Blended learning within an undergraduate exercise physiology laboratory

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“BLENDED" LEARNING, which integrates face-to-face and online instruction (5), offers a promising approach for transforming learning in education (10). When designed well, blended physiology courses can facilitate increased student performance and satisfaction and ultimately enhance student learning. For example, implementation of a blended undergraduate exercise physiology course led to higher grades compared with a traditional course format (8). Similarly, the inclusion of supplemental online learning modules in undergraduate exercise science courses (1, 4) yielded positive outcomes. More recently, Tune and colleagues (12) reported that a blended format led to higher grades compared with a traditional classroom and was well received by students in a graduate level physiology course. While blended methods have been embraced in classroom settings, it is less clear if these methods can be useful in laboratories, which often serve as important companion courses.

Laboratory instruction plays a critical role in science education and offers a number of benefits to students. According to the National Research Council (2), instructional laboratory activities help to 1) enhance mastery of subject matter, 2) develop scientific reasoning, 3) understand complexity and ambiguity of empirical work, 4) develop practical skills, 5) understand the scientific process, 6) stimulate an interest in science, and 7) foster teamwork. Interestingly, a few groups have implemented blended learning methods to facilitate learning in undergraduate physiology (3), chemistry (11), and biochemistry (6) laboratories. Specifically, these educators offloaded key materials (e.g., prerecorded videos demonstrating technical laboratory procedures and online modules with prelaboratory questions) so that course information was presented in a more flexible format, students were more prepared for experiments, and more class time was available for active learning. Their data indicated that blended laboratories helped to increased student preparedness and attitudes more so than traditional laboratories. These results are promising and provide a blended model for other disciplines to consider for laboratory instruction.

Most exercise physiology laboratories consist of a prelaboratory reading, an in-class instructor-lead demonstration, and a subsequent hands-on experiment. It is important to point out that limited laboratory equipment and time restrictions can make it difficult for all students to actively participate during class. For example, during a maximal O2 consumption (VO2max) test, which involves an expensive metabolic cart and cycle ergometer, the majority of students often stand around a computer display while only a handful of students are actively engaged (7). Furthermore, after the instructor-lead demonstration and initial student experiment, little time is left for students to repeat the exercise protocol so that they can participate and experience all aspects of the experiment (exercising as the subject, operating laboratory equipment, and recording data). Implementation of a blended approach might help to circumvent some of these limitations, maximize use of class time, and offer a more effective laboratory experience. To the best of our knowledge, there are no reports of educators implementing blended learning in exercise physiology laboratories.

Accordingly, the purpose of the present study was to compare student performance and perceptions between blended and traditional laboratories in an undergraduate exercise physiology laboratory. Specifically, we developed a series of blended exercise physiology laboratories by offloading prerecorded instructor demonstrations so that we could offer multiple learning platforms, facilitate increased student preparedness, and allow more time for active learning. Based on previous reports, we hypothesized that blended laboratories would facilitate improved performance on laboratory assignments and practi-
cum exams and be more favorably received by students compared with traditional laboratories.

METHODS

Course description. The experimental procedures used in study were reviewed by the Institutional Review Board of Michigan Technological University and determined to have an exempt status. After approval, data were collected from the fall 2014 undergraduate exercise physiology laboratory offered by the Department of Kinesiology and Integrative Physiology. The exercise physiology laboratory (EH 4211) is a one-credit course that is taken concurrently with the three-credit exercise physiology lecture (EH 4210). This upper-division exercise physiology series is required for Exercise Science majors and also routinely attracts nonmajor students from Biological Sciences and Biomedical Engineering majors. At the completion of the laboratory, students are expected to be able to 1) operate laboratory equipment and administer a variety of exercise testing protocols; 2) evaluate physiological responses to acute exercise; 3) use Microsoft Excel to perform basic data entry, graphing, and statistical analyses; and 4) interpret and apply findings to real-world scenarios in health, exercise, and sport.

Experimental overview. During the fall semester, laboratory sections were offered on either Tuesday (section 1) or Wednesday (section 2). Specifically, 16 students were enrolled in laboratory section 1 (6 men and 10 women, 12 majors and 4 nonmajors) and 17 students were enrolled in laboratory section 2 (8 men and 9 women, 13 majors and 4 nonmajors). Each section was further subdivided into two equal subsections to facilitate smaller in-class experiments. Thus, each week, small groups of approximately eight to nine students met separately for 90 min to carry out the laboratory experiment under the supervision of the same faculty instructor (i.e., ~8:1 student-to-faculty ratio). Note that a graduate student teaching assistant also assisted the instructor with delivering the laboratory activities each week. Using a randomized, crossover design, four laboratory topics were delivered in either a blended or traditional format (as described below; Fig. 1). Section 1 completed blended laboratories for neuromuscular power and blood lactate and traditional laboratories for \( \dot{V}O_{2\text{max}} \) and muscle electromyography (EMG). In contrast, section 2 completed blended laboratories for \( \dot{V}O_{2\text{max}} \) and EMG and traditional laboratories for neuromuscular power and blood lactate. Both sections completed the same assignments and laboratory practicum exams. Pre- and postcourse surveys were administered to assess changes in student perceptions. Finally, in an effort to blind students to the pedagogical comparison, students were informed that laboratory exercises could differ slightly between laboratory sections and thus should be concerned only with their specific laboratory section.

Blended laboratories. For blended laboratories (Fig. 2), students first completed an assigned reading that provided theoretical background information, an overview of the experiment, and step-by-step instructions for performing the experiment. Subsequently, students watched a series of brief video demonstrations (3 videos × 5 min/video = ~15 min). Specifically, during the videos, the instructor 1) introduced the laboratory equipment, 2) demonstrated how to use the equipment and administer the exercise protocol, and 3) pointed out aspects of equipment safety. During the videos, students were also prompted with a total of three questions to reinforce key points related to equipment operation, the exercise protocol, and/or safety precautions. Thus, the videos extended on the traditional assigned reading and highlighted the technical skills needed for the experiment. All prelaboratory materials (as well as postlaboratory materials) were accessible through the course learning management system (Canvas, Salt Lake City, UT). At the beginning of class, the instructor checked student understanding with a short quiz consisting of approximately five questions during which students responded using a personal response system (i-clicker, Orange, VA). The instructor proceeded to the next question when 75% of the students answered correctly. If <75% of the students answered correctly, then additional time was provided for either peer instruction or a small-group discussion before the question was asked again. Quizzes were graded for participation...
only. During this time, the instructor answered any questions from the videos and quiz and provided any general clarification as needed (i.e., microlecture). Subsequently, students proceeded directly to the experiment, where the instructor helped to assist students rather than lead them through experiment. Note that the blended format in this study was inspired by and partially modeled after the blended approach used by McLaughlin and colleagues (9).

**Traditional laboratories.** For traditional laboratories, students first completed the same assigned reading described above (theoretical background information, overview of the experiment, and step-by-step instructions). At the beginning of class, the instructor summarized the main points from the reading and then proceeded by giving a demonstration of the laboratory equipment used for experiment. During the demonstration, a few students were actively involved with the demonstration while most students observed. The instructor also answered questions during this time. After the completion of the demonstration, students then performed the experiment on their own while the instructor was available to assist them.

**Student performance.** Laboratory assignments consisted of essay questions that were aligned with the course learning objectives. Specifically, each assignment included a series of questions related to 1) the methods used in the experiment, 2) data entry and graphing in Excel, 3) interpretation of findings, and 4) applications of findings. Students had 1 wk to complete the assignment and submit it through the course learning management system. An in-house rubric specific to the assignment was used to assign each response a point value ranging from 1 to 5 (i.e., poor, below average, average, good, and excellent). Total points for each assignment were recorded. To avoid potential investigator bias, the instructor who graded all laboratory assignments was blinded to the delivery method when evaluating.

For the laboratory practicum exams, students had to demonstrate the ability to 1) administer a laboratory testing protocol and 2) record physiological measurements for two different exercise physiology topics. During the practicum exams, students were prompted with several questions to check their understanding. Students were generally informed of the protocols and skills that they could be tested on. The faculty instructor and a graduate student (who was not involved with teaching the undergraduate exercise physiology laboratory) separately evaluated each student’s practicum performance using a standardized rubric to assign each skill/answer a point value ranging from 1 to 5 (i.e., poor, below average, average, good, and excellent). Total practicum points from each independent investigator were averaged to obtain a composite score. If the scores differed by >3% between the two investigators, then the higher score was used. Practicum 1 took place during the middle of the semester, and practicum 2 took place at the end of the semester.

**Student perceptions.** Before the start of the course, a survey was administered to obtain student perceptions related to general science laboratory courses taken (i.e., typical engagement and participation behavior), confidence performing exercise physiology testing protocols, and preference for laboratory content delivery. Upon completion of the course, a similar survey was administered with a focus on student perceptions specific to the current exercise physiology laboratory course. Survey questions were quantified using a Likert scale ranging from 0 and 4 (i.e., unable to comment, strongly disagree, disagree, agree, and strongly agree).

**Data analysis.** To evaluate the main effect of laboratory section (section 1 vs. section 2), repeated-measures ANOVA was used to assess differences in assignment scores. For each specific laboratory topic, an independent t-test was used to assess differences in assignment scores between laboratory sections. Furthermore, to evaluate the main effect of laboratory format (blended vs. traditional), an independent t-test was used to compare differences in assignment scores. Separate independent t-tests were used to assess differences in practicum 1 and practicum 2 scores. Repeated-measures ANOVA was used to assess differences in student perception scores. Statistical procedures were performed using IBM SPSS Statistical Software (IBM, Armonk, NY). Data are presented as means ± SD, and α was set to 0.05.

**RESULTS**

Video demonstrations. The majority of students in laboratory section 1 self-reported watching the online video demonstrations (100% watched videos for at least one blended laboratory and 81% watched videos for both blended laboratories). Similarly, most of the students in laboratory section 2 reported watching the video demonstrations (100% watched videos for at least one blended laboratory and 76% watched videos for both blended laboratories). Nearly all of the students in laboratory section 1 (15 of 16 students) and laboratory section 2 (15 of 17 students) completed all four laboratory assignments. Accordingly, assignment and practicum data from these individuals were used for analysis.

**Student performance.** Assignment scores did not differ between laboratory sections (P = 0.91). While assignment scores differed across laboratory topics (P < 0.001), there were no differences in scores between laboratory sections for specific laboratory topics (all P > 0.05; Fig. 3). Furthermore, assignment scores did not differ between blended and traditional laboratories (P = 0.62; Fig. 3). Practicum 1 and practicum 2 scores did not differ between laboratory sections (P = 0.55 and P = 0.08, respectively; Fig. 4).

**Student perceptions.** Of the survey questions selected for analysis, student perceptions did not differ between laboratory sections (all P > 0.05) and there were no laboratory section × time interactions (all P > 0.05). Thus, pooled values for the entire laboratory (n = 30) are reported below and in Table 1 and Fig. 5. Students perceived that the exercise physiology laboratory enabled them to participate and stay engaged more than a general science laboratory (P < 0.001; Fig. 5). Students also reported that the exercise physiology laboratory enhanced their learning more than a general science laboratory (P < 0.01; Fig. 5). At the end of the course, students were much more confident in their abilities to perform laboratory protocols specific to 1) neuromuscular power, 2) VO2max, 3) blood lactate, and 4) EMG compared with before the course (all P < 0.001; Table 1).

At the end of the course, student perceptions relating to the value and effectiveness of learning foundational content before coming to class to enhance learning of course material (i.e., blended learning concept) was higher compared with those before the course (P < 0.01; Fig. 5). A greater percentage of students agreed or strongly agreed that learning key foundational content through a video demonstration before class greatly enhanced their learning of course material compared with a preassigned reading (94% vs. 78%, P < 0.01). Similarly, at the end of the course, 73% of students indicated that if presented with an option, they preferred learning important foundational content before coming to class and using more class time for carrying out the experiment and applied learning compared with only 60% at the beginning of the course. Finally, in response to open-ended questions, students indicated that some of their favorite aspects of the blended laboratories included "knowing what to expect" and "more efficient use of class time," whereas some of their least favorite aspects included "videos seemed redundant" and "not being able to ask questions."

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DISCUSSION

In this investigation, we compared student performance and perceptions between blended and traditional laboratories within an undergraduate exercise physiology laboratory. The results indicated that blended laboratories did not significantly improve scores on laboratory assignments and practicum exams. Despite this, feedback at the end of the course was largely positive as students reported being actively engaged during laboratory activities and confident in their abilities to perform exercise physiology testing protocols. Moreover, students’ perceived value of the blended format increased, and they indicated that watching short video demonstrations of key laboratory content before class greatly enhanced their learning of course material compared with a preassigned reading. When coupled with the self-report data, this study provides robust insights regarding both self-perceived and objective assessment of student performance.

In support of our hypothesis, we observed significant differences in student perceptions of the blended laboratory environment. Specifically, a greater percentage of students agreed that learning key laboratory content through a video demonstration before class greatly enhanced their learning of course material compared with a preassigned reading. In addition, at the end of the course, more students (if presented with the option) preferred learning important foundational content before coming to class and using more class time for carrying out the experiment and applied learning compared with before the course (73% vs. 60%). It is also important to note that even though we altered the method for content delivery from the traditional approach, students still perceived that the undergraduate exercise physiology laboratory facilitated participation and engagement and enhanced their learning more so than other general science laboratories they had taken. Overall, these findings are consistent with previous reports indicating that blended laboratories increased student perceptions of blended learning and laboratory preparedness more so than traditional physiology (3), chemistry (6), and biochemistry (11) laboratories.

Taken together with these recent studies (3, 6, 11), our data support an emerging concept that blended learning within a laboratory environment can improve student perception. This is particularly noteworthy given that this improved perception does not appear to compromise traditional objective measures of student performance (i.e., grades), which is consistent with previous findings in a blended physiology laboratory (3). This
may be particularly relevant to educators who find themselves dealing with the unavoidable, and often complicated, influence of student evaluations on annual faculty evaluations and/or the promotion and tenure process. If blended laboratories can lead to a more positive perception of the laboratory experience without compromising student performance, it seems faculty teaching or supervising such courses may want to consider this approach.

Previous pedagogical studies (8, 12) conducted in classroom settings have revealed that blended approaches can quantitatively improve grades in undergraduate and graduate physiology courses. However, it is important to distinguish several key differences between those classroom studies and the present laboratory study. First, in classroom settings (8, 12), a greater portion of course content was likely offloaded compared with our short videos, which highlighted mostly laboratory technical skills. Second, in classroom settings (8, 12), student performance data were compared across 2 yr or multiple sections, whereas in our laboratory setting we implemented a randomized, crossover design. Third, in classroom settings (12), multiple-choice exams were used to assess student performance, which is different from the more common written scientific report that we used for assessment in the laboratory setting. Finally, we speculate that previous studies (8, 12) conducted in classroom settings had much higher student-to-faculty ratios and thus may have benefited more from active learning associated with blended learning. Conversely, our study was conducted in a dynamic laboratory environment that, by default, incorporates a fair amount of active learning even during a traditional laboratory session. Moreover, because we teach the Exercise Physiology course as a capstone course, our department intentionally keeps the student-to-faculty ratio low (~8:1). We acknowledge that there is tremendous variability among institutions of higher education offering exercise physiology laboratories; therefore, we recognize that our findings may not be generalizable to laboratories with much larger student-to-faculty ratios. It remains possible that a blended exercise physiology laboratory with higher student-to-faculty ratios could help improve more objective assessments of student performance (e.g., multiple-choice exams). Finally, we acknowledge that self-perception comparisons between the present laboratory and prior “science-based laboratories” could be confounded by the content/topics (i.e., exercise physiology vs. biology/chemistry/physics).

Table 1. Pre- to postcourse changes in student perceptions related to confidence in performing exercise physiology testing protocols

<table>
<thead>
<tr>
<th>Question</th>
<th>Precourse</th>
<th>Postcourse</th>
</tr>
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<tbody>
<tr>
<td>I feel confident that I could administer a maximal power test and determine an individual’s maximum neuromuscular power.</td>
<td>1.33 ± 1.30</td>
<td>3.40 ± 0.56*</td>
</tr>
<tr>
<td>I feel confident that I could administer a graded exercise test and maximal O2 consumption protocol.</td>
<td>1.70 ± 1.26</td>
<td>3.50 ± 0.51*</td>
</tr>
<tr>
<td>I feel confident that I could collect an exercising blood lactate measurement.</td>
<td>1.43 ± 1.48</td>
<td>3.60 ± 0.50*</td>
</tr>
<tr>
<td>I feel confident that I could administer an isolated maximal voluntary contraction test to determine peak muscle electromyographic amplitude.</td>
<td>1.33 ± 1.21</td>
<td>3.43 ± 0.57*</td>
</tr>
</tbody>
</table>

Likert scale items were measured on a four-point scale ranging from unable to comment (0) to strongly agree (4). *P < 0.001 vs. precourse.

Fig. 5. Pre- to postcourse changes in student perceptions. Survey questions were targeted at identifying typical engagement and participation behavior and general preference for content delivery. Questions were assessed using a Likert scale ranging from unable to comment (0) to strongly agree (4). *P < 0.01 vs. precourse.

**Survey Question**

**Q1**
Pre: General science labs greatly enhance my learning.
Post: This exercise physiology lab greatly enhanced my learning.

**Q2**
Pre: I participate and stay engaged throughout experiments during general science labs.
Post: I participated and stay engaged throughout experiments during this exercise physiology lab.

**Q3**
Pre: Learning key foundational content prior to coming to a general science lab greatly enhances my learning of course material.
Post: Learning key foundation content prior to coming to this exercise physiology lab greatly enhanced my learning of course material.
Our data advocate consideration of blended learning within an undergraduate exercise physiology laboratory; however, it should not be done blindly. Successfully implementing blended learning in our exercise physiology laboratory was quite time consuming as we spent many hours during the semester recording and preparing the prelaboratory videos and working to integrate them into the existing course. While we did not quantify this directly, we estimate that converting each traditional laboratory to a blended laboratory took at least 10 h of total time. Fortunately, this time was split across the instructor and graduate student (departmentally supported), making it more reasonable. Moreover, we received tremendous support from our Center for Teaching and Learning as well as Information Technology. Without this support, creating the blended laboratories would have been an incredibly daunting task. Now that the blended laboratories are produced, we expect this initial investment to make the faculty and department more efficient in many ways. Indeed, the blended laboratory videos have also served as a useful review tool that we have used in our graduate exercise physiology laboratories. Furthermore, our department is currently working to implement blended learning in other undergraduate laboratories, such as 1) exercise prescription and 2) biomechanics. Finally, future modifications that could improve the effectiveness of the blended laboratories include finding better ways to ensure that all students watch the video demonstrations (e.g., assigning participation points) and integrating the prelaboratory quiz into the video demonstrations.

In summary, these are the first data to document the implementation of blended learning within an undergraduate exercise physiology laboratory. Blended laboratories provided a viable alternative for delivering content that was favorably perceived by students and did not compromise student performance. These findings support an emerging concept of incorporating blended formats in laboratory settings and may have implications for educators who wish to improve laboratory instruction.

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**REFERENCES**