The objective of this study was to determine whether students within a large (100–160 students) didactic lecture-based course, “Elementary Physiology” (EP), who were given an active-learning opportunity would perform better on objective examinations over EP material compared with their classroom peers who did not have the same active-learning experience. This was achieved by offering the EP students the option of taking a supplemental one credit hour discussion-based course, “Case Studies in Physiology” (CSP). Approximately 14% of the EP students opted for the CSP course. The format of CSP consisted of a one-hour-per-week discussion of applied problems based on the factual information presented in EP. On a subjective scale of 1 to 4, the CSP students felt that the course helped them to understand the EP material (3.5). This was reflected in the EP examination results for which the CSP students scored significantly higher compared with their non-CSP peers (81.1% vs. 75.7%; \( P < 0.05 \)). These results indicate that when active-learning methods, such as discussion of applied problems, are used as a supplement to didactic lectures in physiology, performance on objective examinations of lecture material is improved.

**Key words:** active learning; case studies; elementary physiology

Educators have shown that learning a scientific discipline, such as physiology, is facilitated when students are actively engaged with the material to be learned (3, 11, 12, 15) and in the process of building their own mental models of the information and concepts being taught (14). However, at present, most elementary physiology courses consist primarily, if not exclusively, of factual information presented by way of didactic lectures usually to large classes (17) with little or no opportunity for students to actively engage the material.

To foster student engagement with course material, a variety of in-class (2, 4, 5, 13, 18, 21) and out-of-class (7, 16) teaching methods and procedures have been devised to enhance active learning in the large class setting. Although subjective evaluation of these methods by students has generally been quite positive, there is a paucity of objective data as to whether or not they improve classroom performance (e.g., test scores). Furthermore, in some studies that have evaluated active learning in terms of classroom performance, methods of teaching and methods of performance evaluation were not always matched. For example, in some cases, a similar evaluation instrument, an objective examination, was used to compare students taught by different methods, problem-based
learning and didactic lectures, whereas in others, such as our previous study, different evaluation procedures, objective examinations and essays, were used to compare students taught by the same method, the didactic lecture.

To address this issue, the purpose of the present study was to compare students given active-learning opportunities with other students in an elementary physiology course designed such that the methods of information delivery (didactic lectures) and the methods of grading students on that information (objective examinations) were the same for both groups. This was achieved by exposing a group of students within a didactic lecture-based elementary physiology course to active-learning experiences outside the lecture setting. These students and their classmates that did not have an active-learning experience attended the same didactic lectures and were evaluated by the same multiple-choice examinations.

METHODS

Educational setting. The educational setting for this study was a one-semester, three-credit-hour didactic lecture-based course titled “Elementary Physiology” (EP). This is an undergraduate introductory survey course in basic human physiology, the prerequisite for which is one semester of college biology. Further characteristics of the EP course are described elsewhere.

The present study spanned two semesters, Fall of 1998 and Spring of 1999. During this time frame, 24% of the EP students were physical education majors, 24% were in a pre-healthcare professions tract, 15% were in the baccalaureate nursing program, and 12% were in a variety of other undergraduate programs. The remaining 25% of the EP students were undeclared as to a major.

During the period of this study, one of us (B. Birge) instructed the EP course in a didactic lecture format. The primary method of performance evaluation for course grades in EP was a series of objective multiple-choice examinations totaling 115 points. In addition, students had the option of earning up to 10 extra-credit points through out-of-class assignments that were designed, administered, and evaluated by the EP instructor (B. Birge). As an example, several of the extra-credit assignments consisted of having the students read a particular chapter in the course text that was on a topic not covered in lecture (e.g., the immune system) and then write up and submit their answers to selected study questions at the end of the chapter. The extra-credit assignments were novel to all students in that they were on topics not covered in either the EP lectures or in the supplemental active-learning experience, described in the following paragraph.

The other author (D. Richardson) instructed a concurrent one-credit supplementary course titled “Case Studies in Physiology” (CSP). This is a nonrequired course that provides an opportunity for the EP students to enhance their learning of physiology by discussing applied problems related to topics being presented in the EP course. During the first class period of EP, students were given information on the nature of the supplemental course (CSP). It was emphasized that CSP is optional and that the course is designed to help students to grasp the material presented in the main course (EP). However, it was stressed that taking or not taking CSP would have no influence on a student’s grade in EP. Students interested in the CSP course were able to add it to their schedules during the first week of the semester.

Enrollments in EP for the Fall ‘98 and Spring ‘99 semesters were, respectively, 100 and 160 students. Corresponding enrollments in CSP were 14 and 22 students (i.e., ~14% of the EP population). Because the key element of the CSP course was class participation, the Spring ’99 class of 22 students was divided into 2 sections of 11 students each, with the same instructor (D. Richardson) for both sections.

The format of CSP consisted of a one-hour-per-week discussion of applied problems in physiology using the guidelines of Davis (6) for conducting discussion groups. The problems were either specific clinical cases or general applications of lecture material. The clinical cases were obtained from a case-studies text that the students purchased. The applied problems, a sample of which is given in Table 1, were designed by the authors (D. Richardson and B. Birge) on the basis of what was emphasized in lecture. The selection of cases and design of problems were such
that those discussed on a given week corresponded to topics presented in the EP course the preceding week.

**Evaluation.** The effectiveness of CSP on student learning in EP was evaluated both objectively and subjectively.

**Objective evaluation** consisted of comparing examination scores in EP between the CSP and non-CSP students. For this purpose, the students were divided into groups in accordance to those who did and those who did not elect to do the extra-credit assignments in the EP course. The following matrix gives the number of students in each of these groups:

<table>
<thead>
<tr>
<th></th>
<th># Students with extra credit in EP</th>
<th># Students w/o extra credit in EP</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSP students</td>
<td>33</td>
<td>3</td>
</tr>
<tr>
<td>Other students</td>
<td>172</td>
<td>52</td>
</tr>
</tbody>
</table>

*not included in data analysis

The reasons we divided the students in accordance to participation in the extra-credit assignments were: 1) doing these assignments may be beneficial in the objective exams, notwithstanding the selection of topics outside those covered in the EP lectures; and 2) there may be motivational differences between students who do and those who do not elect the extra-credit option.

**Subjective evaluation** consisted of a questionnaire administered to the CSP students at the end of the semester. This document asked the students to give numerical ratings to a series of questions concerning the CSP course and its impact on EP. In addition to the questions, students were encouraged to provide their own written comments.

**Data analysis.** Because, as shown above, only three of the CSP students did not elect the extra-credit option in EP, this group was not included in the data analysis. Accordingly, objective analysis consisted of performing a one-way ANOVA on examination scores in EP of the following three groups: 1) CSP students with extra credit; 2) other EP students with extra credit; and 3) other EP students without extra credit. Post hoc comparisons were used to test for significant differences between group means at the $P < 0.05$ level of probability.

Subjective analysis consisted of obtaining average ratings for each item in the student evaluation document for CSP. No additional statistical procedures were performed on these data.

**RESULTS**

**Objective.** Table 2 presents average examination scores in EP for the three groups of students analyzed. Scores of the CSP group (row 1) were significantly higher compared with the non-CSP students who did (row 2) or did not (row 3) elect the extra-credit option in EP. The non-CSP students who elected extra credit scored 3.5% higher compared with students who did not do the extra credit, but the difference was not significant.

**Subjective.** Table 3 gives the results of the student evaluation of CSP. The first three items relate CSP to the main course, EP, whereas items four and five...
relate the CSP course to the students’ general interest in the healthcare profession. The average rating for these first five items ranged between 3.0 (agree) and 4.0 (strongly agree).

The last item in Table 3 gives an overall course rating and indicates that the students thought highly of the CSP course. This was supported by the observation that 26 of the 36 CSP students (72%) submitted written evaluations, and all but three of these contained positive comments. For example, the words “very helpful” appeared in at least 10 of the evaluations and “helped” or “helpful” in another four. Other positive comments such as “. . . instrumental to my understanding . . .,” “. . . helped to apply learning (of physiology) to real-life situations . . .,” and “. . . the course gave me the atmosphere I needed to succeed . . .” were also included. A few students submitted criticisms such as “. . . the workload was a little much for a 1-h course . . .,” “. . . consider making this class pass/fail or lighten the grading . . .,” and “. . . toward the end of the semester, the problem sets required more in-depth knowledge than was covered in the lecture class (EP) . . .” This latter comment, although submitted by only one student, is consistent with the observation that the CSP class, as a whole, gave its lowest rating to the evaluation item dealing with the correlation between the CSP problems and material presented in EP (Table 3, item 3). Nonetheless, the average rating on this item was 3.3 out of a possible 4.0. This means that, as a class, the students agreed that the discussion problems in CSP correlated with EP material, but they did not strongly agree on this point. We do not know why some students may have felt that the CSP problems did not correlate with EP material, but we suspect that it is because these students had very little, if any, prior experience with courses focused on applied problems. Regardless of reason, the relatively low rating of this item suggests that instructors should take care to point out connections between applied problems and lecture material, because these connections may not always be obvious to students.

**DISCUSSION**

Educational methods that provide students with the opportunity to become actively engaged with the material to be learned have become well-established alternatives, as well as adjuncts, to the classic didactic lecture at all levels of education. The one aspect that the various active-learning methods have in common is that they are highly valued by participating students (1, 2, 7, 16, 20), and present results are in agreement with this observation (Table 3). However, as pointed out in the introduction, there is a relative paucity of information as to the effects of active learning on indices of student performance, such as objective examinations. Furthermore, what information is available on this point is equivocal.

The present study was designed to determine whether students within a didactic lecture-based course, EP, who were given an active-learning opportunity, would perform better on objective examinations over EP material compared with their classroom peers who did not have the same active-learning experience. This was achieved by offering the EP students the option of taking a supplemental one-credit-hour discussion-based course, CSP. In two successive semesters, ~14% of the EP classes opted for the CSP course.

The main finding of the present study is that the CSP students did perform significantly better in EP examinations compared with their non-CSP peers (Table 2). On the surface, these results seem to contradict those of other studies that suggest that active learning does not significantly improve scores on objective
examinations. For example, medical students at several universities who went through a preclinical problem-based curricula did not score better on the NBME Part I examination compared with students from lecture-based curricula (1, 8, 10, 20). However, in these studies, active-learning procedures (e.g., problem-based learning) replaced the conventional lecture setting. In contrast, the results of the present study indicate that when active learning is used as a supplement to, rather than a replacement of, the didactic lecture, performance on objective examinations is improved (Table 2).

The results of the present study are similar to those of Chu (5) who used in-class case studies to supplement didactic lectures in a course on epidemiology and biostatistics. He found a significant ($P = 0.01$) increase in overall examination scores of the active-learning students. In other studies, Anderson (2) found a “shift to the left” in the grade distribution (i.e., more As and Bs) of a large-class environmental science course when the students were given supplemental active-learning experiences. Students at Sun Yat-sen University, People’s Republic of China, who used self-directed learning to supplement lectures, scored the same or significantly higher on examinations in 15 different courses compared with their peers who did not participate in the lecture supplement (21).

It could be argued that the higher EP examination scores of the present CSP students were not related to any active learning on their part, but rather that their improvement was simply due to an additional hour of instruction per week. We were able to examine this possibility in a serendipitous manner during a recent semester for which it was not possible to divide the CSP class into small discussion groups because of scheduling problems. For this one semester, the CSP class was conducted in a large-group (20 students) format in which classroom discussion comprised only 20% of a students grade. Attendance and brief written assignments made up the remainder of the grading criteria. In essence, this class was more like a 1-h review session than a problem-discussion class. The results of this one semester experience showed no significant difference in EP examination scores between the CSP and non-CSP students (77.7% vs. 75.9%; $P > 0.56$). Although these results are preliminary, they clearly suggest that active participation, above occasional discussion and providing brief written answers to problems, is necessary for students to significantly benefit from a supplemental class experience such as CSP. In this context, active participation on the part of students seems to be the common factor in other supplemental procedures that have been shown to assist in learning (2, 5, 21).

Because the students in the CSP course were self selected, it could be argued that their higher examination scores in EP reflected motivation factors unrelated to the supplemental course. However, the categorization of student groups in accordance to those that elected to do extra-credit assignments in EP should have, at least in part, equalized motivational factors between the CSP (Table 2, row 1) and non-CSP (Table 2, row 2) students. Furthermore, a previous study (10) showed no significant difference in scores on a standardized objective examination between students who were randomized into an active-learning curriculum and students who self selected this curriculum. Finally on this point, the present CSP students perceived that this course did help them to understand physiology (Table 3). So, whereas motivation may have played some role in the higher examination scores of the CSP students, it is unlikely that this was the determining factor.

From the results of the present study, vis-a-vis other evidence in the literature, we conclude that information recall on course examinations in elementary physiology is enhanced when active learning is used in addition to, as opposed to in lieu of, didactic lectures. Accordingly, we recommend that physiology instructors who use the didactic-lecture method as their mainstay of information delivery consider supplementing lectures with one or more active-learning methods designed for the large class setting (2, 4, 5, 7, 11, 13, 16, 18, 21).

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