HOW WE TEACH | Generalizable Education Research

Best practices for learning physiology: combining classroom and online methods

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Anderson LC, Krichbaum KE. Best practices for learning physiology: combining classroom and online methods. Adv Physiol Educ 41: 383–389, 2017; doi:10.1152/advan.00099.2016.—Physiology is a requisite course for many professional allied health programs and is a foundational science for learning pathophysiology, health assessment, and pharmacology. Given the demand for online learning in the health sciences, it is important to evaluate the efficacy of online and in-class teaching methods, especially as they are combined to form hybrid courses. The purpose of this study was to compare two hybrid physiology sections in which one section was offered mostly in-class (85% in-class), and the other section was offered mostly online (85% online). The two sections in 2 yr (year 1 and year 2) were compared in terms of knowledge of physiology measured in exam scores and pretest-posttest improvement, and in measures of student satisfaction with teaching. In year 1, there were some differences on individual exam scores between the two sections, but no significant differences in mean exam scores or in pretest-posttest improvements. However, in terms of student satisfaction, the mostly in-class students in year 1 rated the instructor significantly higher than did the mostly online students. Comparisons between in-class and online students in the year 2 cohort yielded data that showed that mean exam scores were not statistically different, but pre-post changes were significantly greater in the mostly online section; student satisfaction among mostly online students also improved significantly. Education researchers must investigate effective combinations of in-class and online methods for student learning outcomes, while maintaining the flexibility and convenience that online methods provide.

hybrid courses; physiology education; blended learning

KNOWLEDGE OF PHYSIOLOGY is essential to professional allied health programs and to quality clinical practice (5). Understanding of human physiology promotes critical thinking and serves as an important basic science foundation for achieving competence in clinical areas, such as pathophysiology, health assessment, pharmacology, and pharmacotherapeutics. Studies of incorporating online technology into physiology courses suggest that technology can enhance the student learning experience and produce final course grade averages or other student learning outcomes that are at least equal to those achieved in traditional physiology courses (4, 8, 10–12).

As described in a 2010 report by the U.S. Department of Education, a meta-analysis of online vs. in-class studies of online and traditional lecture courses revealed that online students performed “modestly” better than in-class students. Of 50 studies included in the meta-analysis, online students performed significantly better than in-class students in 11 of 50 included studies, whereas in-class students performed significantly better than online students in 3 of the studies (15). The evidence reviewed in this report indicates that even better student outcomes are produced in comparisons of hybrid courses, those that combine online and in-class methods, to courses using in-class or online methods alone. The authors of this report caution educators that it may not be the online method per se that accounts for these results. It may be that online methods require students to spend more time engaged with the course content (15).

Online and online-enhanced courses ensure that both traditional and nontraditional students have access to the basic science prerequisites for health science professional programs and meet the growing demand for online basic science education (14). Additional research about the best methods to teach online courses is needed to ensure that student learning outcomes in online and hybrid courses in physiology are equal to or better than those achieved with traditional lecture courses.

Although there are other examples of online methods in physiology instruction (4, 8, 10–12), the present study is unique in that two sections of an entire systems-based physiology course are compared using multiple measures, including a pretest and posttest. The purpose of this study included two aims, 1) to compare student learning outcomes and 2) to compare student satisfaction with the instructor between students enrolled in two sections of a course in physiology in two cohorts (years 1 and 2), those enrolled in a mostly classroom-based physiology course (In-Class), and those enrolled in a mostly online course (Web), to describe the most effective of two combinations of online and in-class instruction. A secondary purpose was to use the results of data analysis to improve course delivery in year 2 and in subsequent offerings to improve student learning outcomes for those students.

MATERIALS AND METHODS

Design

The design was a quasi-experimental comparison of student learning outcomes and student satisfaction ratings between two hybrid offerings of a course in physiology over 2 yr: one mostly online, identified as the Web class, and one mostly taught in a classroom format, identified as In-Class (9). Random assignment was not possible in this study because students residing in other states or students with schedule conflicts had to register in the section that fit with
degree requirements and other factors. Demographics comparisons were made to assess comparability between sections and cohorts.

The In-Class and Web sections had the same content, learning objectives, textbook, and online exams. Learning objectives were grouped according to the weekly lecture topic in the In-Class section or the online module topic in the Web section. Discussions to promote interactivity were customized for the mode of delivery. For example, the In-Class students were given questions to discuss with their peers during various points of the lecture. The Web students were assigned to groups and given questions to discuss online using an asynchronous online forum.

Theoretical Framework

Delivery of both offerings in this physiology class was based on Cognitive Constructive Learning Theory that has its roots in the neuroscience concepts of short-term and long-term memory. The emphasis is on learning as an active process in which students integrate new knowledge into information they already know. First a student must recognize that there is new information. As the student pays attention to this new information, it is coded into short-term memory. The goal is to encode information into long-term memory through application and retrieval of information from short-term memory (6).

Description of the In-Class Section

In the In-Class section of the physiology class, content was delivered via weekly 3-h class periods over 15 wk with added online components. Ideally, the instructor lectured 10–15 min, stopping to encourage interactivity and student discussion through the presentation of multiple choice questions and critical-thinking exercises, such as “think-pair-share” (7). Course delivery was enhanced by use of a web-based learning management system (LMS), where students found lecture notes, a syllabus, communication tools (e-mail and an online discussion tool), online practice questions with programmed feedback, and online exams. Students were encouraged to submit written questions at the end of the class period or via postings to an online forum on the class website. The instructor compiled the questions from the classroom and posted answers on the online forum, encouraging students to ask follow-up questions or add information the class might find helpful.

In the In-Class section, the majority of student-teacher and student-student contact occurred in the classroom and was enhanced by online resources. According to the university guidelines, a student in a 3-credit course spends 3 h/wk in class and invests an additional 2 h-credit wk⁻¹ for preparation and study. From web logs of the LMS, students spent 1–2 h/wk online, which is between 11 and 22% of the time commitment. From this range, it is estimated that ~85% of the time commitment occurred in traditional classroom activities (inside and outside of class), supplemented with 15% online activities outside of class.

Description of the Web Section

In the Web section, the same content presented in the In-Class section was delivered online via 14 content modules using a web-based LMS, enhanced with classroom activities. Over a 15-wk semester, two of the online modules were delivered in class, and the remaining modules were delivered online, such that the distribution was estimated to be ~85% online activities and 15% classroom activities. The modules were originally developed, implemented, and evaluated by a partnership mandated to bring graduate instruction to aging students to ask follow-up questions or add information the class might find helpful.

The instructor served as the instructional designer and group facilitator, rather than as a traditional lecturer. The majority of student-teacher and student-student contact occurred via the web and was supplemented by two 3-h classroom meetings: the first on genetics and inheritance and the second on gastrointestinal physiology and pathophysiology.

Each module contained learning objectives, reading assignments, a checklist for weekly activities called a “work plan,” online content on physiology and pathophysiology, links to websites on physiology, discussion questions, and practice quizzes. Students were given a schedule for completing the 14 modules so that all students were working on the same modules at the same time. During year 1, students participated in online discussions of module content in groups of five to six students, with each group worked together to answer 8–14 questions posted by the instructor. In addition, there were two assignments in which students submitted individual responses to 10–12 essay questions.

In the Web section, students were assigned to discussion groups of five or six students in which they worked together to organize information from their readings. Online student discussions of open-ended questions essentially replaced lectures as a means of learning the material. The use of online discussions of questions based on the course learning objectives was a way for students to take more responsibility for their own learning. Some discussion questions were straightforward assessments of physiology content; e.g., “What are the major ways oxygen is carried in the blood?” or “How is blood glucose level regulated by insulin and glucagon?” These questions allowed the instructor, acting as a facilitator, to evaluate the students’ understanding of the material. In addition, more complex questions were posed that required students to solve problems or to integrate physiological concepts into their own experiences. For example, students were asked, “Is homeostasis a process that enables the body to keep the heart rate at a constant level of 72 beats per minute? Why or why not?” and “Is inflammation good or bad? Defend your answer.” Students were encouraged to cite physiological examples from the current literature or to describe experiences from their own clinical practice to support their discussion answers. The instructor would react to student online postings, answer questions, pose additional questions, and give feedback on the quality of the work in each student group.

Four of the modules (cell physiology, cellular adaptation, pulmonary physiology, and renal physiology) contained interactive animations developed through the partnership mentioned previously (1). The exercises were developed to help students immediately apply content they had read in the text and module pages. For example, students used a “drag and drop” exercise to identify the signs and symptoms of renal failure. Students would click on a selection and drag it over to a graphic of a kidney. Correct answers stay in place; incorrect answers bounce back to the original list of selections. Students were able to reset the exercise and perform it as many times as they wished to reinforce individual learning.

The cardiovascular module contained an “online lab.” Students were asked to monitor their pulse at baseline, in the supine position, with sudden standing, and a few minutes after standing. Students were asked to relate their results to the process of negative feedback and the baroreceptor reflex. Students posted their pulse changes and any other observations online. The instructor compiled and averaged the student data and posted this information online.

Sample

The study population comprised graduate students in nursing, nutrition, genetic counseling, and informatics. The sample consisted of all students registered for either section of a physiology course housed within a school of nursing at a major Midwestern public university. During year 1 (2006), 108 students completed the course (In-Class, n = 63; Web, n = 45). A decision was made to collect a second year
of data to see if evaluation-driven course revisions would affect the outcomes found in the preliminary analysis. During year 2 (2007), 127 students completed the course (In-Class, n = 71; Web, n = 56).

Measures

Demographics. Year 1 students completed a demographics questionnaire that included the following information: age, sex, grade point average, major, type of format the student chose, format preferred by the student, reason for choosing a particular format, previously completed graduate credit hours, and previously web-delivered credit hours. After an analysis of year 1 data, the investigators decided to analyze a second year of data after the class had already been completed. Only sex and major information were collected from the year 2 class rosters to expedite the second analysis.

Student learning outcomes. To determine the effectiveness of each hybrid section of the course for achieving student knowledge outcomes, researchers analyzed student scores on a 50-item multiple choice exam using the assessment tool within Web Vista. Students took the 50-item test as both a pretest and as a final examination, but performance on this test did not contribute to the students’ final grades. In addition, student knowledge of content was measured with five timed, open-book, online exams with the same testing items for both classes. Software within the LMS calculated the point biserial correlation coefficient, a measure of question discrimination, for each exam item, permitting the investigators to compare student performance between the two class sections on each item (9).

Student satisfaction with instructor. At the completion of each course, students were also asked to complete a standard form for rating satisfaction with an individual instructor based on the perception of his or her teaching of the course, known as Form D (16). This form contains 11 items about the instructor; a higher rating on each item indicates a higher level of satisfaction with a given characteristic of the instructor, such as overall teaching ability and respect and concern for students. Students were instructed to rate the teacher on each item on a scale of 1–7 (1 = poor and 7 = exceptional). At the time of the study, this form was available to students online.

Form D was created and adopted at the university before the development of online course delivery methods. The questions on Form D may be more appropriate for evaluating traditional lecturers, but both the In-Class and Web sections were evaluated with the form because the institution in this study used this form for merit evaluation of instructors, regardless of the method of course delivery.

Data Collection

Data collection occurred during the fall semesters of 2006 and 2007. Before year 1, students in both sections were informed about the research study by e-mail. After institutional review board (IRB) approval was received, the course instructor, who is also an investigator, used class time to explain the study in detail, explain the consent process, distribute demographic questionnaires, and instruct students how to access and take online evaluations. The instructor then introduced the other investigator and left the room. The remaining nonteaching investigator collected completed questionnaires and provided mailing instructions for submitting additional questionnaires. Each student was assigned a unique identification code for the study; the code list was secured by the nonteaching investigator so that the course instructor was blinded to the list of participants. All collected questionnaires were stored and secured in the nonteaching investigator’s office. As data were entered for analysis, identifiers were deleted, and data records were labeled with the unique code to protect student privacy and to preserve confidentiality. During the last 2 wk of the term, students were sent online reminders to complete the fifth exam, the course posttest, and the online Form D.

After the completion of the year 2 course offering, the investigators applied for an IRB extension to permit a second year of data analysis. Because approval by the IRB was extended after the year 2 cohort had completed the course, the data were collected retrospectively. The same measures had been used (test scores and satisfaction), but extensive demographic data were not available. The course instructor was able to extract sex and academic major from university class rosters.

Data Analysis

After the year 1 course was completed, data from the demographic questionnaires, all exam scores from the LMS grade book, and the student satisfaction data were entered into an SPSS spreadsheet by a graduate research assistant. Group characteristics expressed as a percentage (sex, major, and section preference) were compared using the χ² test. Histograms of interval student data revealed nonnormal data distributions; the remaining demographic data, exam scores, and satisfaction ratings were compared using the Mann-Whitney U-test and are reported as means and standard deviations (9). Comments from student satisfaction forms in year 1 were analyzed for major themes and were used to revise both sections of the course for year 2.

After the year 2 course was completed, the course instructor/investigator entered de-identified student exam data, student sex and major (nursing or other health science majors) demographic data, and student satisfaction data into a spreadsheet for analysis. As with the year 1 data, year 2 data were also not normally distributed; In-Class and Web sections were compared using the Mann-Whitney U-test and are reported as means and standard deviations (Tables 1–3) (9).

Given that the year 2 Web section contained a high proportion of health science students who were not nursing students (mainly nutrition and genetic counseling students), it was possible that the pretest-posttest differences could be attributed to the previous coursework completed by the students in the sample. The data were reanalyzed after removing the nonnursing students from both sections.

RESULTS

Demographics

Comparisons of demographic data for the first cohort of In-Class and Web student groups were made in relation to sex, degree major, age, grade point average, previously completed online credits, and previously completed graduate credits for the In-Class (n = 53) and Web (n = 38) courses. In year 1, there were no significant differences based on this analysis (data not shown). Each student group from the first cohort had three students of diverse ethnicity, but these data could not be analyzed because there were such low numbers; there were no apparent differences between student groups in racial or ethnic composition. Access to the students’ preferred section was the only significant difference between the groups (χ² test, P < 0.001). All of the year 1 In-Class students preferred to enroll in the hybrid In-Class section, whereas 76% of the year 1 hybrid Web students enrolled in their preferred section. The remaining 24% of the year 1 Web students reported having to enroll in the Web course, even though it was not their preference, either because they lived too far from campus to attend a weekly class or because their schedules did not allow them to attend the In-Class section.

Year 2 demographics were retrospectively collected from class rosters. Table 1 shows student demographics for both years in terms of sex and major. There were no significant differences in sex composition between the two sections for either year. There were significantly more nonnursing majors enrolled in the Web section during year 2 (χ², P < 0.001) (9); of the year 2 Web students, 34% were nonnursing majors compared with 1% for the In-Class students.
Student Learning Outcomes

Exam scores. Student learning outcomes were compared between the Web and In-Class sections based on the analysis of exam scores, including five exams, each with 40 items. Mean scores were compared across sections on each exam and then by an overall mean. There were no significant differences between the In-Class and Web groups for either year of course delivery in the overall mean exam score (Table 2).

There were two differences on individual exams. In year 1, the In-Class students scored significantly higher on exam 2 (Neurophysiology and Endocrinology) than did the Web students (Table 2, P = 0.01). Item analysis indicated that the Web students had more difficulty with the neurophysiology content. After online course revisions in year 2, this difference on exam 2 was not seen in this second cohort of students. In year 2, however, the In-Class students scored significantly higher on exam 3 (Blood, Immune, and Cardiovascular Physiology) than did the Web students (Table 2, P = 0.001). Item analysis indicated that the cardiovascular content was most difficult for the Web students; this was an unexpected result, given that the previous cohort did not score differently on the cardiovascular material.

Preexam-postexam scores. Before the start of the course, students took a 50-item test. Students were given the same 50-item test the last week of the semester. Results of the analysis of change scores from pre- to posttesting in year 1 showed no significant differences between the Web and In-Class sections. In year 2, however, the Web posttest-pretest difference was significantly greater than that for the In-Class section (Table 2, P = 0.002).

Student satisfaction with instructor. Student satisfaction with the instructor was measured using individual student ratings on Form D (16). Mean ratings were compared on 11 items between sections in both years. Because students had to log onto a university website on their own time to complete the Form D instructor ratings, the completion rate of evaluations was variable for the four sections (In-Class year 1 = 63%, Web year 1 = 77%, In-Class year 2 = 75%, Web year 2 = 27%).

The median scores reported in Table 3 indicate that students in the In-Class and Web year 1 sections rated the course instructor highly (Form D, ratings of 1–7). The year 1 In-Class and Web students were not significantly different in how they rated the “instructor’s knowledge of the subject matter” (item 2, P = 0.06). However, the students in the year 1 In-Class section rated the instructor significantly higher in all other aspects of teaching than did the year 1 Web section. Of note, students in the year 1 In-Class section rated the instructor significantly higher in the “use of technology to enhance your learning experience” (item 6, P = 0.004) and “the instructor’s success in getting you to think” (item 7, P = 0.001).

Year 2 In-Class and Web students also rated the instructor highly (Form D, ratings 3–7). There was no significant difference between the instructor ratings of year 2 In-Class and instructor ratings of year 2 Web students for 10 of 11 items. The one exception was item 3 “respect and concern for students?” (Table 3, P = 0.028).

Table 1. Students demographics

<table>
<thead>
<tr>
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<tbody>
<tr>
<td></td>
<td>In-Class</td>
<td>Web</td>
</tr>
<tr>
<td>n</td>
<td>63</td>
<td>45</td>
</tr>
<tr>
<td>Sex, %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>84</td>
<td>87</td>
</tr>
<tr>
<td>Male</td>
<td>16</td>
<td>13</td>
</tr>
<tr>
<td>Major, %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nursing</td>
<td>95</td>
<td>91</td>
</tr>
<tr>
<td>Nonnursing</td>
<td>5</td>
<td>9</td>
</tr>
</tbody>
</table>

n, No. of students. Note: All between-group comparisons were performed with χ². *P < 0.001.

DISCUSSION

The purpose of this study was to compare student learning outcomes and student satisfaction in a mostly online hybrid course (Web) with those of students in a simultaneously taught mostly in-class hybrid course (In-Class) to determine whether differences in the amount of online learning were related to differences in exam scores, pre-post improvements in knowledge, and satisfaction with the instructor. The sample included students in two cohorts of students in the health professions with Web and In-Class sections offered for each cohort (years 1 and 2). Student learning outcomes as measured by exam scores were not significantly different between sections in each cohort. Outcomes measured by pre- to posttest improvement scores showed significantly better scores in the Web section in year 2. Student satisfaction with the instructor was high overall in both sections and in both cohorts.

Exam Results

Exam results from year 1 indicated that the In-Class students performed better on an exam testing neurophysiology and endocrinology content. Item analysis of exam questions indicated that cellular neurophysiology concepts were the most troublesome for this cohort of Web students. Comments from student evaluations of the instructor confirmed the item analysis; students reported they had difficulty learning cellular

Table 2. Student performance on exams

<table>
<thead>
<tr>
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<tbody>
<tr>
<td></td>
<td>In-Class</td>
<td>Web</td>
</tr>
<tr>
<td>n</td>
<td>63</td>
<td>45</td>
</tr>
<tr>
<td>Exam 1</td>
<td>35.9 (3.9)</td>
<td>35.6 (3.4)</td>
</tr>
<tr>
<td>Exam 2</td>
<td>35.8 (4.0)*</td>
<td>35.2 (3.6)*</td>
</tr>
<tr>
<td>Exam 3</td>
<td>35.9 (2.7)</td>
<td>36.2 (3.0)</td>
</tr>
<tr>
<td>Exam 4</td>
<td>35.8 (3.2)</td>
<td>35.4 (3.0)</td>
</tr>
<tr>
<td>Exam 5</td>
<td>36.4 (2.2)</td>
<td>36.1 (2.2)</td>
</tr>
<tr>
<td>Exam means</td>
<td>36.0 (2.6)</td>
<td>35.7 (2.4)</td>
</tr>
<tr>
<td>Pretest</td>
<td>23.4 (4.4)</td>
<td>24.3 (3.8)</td>
</tr>
<tr>
<td>Posttest</td>
<td>35.0 (6.6)</td>
<td>34.8 (6.1)</td>
</tr>
<tr>
<td>Posttest-pretest</td>
<td>11.5 (6.6)</td>
<td>10.5 (6.5)</td>
</tr>
</tbody>
</table>

Values are means (SD); n, no. of students. Note: Maximum score on each exam was 40 points. Exam 1 tested Genetics and Cell Biology; exam 2 tested Neurophysiology and Endocrinology; exam 3 tested Blood, Immune System, and Cardiovascular System; exam 4 tested Respiration, Renal Physiology, and Acid-Base Balance; and exam 5 tested Gastrointestinal Physiology, Reproductive Physiology, and Embryonic Development. Maximum score for pretests and posttests was 50 points. All exam comparisons between student groups were performed with the Mann-Whitney U-test. *P = 0.01. **P = 0.001. ***P = 0.002.
neurophysiology from readings and discussions alone. The instructor/researcher recorded a series of online presentations with audio used by the second cohort of students. These presentations addressed topics in cellular physiology such as resting membrane potential, action potentials, synaptic transmission, motor pathways, and sensory pathways. Year 2 Web student feedback was immediate and positive, and the instructor made additional presentations covering topics in blood and immune physiology, renal physiology, acid-base balance, and reproductive physiology.

Year 2 Web students did not perform as well as In-Class students on exam 3; item analysis revealed that the content in question was cardiovascular content. Students may have benefited from an online cardiovascular activity like an asynchronous discussion or online question-and-answer session to help the students engage in the cardiovascular content.

Comparisons between in-class sections and web-delivered sections of a physiology course show no significant differences in exam averages (Table 2). The hybrid Web course was ~85% online, estimated from 12 modules completed fully online with 2 modules completed from two in-class sessions. The hybrid In-Class course was estimated to be 15% online, given that these students took advantage of web tools such as online quizzes with feedback about the correct and incorrect answers and online discussion boards for asking questions of the instructor and student peers. Optimal combinations of online vs. in-class activities should be explored further; however, given that both sections were hybrid sections, perhaps students performed equally well because both groups of students engaged in student-centered, active learning with adequate feedback and interactivity (3). Delivery of blended, rather than strictly online courses, and instructor-directed rather than independent, self-directed courses, have been shown to be related to better learning outcomes, according to the U.S. Department of Education (15).

There was a significant difference in the pretest-posttest scores of the year 2 students; year 2 Web students showed significantly greater improvement in pretest-posttest scores (Table 2). A 2017 review reports that, among nursing students, e-learning produced test scores ~5 points higher than traditional classroom learning (13). Given that the year 2 section contained a high proportion of health science students who were not nursing students (mainly nutrition and genetic counseling students), it was possible that the pretest-posttest differences could be attributed to the backgrounds of the students in the sample. The data were reanalyzed after removing the nonnursing students from both sections. The pretest-posttest conclusions were the same (data not shown) in that the Web section improved more than the In-Class section, although a possible interpretation is that the Web students were able to catch up with their In-Class peers, as measured by their performance on the posttest. Consequently, the present study

Table 3. Instructor evaluation

<table>
<thead>
<tr>
<th>Form D Instructor Evaluation Items</th>
<th>In-Class</th>
<th>Web</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall teaching ability?</td>
<td>6.7 (0.5)</td>
<td>6.4 (0.7)</td>
<td>0.012*</td>
</tr>
<tr>
<td>Knowledge of the subject matter?</td>
<td>6.7 (0.5)</td>
<td>6.8 (0.4)</td>
<td>0.83</td>
</tr>
<tr>
<td>Respect and concern for students?</td>
<td>6.9 (0.3)</td>
<td>6.7 (0.5)</td>
<td>0.06</td>
</tr>
<tr>
<td>Rapport with you as a student?</td>
<td>6.7 (0.6)</td>
<td>6.3 (1.0)</td>
<td>0.02*</td>
</tr>
<tr>
<td>Use of technology to enhance your</td>
<td>6.8 (0.4)</td>
<td>6.3 (1.1)</td>
<td>0.03*</td>
</tr>
<tr>
<td>Learning experience in the course?</td>
<td>6.6 (0.7)</td>
<td>5.7 (1.1)</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Success in getting you to think?</td>
<td>6.7 (0.5)</td>
<td>6.5 (0.9)</td>
<td>0.24</td>
</tr>
<tr>
<td>Attention to what helps you learn?</td>
<td>6.5 (0.7)</td>
<td>5.8 (1.4)</td>
<td>0.002*</td>
</tr>
<tr>
<td>Respect for students’ individual</td>
<td>6.6 (0.6)</td>
<td>5.9 (1.4)</td>
<td>0.004*</td>
</tr>
<tr>
<td>Differences?</td>
<td>6.5 (0.6)</td>
<td>6.3 (1.0)</td>
<td>0.62</td>
</tr>
<tr>
<td>Helpfulness of feedback given to</td>
<td>6.7 (0.6)</td>
<td>6.1 (0.9)</td>
<td>0.001*</td>
</tr>
<tr>
<td>you about your performance?</td>
<td>6.7 (0.5)</td>
<td>6.7 (0.5)</td>
<td>0.51</td>
</tr>
<tr>
<td>Clarity in presenting or discussing course material?</td>
<td>6.5 (0.7)</td>
<td>5.2 (1.7)</td>
<td>&lt;0.001*</td>
</tr>
</tbody>
</table>
| Values are means (SD); n, no. of students. Note: All comparisons between student groups on the Form D instructor evaluation were performed with the Mann-Whitney U-test. Scores range from lowest to highest (1–7). *Statistical significance.
identifies potentially confounding factors, such as the students’ previous educational experience, not addressed in previous comparisons of in-class and online course delivery. In this sample, it is unknown if there are large differences in previous course work in biology, chemistry, or introductory physiology that would explain differences in the pretest performance.

A major finding of this study is that students can successfully learn physiology in either a mostly classroom setting or mostly online setting (Table 2). This result confirms the meta-analysis of 51 studies from the health sciences literature by Cook and colleagues reporting that students perform as well online as their peers in traditional lecture settings (3). These results are also consistent with a meta-analysis from the U.S. Department of Education in which they report that the outcomes between online and blended courses are comparable (15).

Student Satisfaction with the Instructor

The second aim of this study was to compare student satisfaction with the instructor to determine whether the instructor made a difference in learning outcomes. The instructor was the same, experienced individual who had taught physiology in previous years of both sections. We also wanted to use this feedback from students to improve future course offerings. Although both sections of students rated the instructor highly, year 1 In-Class students were significantly more satisfied than the Web students with the instructor, as measured by a standardized university evaluation form (Form D). This is an intriguing result, given that both course sections were taught by the same instructor during the same academic term. The same instructor was rated higher by year 1 In-Class students with respect to teaching ability, respect and concern for students, clarity of presentation, use of technology, rapport with students, success in getting students to think, respect for individual differences, and encouragement of students to express alternative views (Table 3). Using technology for learning, getting students to think, and encouraging students to express alternative views are purported advantages of online learning (15).

The course instructor used evaluation comments from year 1 students to revise both sections of the course for the subsequent year. Year 1 Web students reported the perception that the workload was significantly greater than the learning benefit; this was a major source of dissatisfaction. In response, the course instructor decreased the number of discussion assignments from eight to four in year 2. In addition, assignments requiring the students to answer essay questions on their own were eliminated. Four of the year 1 discussion assignments were replaced with narrated power point lectures with quizzes for year 2. This change in assignments not only addressed the comments of the Year 1 Web students about workload, but also addressed student feedback concerning the instructor’s lack of rapport with year 1 Web students. Although the year 1 Web course had a lot of built-in interactivity, the students did not meet the instructor until the first on-campus meeting that took place during the fourth week of the Web class. The addition of online presentations permitted year 2 Web students to hear the instructor’s voice on a regular basis and make a connection with the instructor before the first face-to-face meeting.

One result from this study is that, after the instructor made changes to the web-delivered course based on year 1 student feedback, the satisfaction of the year 2 students improved (Table 3), even as student exam performance was maintained and the pretest-posttest differences improved (Table 2). Web section changes that were implemented based on the previous year’s evaluations appeared to have had a positive impact on student satisfaction.

The investigators have personally observed a greater demand for online courses from administration, faculty, and students. Despite their desire for more online courses, students may not know what to expect from an online course. Students may expect an online course to include lecture videos, for example, and may be disappointed when the online modules do not meet their expectations. In the comment section of the Form D instructor evaluation, two of the year 1 Web students expressed a desire for videotaped lectures. Instructors must address student expectations early in a course, regardless of whether that course is in-class or online (14).

In addition, students who prefer classroom instruction but must take online courses because of scheduling conflicts or because in-class options are not available may be less satisfied with their experience (2). In the present study, 24% of year 1 Web students would have preferred to be in the In-Class section. The inability to provide students with their preferred method of instruction may have influenced the satisfaction results of the year 1 Web students. Instructors are understandably concerned about student satisfaction, given that tenure and promotion decisions are partially based on student evaluations (16).

Strengths and Limitations

Strengths of the present study are the use of a quasi-experimental, pretest-posttest design, the comparison of two sections of an entire 15-wk physiology course using the same curriculum, the same online exams, the same instructor, and the same multiple learning and satisfaction measures. All of these elements helped to reduce the external threats to validity (9). Furthermore, these authors present details about learning practices used in the courses analyzed here; in the literature, there are variable practices in different courses, and it is difficult to make comparisons of published studies on e-learning for which information about specific course practices are unknown (15).

A limitation of the present study includes the inability to randomize students to control and experimental groups. Several of the Web students lived in other states and thus were unable to attend a weekly lecture session. These students had to enroll in the Web section. It is unknown if differences in knowledge outcomes between groups would have been different with a larger sample size. In particular, only 15 students completed student evaluations in the second cohort of Web students and there may not have been enough students to show a significant difference. There may be other moderating variables not accounted for in this study, such as the types of assignments, learning styles of the students, and previously completed course work. Finally, the strongest analysis methods could not be used because of nonnormal distributions of data (9).
Conclusion

The results of the present study contribute to the body of evidence supporting equal learning outcomes for students using online learning methods and improvement of student satisfaction with evidence-based course revisions. Multiple measures of learning outcomes in an entire physiology course are a major strength of this study. Although purely online learning has been shown to be as effective as traditional classroom learning, there appears to be an advantage for learning in a blended environment, which is consistent with the results shown here. However, this mode of delivery makes comparisons of different blended sections difficult (15). Faculty in professional allied health programs must determine the goal of online education. If the goal is to increase the number of students served, then it is important to maintain the quality of instruction as student enrollment increases. If the goal is to promote knowledge acquisition and critical thinking, and both methods are comparable, then educational institutions must also incorporate ways to enhance individual student learning outcomes, regardless of the medium.

Future studies, however, must address more than the average student experience. Learning style, as measured by a validated inventory, culture, major area of study, previously completed course work, and previous experience with online courses, may all influence the learning outcomes of students in online classes. Ultimately, research is needed to examine whether online and online-enhanced education improves the retention of course content and produces allied health professionals who perform as well or better in the clinical arena.

DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the author(s).

AUTHOR CONTRIBUTIONS

L.C.A. conceived and designed research; L.C.A. performed experiments; L.C.A. analyzed data; L.C.A. interpreted results of experiments; L.C.A. prepared figures; L.C.A. drafted manuscript; L.C.A. and K.E.K. edited and revised manuscript; L.C.A. and K.E.K. approved final version of manuscript.

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