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Student Choice of Traditional or Blended Learning Activities Improves Satisfaction and Learning Outcome

Dr. Brian P. Helmke, University of Virginia

Brian Helmke is currently Associate Professor of Biomedical Engineering at the University of Virginia. He received the B.S.E. in bioengineering from the University of Pennsylvania, the B.S.Econ. from The Wharton School of the University of Pennsylvania, and the Ph.D. in bioengineering from the University of California, San Diego. Brian's research interests include cardiovascular physiology, cellular mechanobiology, and nanotechnology-based biomaterials. He is also interested in technology-enhanced teaching and in experiential learning for undergraduates in science and engineering.

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Of particular interest to designing effective BME courses is how to align content-dependent professional expectations with a learner-centered classroom environment. Often the focus is primarily on what the instructor is doing to deliver content rather than what the student is doing to interact with the content and take responsibility for his/her own learning. Course designs that provide students with choices of assignments motivate learning by allowing students to align their desired content interests, commitment level, and types of activity, and increased student autonomy fosters student motivation [1].

Low-stakes formative assessments represent one method to improve student motivation and learning [2]. If the assignments are ungraded or lightly graded, students can be encouraged to take risks in problem solving, especially if feedback is specific, frequent, and immediate. Such risk-taking and feedback may promote student self-assessment and support students to take control of their learning according to their individual goals for the course. In contrast, students who prefer the traditional lecture-based course format may demonstrate open resistance to the blended classroom format even though learning outcomes may be improved compared to the traditional format [3]. Resistance and frustration may arise because an active learning–based course departs from students' expectations of how a "good" college class should be organized [4]. This response is especially prevalent for junior- and senior-level undergraduates, who have become more established in their college learning habits. The emotional response associated with reduced learner satisfaction may inhibit the student's ability to self-assess learning in these cases. This study aimed to test the hypothesis that offering students the choice of whether to complete formative assessments may increase learner satisfaction and motivation while simultaneously increasing learning in a blended classroom.

This hypothesis was tested in BME 4641 Bioelectricity, an upper-level elective course with students majoring in biomedical engineering or electrical and computer engineering. Two portfolios of learning activities were designed. Portfolio 1 was traditional and consisted of summative assessments based on homework problems and quarterly tests. In addition to summative assessments, Portfolio 2 included low-stakes formative assessments such as in-class interactive questions and surveys, team-based discussions, and practice problems. Summative assessments were the same as those in Portfolio 1 but were weighted less to accommodate the broader range of learning activities. All students completed Portfolio 2 for the first quarter of the course to expose them to the formative activities and allow them to make an educated choice for the rest of the semester based on their preferences.

Students were asked end-of-course survey questions to interrogate their perceptions of the learning environment, learning satisfaction, and the quality of student-faculty interactions. Results from Likert-type questions mapped to positive outcomes without evidence of student resistance. Responses to an open-ended question indicated that students appreciated the autonomy to adjust their workload and the reduced stress of low-stakes activities (if applicable). Overall, these results demonstrate that offering students a choice of classroom activities can increase learner satisfaction without significantly affecting summative assessment results, and

students who prefer a blend of formative and summative assessments experience improved overall grades as a result.

Research Methods

Course Design

BME 4641 Bioelectricity is an elective course populated primarily by 3rd- and 4th-year undergraduate biomedical engineering and electrical engineering students. Two course offerings with the same instructor were included in this study: 21 students in the fall semester of 2016 and 30 students in the fall semester of 2017. The course content was divided into four units based on (1) electrical properties of cell membranes, (2) the Hodgkin-Huxley model of action potential propagation, (3) synaptic transmission, and (4) measurement and analysis of bioelectric signals. The course content was the same in both of the course offerings included in this study. The courses met twice each week for 75 min.

Two portfolios of assessments were created for each unit. Portfolio 1 (control, "traditional") consisted of homework problems (50% of the grade) and a unit test (50%). Portfolio 2 (intervention, "blended") was comprised of the same homework problems (35% of the grade) and unit test (35%), as well as concept questions (15%) and/or practice problems (15%) completed during or between each class session. The weight of the summative assessments was adjusted to accommodate the low-stakes formative assessments. Concept questions were designed to help students learn to connect detailed course content with their outside experiences, other courses in the curriculum, and their own career goals. Some of these questions asked students to reflect on and self-assess their own learning processes. Practice problems were low-stakes, "lightly graded" (for completion only) problems that were similar to homework and test problems. For the first unit of the course, students were required to complete Portfolio 2 (blended) to expose them to the active learning–based style. This experience allowed them to make an informed choice of their preferred portfolio for Units 2, 3, and 4. A student choosing the traditional portfolio was instructed to complete only the homework and test for the unit. Students who were undecided were allowed to complete the low-stakes activities and choose their preferred portfolio based on the higher grade of the two.

In a typical learning cycle surrounding a class session, students were assigned a textbook reading to complete before class. The class session consisted of alternating periods (averaging 10-15 min) of interactive lecture and student work time. Interactive lectures clarified and reinforced foundational knowledge and its application from the reading assignments, and students were expected to respond to questions about the reading, to fill in connections to previous class material, and/or to volunteer examples from their own experiences (in other classes, internships, research projects, etc.). Student work time enabled students to work on concept questions, practice problems, and homework problems. Since these work times were usually not long enough to allow for problem completion, students choosing the traditional portfolio (Portfolio 1) were also encouraged (but not required) to use this time to set up a solution framework even if they did not intend to complete the problems for submission. After class, students choosing the blended portfolio (Portfolio 2) completed the formative assessments they began in class and

submitted them electronically before the beginning of the next class. The beginning of the next class began with discussion of solutions from these formative assessments. From this combination of activities, all students in the class benefited from discussion of application and integration of the foundational knowledge, enabling all students the possibility to achieve all course objectives assessed by summative assessments.

Survey Instrument

Students completed an end-of-course survey that contained Likert-type questions about the learning environment and contributions of class activities to learning, learner satisfaction, and the quality of faculty-student interactions. For Likert-type questions, student answers were encoded on a five-point scale as “strongly disagree” (1 point), “disagree” (2 points), “undecided” (3 points), “agree” (4 points), and “strongly agree” (5 points). At the end of each survey section, students were asked an open-ended question to provide additional comments to evaluate the perceived effect of portfolio choice on their motivation and learning.

Statistical Analysis

Unit grades, course grades, and summative assessment scores for students choosing Portfolio 1 (traditional) vs. Portfolio 2 (blended) were reported as mean score ± standard deviation. Means were compared using an unpaired *t*-test, and scores were considered to be significantly different if the type I error was less than 0.05.

Likert-scale responses were encoded on a scale of 1 (strongly disagree) to 5 (strongly agree), and mean ± standard deviation were reported. A mean score of at least 4.0 for a question was interpreted to mean that students viewed the topic of the question positively.

Results

Learning Outcomes

In order to determine whether overall course grades were biased by the choice of work portfolios available to the students, average grades for the class were computed using both portfolios (Figure 1). The grades computed using the blended learning portfolio were not significantly different from those computed using the traditional portfolio, regardless of which portfolio individual students actually chose to complete. Grades were similar for each unit individually as well as for the overall course grade. Since Unit 1 required students to participate in the blended learning portfolio, course grades were also compared by averaging only Units 2-4; these grades were also not different between the two portfolio styles. Since the method of computing the overall grade for either individual units or for the entire course did not affect the average grade for the class, portfolio choice did not bias the average grade in the class.

After Unit 1 was complete, students were allowed to choose a portfolio preference for Units 2-4. For each of the latter units, students earned the higher of the two scores when computing their grades; they effectively chose the traditional method by not completing the low-stakes activities. Out of 51 students total, 30 (59%) chose the blended portfolio for Unit 2, 41 (80%) chose the

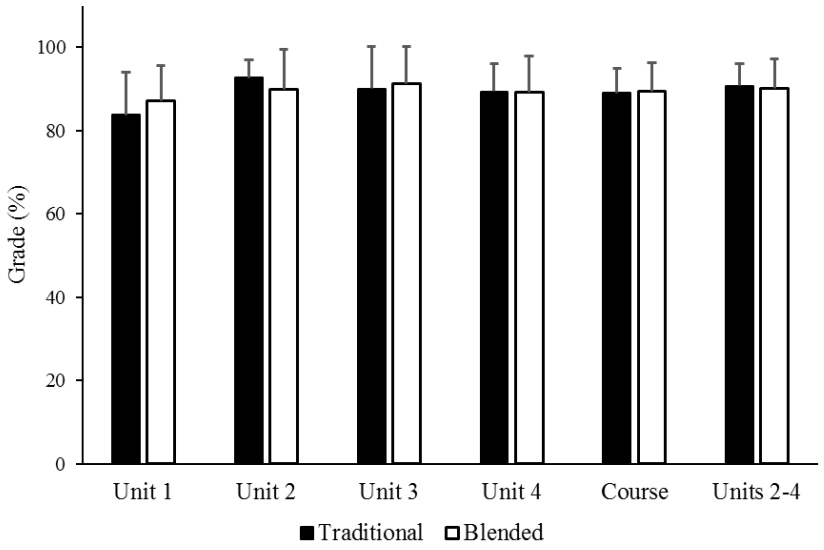

Figure 1. Grade by unit for all students computed using either the traditional or blended portfolios. Also shown are total course grade and total grade computed from Units 2-4 only. Mean ± SD.

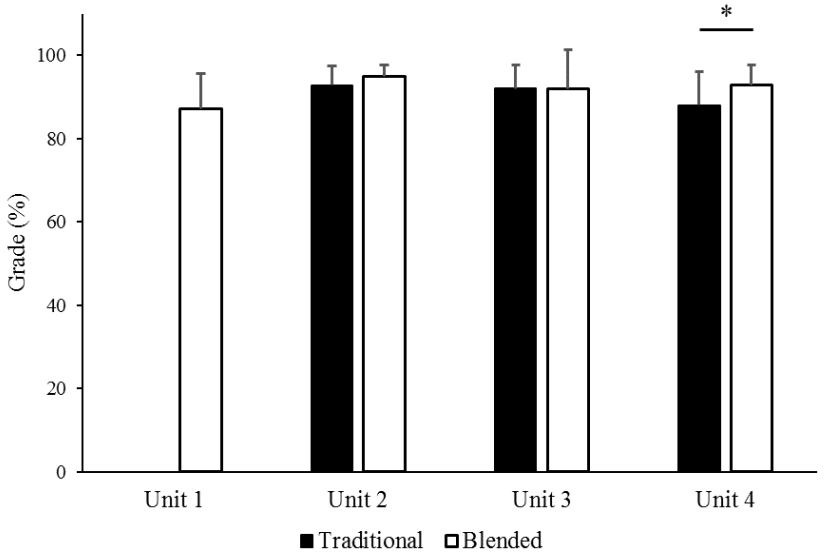

*Figure 2. Grade by unit comparing students who chose each portfolio. Mean ± SD, *p<0.05, t-test.*

blended portfolio for Unit 3, and 34 (67%) chose the blended portfolio for Unit 4. The total unit grades for only students choosing each portfolio were computed and compared (Figure 2). For Units 2 and 3, grades were not different between students in the two portfolios. For Unit 4, students who chose the blended portfolio earned a significantly higher unit grade (unpaired *t*-test, $p<0.05$).

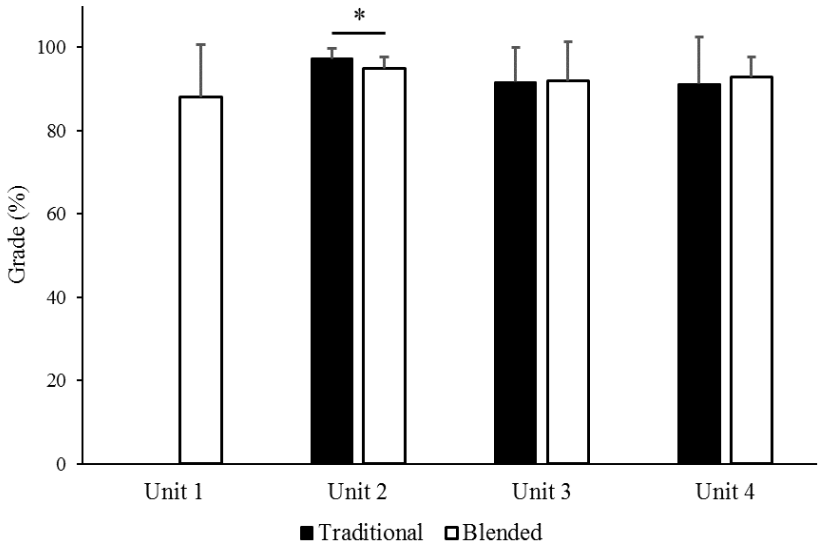

*Figure 3. Average homework grades by unit comparing students who chose each portfolio. Mean ± SD, *p<0.05, t-test.*

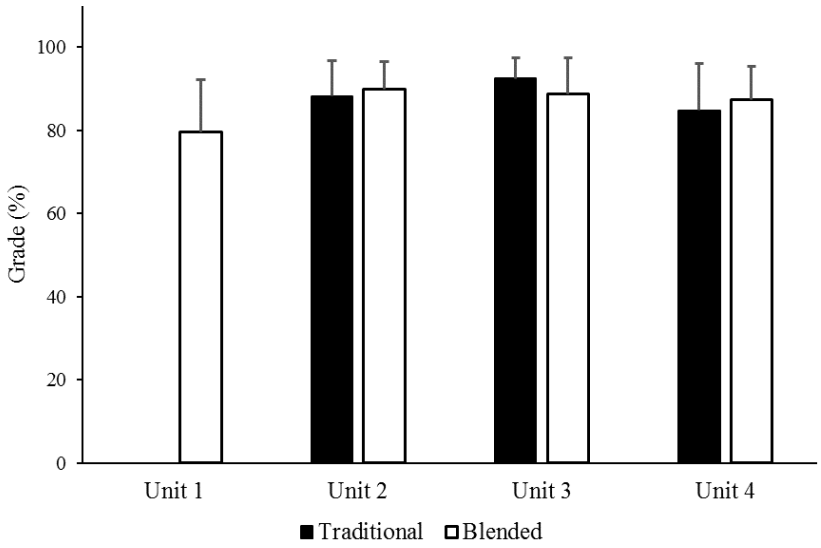

Figure 4. Average tests grades by unit comparing students who chose each portfolio. Mean ± SD.

In order to determine whether the choice of portfolio affected outcomes on individual graded assessments, average grades for the two major categories of graded assessments, homework and tests, were computed and compared. Comparisons were performed only for Units 2-4, since students were required to complete the blended portfolio for Unit 1. Unit 2 homework grades were significantly lower for students who chose the blended portfolio (unpaired *t*-test, $p<0.05$) but were not different for Units 3 and 4 (Figure 3). Unit test scores were similar for groups of students who chose each portfolio style (Figure 4).

Table 1. Learning Environment. Likert-type scores were encoded on a scale from 1 (strongly disagree) to 5 (strongly agree). Mean ± SD.

Overall, the learning environment in this course was supportive and helped me learn.	4.35 ± 0.76
The resources posted on the course website before class discussion helped me learn.	4.06 ± 0.78
The class discussions helped me explore the class content.	4.29 ± 0.66
The Concept Questions and Practice Problems helped me learn.	4.49 ± 0.64
Homework problems and test questions helped me assess my progress learning the course content.	4.12 ± 0.62
The structure of this course encouraged me to explore outside resources to help me learn.	3.94 ± 1.07
I can relate what I learned in this course to other courses, my Capstone/Thesis project, and topics in the fields of biomedical engineering and medicine.	4.12 ± 0.88

Learning Environment

Student perceptions of the learning environment were assessed using a series of seven Likert-type questions encoded on a five-point scale (Table 1). Student response to a question was interpreted to be a positive response if the mean score was at least 4.0. Using this threshold for evaluation, students responded positively to most aspects of the learning environment. Notably, the highest scores were associated with helpfulness of the low-stakes Concept Questions and Practice Problems, in-class discussions, and the overall supportiveness of the learning environment. The benefit of homework and test problems in self-assessing progress in learning course content also scored positively. Interestingly, the structure of the course encouraging exploration of outside resources to support learning did not score above 4.0, even though many of the course activities required interaction with outside resources from the internet and published literature.

Learner Satisfaction

Students responded to three Likert-type questions about their satisfaction with their own learning in the course (Table 2). Using the five-point Likert scale, responses were interpreted to be "positive" if the mean score was at least 4.0. Responses to all three questions met this criterion. Students liked the teaching style and learning environment, they were satisfied with their

Table 2. Learner Satisfaction. Likert-type scores were encoded on a scale from 1 (strongly disagree) to 5 (strongly agree). Mean ± SD.

I liked the teaching style and learning environment in this course.	4.25 ± 0.74
I am satisfied with how well/how much I learned in this course relative to my level of effort towards learning.	4.20 ± 0.77
I am satisfied with the number and quality of opportunities to assess my own understanding and learning that I received in this course.	4.29 ± 0.64

learning in the course, and they were satisfied with opportunities to self-assess their own learning.

Student-Faculty Interactions

Students responded to five Likert-type questions encoded on a five-point scale about the quality of student-faculty interactions in the course (Table 3). Responses were interpreted to be "positive" if the mean score was at least 4.0. Mean scores for four questions met this criterion. Students felt that the instructor was readily accessible and that the student-instructor interactions were supportive of learning. One question scored slightly below the threshold for a positive response: feedback about progress toward meeting course objectives.

Table 3. Student-Faculty Interactions. Likert-type scores were encoded on a scale from 1 (strongly disagree) to 5 (strongly agree). Mean ± SD.

The structure of this course encouraged me to interact with my instructor and teaching assistant.	4.10 ± 0.87
I am satisfied with the level and quality of student-instructor interactions in this course.	4.49 ± 0.57
Student-instructor interactions in this course were supportive and helped me learn.	4.39 ± 0.72
The instructor was readily accessible when I needed help with my learning.	4.51 ± 0.67
I am satisfied with the amount and quality of feedback about my progress toward course objectives that I received in this course.	3.94 ± 0.98

Grading Strategy and Student Motivation

Students were asked to respond to the following open-ended prompt: "How did having a choice of grading strategy affect your motivation and learning in this course?" Out of 51 responders, 15 (29%) reported that the choice of grading strategy increased their motivation and incentivized and/or improved their learning in the course. Twenty-two students (43%) reported that the grading strategy had no effect on their motivation, and 14 (27%) of these students indicated that they planned from the beginning of the semester to complete all assignments independently of the grading strategy. Two students (4%) reported that the grading strategy reduced their motivation. Each of these two students gave reasons associated with a desire to complete only the minimum possible work to achieve their desired grade in the course. Students who experienced increased or no effect on motivation often commented that the grading strategy reduced their stress associated with grading (15 responses, 29%) so that they could focus on their learning and on gaining a conceptual understanding of course material (5 responses, 10%). Two students (4%) expressed appreciation that the instructor cared about them individually enough to accommodate their learning style.

Discussion

Two primary observations arise out of this study: (1) designing courses that include offering students choices of optional assessments does not compromise learning outcomes measured by summative assessments, and (2) students respond positively to the added autonomy associated with the availability of choices.

Traditional course designs in biomedical engineering often emphasize content coverage, especially in courses involving substantial mathematical content. Faculty sometimes hesitate to shift toward learner-centered course design because of pressure to ensure that students meet learning outcomes based on summative assessments [5]. Moreover, instructors may hesitate to yield control over the class activities because of a comfort level with the "old" way or because of a belief that self-directed students may not follow the expected course content [6]. Alignment of the professional expectations associated with standard content coverage and student interests in broadly defined, interdisciplinary areas in biomedical engineering represents a challenge for curriculum design.

This bioelectricity course demonstrates that offering students choices of activities centered on standard content in the field of cellular electrophysiology and neurophysiology did not compromise their ability to achieve course objectives in terms of learning outcomes. Students who completed concept questions and practice problems performed equally on summative assessments to students who chose a more traditional approach based on studying class notes and reading materials to prepare for the major assessments. Moreover, since the method of computing the overall grade for either individual units or for the entire course did not affect the average grade for the class (Figure 1), students were not able to "game the system" by choosing a portfolio that would give them an "easier" grade. Overall, these observations suggest that students achieved the learning objectives for the course (as indicated by graded summative assessments) regardless of which learning portfolio they chose.

Low-stakes activities were designed to help students explore a topic in more depth, appreciate both historical and contemporary experimental and modeling approaches, and connect course content to their own experiences and career plans. Students were encouraged to take risks by outlining problem solutions even if they were unsure of the validity of some of their answers. This approach also helped students identify, evaluate, and defend assumptions in their problem-solving approaches. Students' appreciation for this approach was demonstrated in their responses to the open-ended survey question. Several students commented about the satisfaction of feeling comfortable enough to try out a problem solution without the associated stress or worry of getting the answer perfectly correct.

Despite learning gains often associated with a blended learning format, students may nevertheless demonstrate resistance and frustration with active learning approaches [3], [4]. Student resistance is linked to factors such as a preference for traditional lecture-homework-test formats [3]. The choices offered to students in this bioelectricity course appeared to alleviate that concern. Students demonstrated a positive perception of the overall learning environment, satisfaction with their learning relative to effort, and appreciation for the ability to skip formative activities if they were not as interested in the topic or were stressed about other time commitments.

Another expectation in this study is that the course style influences the quality of student-faculty interactions [7]. Smaller class size and active learning approaches are typically thought to improve these aspects of the student experience, perhaps because of the increased frequency of interaction and opportunity for advising or mentoring that arises from discussing course content in an upper-level elective. Indeed, student-faculty interactions were viewed positively by students in the bioelectricity course, and students especially appreciated the accessibility of the instructor. Increased frequency and quality of student-faculty interactions support students' desire to connect their learning to their career development [8].

A limitation of this study is that the classroom culture encouraged active participation of students regardless of their choice of learning portfolios. The active participation of all students in the in-class activities may have partly masked differences in summative assessment scores that might have resulted if students choosing the traditional portfolio completed a more traditional activity instead (e.g., watched a lecture). The expectation for voluntary participation in interactive lecture discussions was established on the first day of class by posing open-ended questions to engage students in defining the course topics by finding interesting examples of bioelectric phenomena on the internet. In addition, students were required to complete all learning activities (the blended portfolio) during Unit 1 of the course to enable them to make an informed choice during subsequent units. As a result, most students chose to complete the blended portfolio throughout the course, perhaps because they recognized the learning benefits of the formative assessment activities. Although students were not asked to justify their portfolio choices, it is possible that choosing the traditional portfolio resulted from factors external to the course, such as other time commitments or prioritization of other courses. Enabling this flexibility may have played a part in the high level of student satisfaction with this course.

Although a validated instrument to measure student motivation was not implemented in this study, it is reasonable to hypothesize from student responses that the ability to choose assessment strategies increased motivation for a subset of the students. Another group of students reported

that the choice of portfolios did not affect their motivation because they planned to complete all assignments anyway. This group reflects student comfort level with the traditional roles of instructor assigning required activities and students completing all activities without choice. Allowing students to choose only those activities that they feel will benefit their learning creates some discomfort associated with the cognitive challenge of self-assessment [4]. These same students reported reduced stress associated with grading and increased likelihood to attempt new problems independently. One student mentioned discovering that he enjoyed the extra autonomy despite being wary on the first day of class. Increased autonomy is reflected in the self-determination theory of motivation [9], which can lead to improved outcomes as students explore areas of interest in course content more deeply.

This increased tendency to explore course content and focus on "big picture" concepts that relate to career interests meets learning goals on the affective side of pedagogical models. For example, one student made a direct connection between completing the low-stakes activities and her self-assessment of learning, which can be characterized as "Learning How to Learn" [10]. Two students mentioned feeling that the instructor cares about their learning styles and outcomes, a demonstration of the "Human Dimension" of learning. Students demonstrate "Caring" by noticing that they are incentivized to focus on concepts and make attempts at problem-solving without fear of being wrong.

Overall, this study demonstrated a course design that gives students increased autonomy over their course grading strategy without sacrificing learning outcomes. Student feedback is consistent with increased motivation to learn content as well as aspects of the affective aspects of learning such as caring about the content and identifying strategies to help themselves become life-long learners.

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