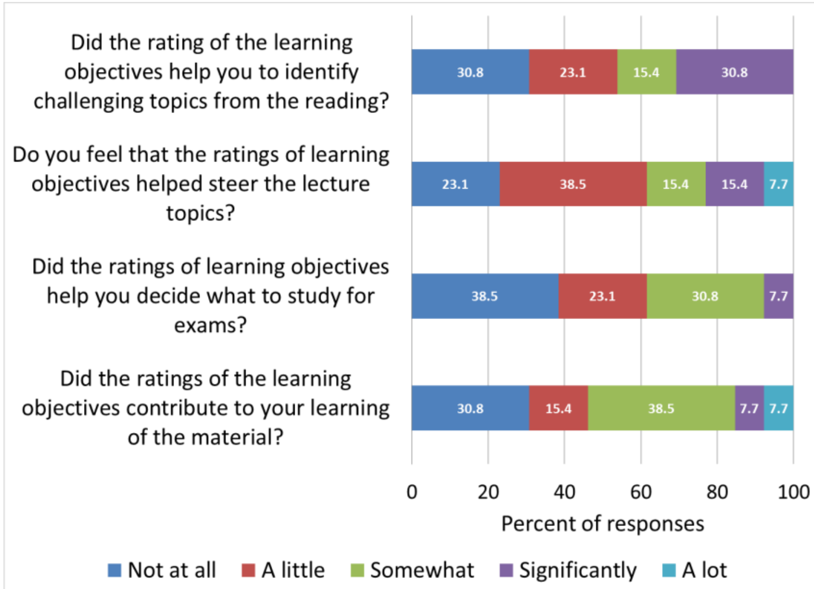

Figure 4: Student responses to survey questions on ratings of learning objectives using the Poll Everywhere text response system. Note that percents do not add to 100 due to rounding.

Students were also asked if they felt the active learning experiences contributed to their success in the course. These results are shown in Figure 5. These responses indicate that respondents were ambivalent about the role of the interteaching and rating of the difficulties of learning objectives in promoting active learning, with approximately 85% responding not at all, a little, or somewhat.

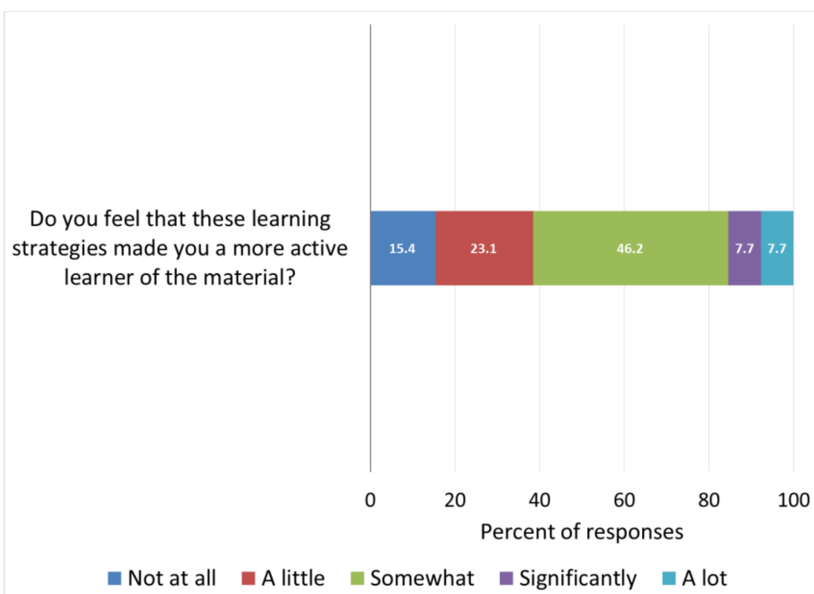

Figure 5: Student responses concerning their attitudes about contributions of learning strategies to their active learning. Note that percents do not add to 100 due to rounding.

The open ended questions provided insight into student attitudes towards the active learning strategies. Comments on what worked best included

I found myself thinking about what I had trouble with more than what I knew really well which allowed me to focus my studies and study what I did not know more than the things I didn't have trouble with.

In class review and discussion of topics we're [sic] helpful to identify the topics I was the weakest in at the time; allowing me to know what to study.

Group discussions

Comments on what could be improved with the learning strategies included

I feel that sometimes my colleagues were not always engaged and some find a lot of things a lot easier than others so it was hard to always be lectured on the things I struggled with.

The Poll everywhere should be used for every student instead of groups. Since there were six groups, some topics were not selected to go over, when they should have been.

Instead of rating how well we know it a test like question would be more helpful

Discussion

This paper describes the implementation of a form of interteaching and a text response system as active learning strategies in a junior-level engineering physiology course. The intervention did not lead to increased academic performance and student attitudes were mixed on the success of the active learning strategies. Respondents liked the interteaching better than the text response system for the rating of the difficulty of learning objectives.

The type of active learning strategies may have an effect on their success in improving academic performance. In a study to evaluate student and faculty attitudes toward active learning, Miller and Metz surveyed 116 dental students on their preferred learning strategies [14]. They rated lectures as their least preferred method of learning followed by reading the textbook. Their favored active learning method was the use of educational games and problem solving, while group work and videos were the least preferred methods of active learning. Since the current study involved group work as an active component, it is possible that this learning strategy is not as effective as others in impacting student achievement. There is evidence from the open ended comments that some students would prefer an individual rather than group rating of the difficulty of the learning objectives.

Previous studies showing an increase in student performance in a physiology course, [6] - [8], often involved large lecture sections (50 to 150 students). It has been noted that one advantage of active learning is the ability to interact more with the course instructor. The section size for our engineering physiology courses are generally less than 30 students. In addition, students are likely to have had previous courses with small class sizes with the engineering physiology instructors. Thus, there is already significant interaction between students and faculty and there is no need to achieve this via active learning.

Data mining techniques, including regression analysis, have been used previously to predict student performance in an attempt to identify which students may have difficulty mastering material in a particular course. For example, Huang and Fang [15] developed four regression models to predict student performance in Engineering Dynamics, with each successive model incorporating more data on student performance from the course of interest (midterm exam grades) and yielding better prediction accuracy. Their first model is similar to the regression model employed here in that overall GPA and grades in pre-requisite math, science, and engineering courses were used as predictor variables and yielded a prediction accuracy of the final exam grade of approximately 88%. Thus, although the results of the implementation of the active learning strategies yielded mixed results, the regression analysis performed for this study may be beneficial to the department going forward in that departmental faculty can now predict, with reasonable certainty, student grades in the physiology course based on their previous academic performance. This information can be used in future semesters to identify students who are likely to struggle in the course and provide interventions such as tutoring or supplemental instruction to help them be successful. This regression model has limitations, however, in that prior academic performance is dependent on a number of factors such as instructor variations in grading and the variety of institutions where the pre-requisite courses were taken (AP/CLEP, 2-year college, 4-year college, etc.). This analysis also does not include factors such as motivation and self-efficacy. The three courses that had the largest coefficients in the regression analysis are Foundations of Biomedical Engineering, General Biology, and Differential Equations. Both Foundations of Biomedical Engineering and General Biology require memorization of large amounts of material and thus success in these courses are not surprisingly a predictor of success in engineering physiology which also requires significant memorization. The models of physiological phenomena introduced in the engineering physiology course generally involve solutions of differential equations, explaining the role of this course in success in engineering physiology.

Proposed changes to the active learning strategies would be to continue with the group discussions, but have them focus on questions related to the more difficult topics as identified by the students in the fall 2017 offering. The text response system could then be used to query individual students, rather than the group, on their answers to these questions as a means of formative assessment. This would be the basis to begin an instructor-led discussion of the topic. This methodology follows a similar successful use of active learning in renal physiology [7].

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Appendix

Survey of Student Attitudes toward the Active Learning Experiences

Did the in-class discussions contribute to your learning of the material?

A lot   Significantly   Somewhat   A little   Not at all

Did the in-class discussions encourage you to keep up with the reading assignments?

A lot   Significantly   Somewhat   A little   Not at all

Did the Poll Everywhere (texting) rating of the learning objectives help you to identify challenging topics from the reading assignment?

A lot   Significantly   Somewhat   A little   Not at all

Do you feel that the ratings of learning objectives helped steer the lecture topics?

A lot   Significantly   Somewhat   A little   Not at all

Did the ratings of learning objectives help you decide what to study in preparation for exams?

A lot   Significantly   Somewhat   A little   Not at all

Did the ratings of the learning objectives contribute to your learning of the material?

A lot   Significantly   Somewhat   A little   Not at all

Do you feel that these learning strategies made you a more active learner of the material?

A lot   Significantly   Somewhat   A little   Not at all

What worked best with these learning strategies?

What could be improved for these learning strategies?