Comparing biology majors from large lecture classes with TA-facilitated laboratories to those from small lecture classes with faculty-facilitated laboratories

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Goodman, Barbara E., Karen L. Koster, and Patrick L. Redinius. Comparing biology majors from large lecture classes with TA-facilitated laboratories to those from small lecture classes with faculty-facilitated laboratories. Adv Physiol Educ 29: 112–117, 2005; doi:10.1152/advan.00054.2004.—The teaching faculty for this course sought to address their own concerns about the quality of student learning in an impersonal large lecture biology class for majors, the difficulties in getting to know each student by name, and difficulties in soliciting answers and reactions from the students during the lecture. Questions addressed by this study were, Do active-learning activities in a small and personal lecture setting enhance student learning more than active-learning activities in large impersonal lectures? and Are students more satisfied with an educational experience in a small and personal lecture setting? Based on faculty perceptions of how they best relate to their students, the prediction was that the students in the experimental group with small lecture classes and increased direct contact with the teaching faculty would learn physiological principles better than the students in the control group in the large impersonal lecture portion of the course. One of the laboratory sections of this large enrollment biology course was randomly selected to be taught with separate small lectures by the teaching faculty. In addition, the teaching faculty participated in the laboratory with these students during their experiments correlated with the lecture material. The students in both groups were compared by pre- and posttests of physiological principles, final course grades, and class satisfaction surveys.

student learning; active learning

BIOLOGY 164 (Principles of Organismal Physiology) has been one of the four core courses required for biology majors at the University of South Dakota since the inception of the new biology core curriculum in the fall semester of 2000. Biology 164 is taught during the spring semester generally to first- and second-year undergraduate students who have just completed Biology 163 (Principles of Cellular and Molecular Biology). Many of the students have also completed Biology 161 (Principles of Genetics and Evolution) and Biology 162 (Principles of Organismal Diversity and Ecology); however, students who are premeds but not biology majors are not required to take the 161 and 162 courses. Most of the students enrolled in Biology 164 have either completed one or two semesters of general chemistry, and some may be enrolled in organic chemistry. Since the Department of Biology has the highest number of undergraduate majors in the College of Arts and Sciences at the University of South Dakota, the annual offerings of Biology 164 have attracted between 75 and 150 students. The course is taught via three 50-min lectures to the entire group of students and an up to 3-h laboratory session with fewer than 24 students each week. The lab sessions are taught by biology graduate teaching assistants (TAs) with support from an upper-level biology undergraduate teaching intern. The lecture hall seats ~300 students in a theatre-style classroom with a front podium, computer, and data projector and two aisles. It is not possible for an instructor to walk between the rows of students while they are seated at the desks.

The teaching faculty for this course (B. E. Goodman and K. L. Koster) sought to address their own concerns about 1) the quality of student learning in the impersonal large lecture classroom, 2) difficulties in getting to know the students by name, and 3) getting answers and reactions from the students during the lecture time by designing an educational experiment with potential for statistical significance that could be implemented with an appropriate control group. P. L. Redinius served as the consultant for the initial experimental design and the statistical analysis. Large lecture classes (130–200 students) with weekly laboratories are the norm at this institution for the four introductory courses for biology majors (Biology 161 through 164) and the general education courses for nonmajors (Biology 101 and 103). Thus the questions addressed by this study were, Do active-learning activities in a small and personal lecture setting enhance student learning more than active-learning activities in large impersonal lectures? and Are students more satisfied with an educational experience in a small and personal lecture setting? Based on faculty perceptions of how they best relate to their students, the prediction was that the students in the experimental group with small lecture classes and increased direct contact with the teaching faculty would learn physiological principles better than the students in the control group in the large impersonal lecture portion of the course.

At the time of this educational experiment, B. E. Goodman was teaching the animal physiology portion of Biology 164 for the third time and K. L. Koster was teaching the plant physiology portion for the second time, although she taught the same material in the previous version of the general biology course for 7 yr. Both Goodman and Koster are experienced teachers and tenured faculty members at the University of South Dakota. The animal physiology portion is ~75% of the course time, is taught as a broad survey of the general principles of physiology via an overview-style systems approach, and has laboratory activities closely correlated with the lecture material. The plant physiology portion is ~25% of the course time, addresses general principles of plant physiology stressing sim-
ilarities and differences between plant and animal physiology, and also has laboratory activities designed to correlate well with the lecture material. The textbook used for the course was *Life: The Science of Biology* (4).

The course philosophy is introduced to the students on the first day of class as a team effort among the students, faculty, and TAs to improve student learning of physiological principles. The faculty members encourage students to ask or e-mail questions at any time. To enhance student learning, various individual and group activities are incorporated throughout the course. These activities have included (see Fig. 1 for some examples) 1) think-pair-share activities during lecture time; 2) an individual report with references about a specific cardiovascular or respiratory disease; 3) formative assessment activities that include writing a question or an answer about the material, stating what was clear/not clear, or writing what new information was learned; 4) case studies during lecture with questions and the answers solicited from the students; and 5) designing, running, interpreting, and presenting a cooperative group experiment to investigate human physiology using the Biopac instruments in the laboratory.

Although attendance is not routinely taken in the lecture classroom, students are highly encouraged to attend lecture, and the answers to the classroom activities (that are testable) were not available to them outside of lecture. Several of the formative assessment activities are used as random attendance checks by having the students write their names on the cards on which they wrote their questions, comments, or answers. Attendance in the laboratory is taken as required by the Department of Biology. Examinations in the course are designed to be 60–70% multiple choice questions that mostly test Bloom’s taxonomy levels of knowledge and comprehension and 30% short discussion questions that are likely to test higher levels of Bloom’s taxonomy (analysis, synthesis, and evaluation). Multiple choice questions are computer-graded and the short discussions are generally graded by the teaching faculty with some assistance by the TAs using a grading rubric. The course objectives for Biology 164 are 1) students will be able to understand and interpret the general principles of physiology; 2) students will compare and contrast the basic concepts of animal physiology with those of plant physiology; 3) students will recognize the physiological and pathophysiological relevance of various systems to organismal life and success; and 4) students will develop and use the scientific method in a collaborative group via the Biopac research project.

In a recent publication, Cuseo (1) has synthesized research that relates to the consequences of large class size on teaching, learning, and retention to evaluate its implications for the success of undergraduate students (particularly first year students). According to Cuseo, there are at least eight deleterious outcomes of teaching students in large-sized classes. These include 1) increased faculty reliance on lecture; 2) less active student involvement; 3) reduced frequency of instructor interaction with and feedback to the students; 4) lower depth of student thinking while in class; 5) lower Bloom’s taxonomy level of learning objectives and learning strategies; 6) lower levels of academic achievement of students; 7) lower level of course satisfaction with learning; and 8) lower student evaluations at the end of the course. Some of these proposed outcomes have been partially addressed by our study and will be discussed later.

**METHODS**

During the Spring 2003 offering of Biology 164, an educational experiment was designed and implemented to evaluate whether the active-learning activities used in the course would be more effective for student learning in the large lecture class format or in a separate small lecture class. Thus one of the laboratory sections (Tuesday afternoon with 20 students, 18 of whom participated in the experiment, including 1 who did not complete the posttest and satisfaction survey due to illness) was randomly selected at the beginning of the course to be the experimental group and the rest of the class was the control group (with 87 students who began and completed the course). The experimental group signed consent forms for the Institutional Review Board-approved exempt experiment entitled “Active Teaching of Biology in Small vs. Large Class Settings.” One student in the experimental group had separate lecture times (taught by the same faculty members) and the teaching faculty participated with them in all laboratory activities with the assistance of one of the biology graduate TAs. The separate lecture times were chosen based on the students’ schedules and consisted of the first hour of the laboratory time on Tuesday afternoons and two 50-min lectures from 5:00 to 6:00 PM on Wednesday and Thursday afternoons. The students in the

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**LEARNING OBJECTIVES FOR RESPIRATORY SYSTEM**

1. Compare and contrast the advantages and disadvantages of breathing air vs. breathing water.
2. Use examples from several different types of organisms, describe how the respiratory system is designed for its primary function.
3. Describe what happens during inspiration and expiration in mammals.
4. Be able to explain how air flow is affected by changes in pressure and changes in resistance and which types of lung diseases affect lung function and why.
5. Explain why premature babies have trouble breathing (lack of pulmonary surfactant).
6. Interpret how the oxygen-hemoglobin dissociation curve indicates the total amount of oxygen available to the tissues at various metabolic levels.
7. Diagram the feedback loops most commonly used to regulate breathing in a mammal including the sensor, effectors, and integrators.

**THINK-PAIR-SHARE ACTIVITIES**

1. Compare and contrast the use of calcium for the action potentials of contractile cardiac muscle cells (excitation) and the contraction of the same cells (excitation-contraction coupling).
2. You are hiking alone in Yellowstone when you go around a curve on the trail and almost run into a huge mother grizzly bear and her two cubs. What will happen to your heart rate, stroke volume, and cardiac output? How is this accomplished?
3. Take a couple of minutes to think about how a room thermostat works and how that would be similar to a physiological reflex loop. Pair up with a neighbor and discuss your ideas. Several groups will be asked to share their ideas with the class.
4. The cessation of reproductive cycles in women is known as menopause. Do men as they age have something similar happening to them like this? What is your evidence?
5. How do birth control pills work? Is there negative feedback involved?
6. Carbon monoxide binds to the oxygen sites on the hemoglobin molecules more than 200 times more avidly than oxygen does. If one is breathing some carbon monoxide in the air, what happens to the oxygen levels in the body? What happens to breathing?
7. What does narrowing of the airways do to the resistance of the airways to air flow?

**MINI CASE STUDIES**

I prefer to use the running problems that are disease-based and accompany each chapter in Silverthorn (5).

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**Fig. 1.** Sample learning objectives and active-learning activities used during the course.
How We Learn

CLASS SIZE AND BIOLOGY STUDENTS

BIOLOGY 164
PRINCIPLES OF ORGANISMAL PHYSIOLOGY
SPRING 2003

NAME

1. All of the following ion movements across membranes would tend to hyperpolarize (make the potential difference more negative) the neuron except:
   A. sodium (Na⁺) ions leaving the neuron; B. potassium (K⁺) ions leaving the neuron; C. calcium (Ca²⁺) ions being pumped back into the sarcoplasmic reticulum; D. orkides (Cl⁻) ions leaving the neuron; E. bicarbonate (HCO₃⁻) ions entering the neuron
   For the following question, choose the correct order of steps for the function described. Some steps might be left out.
   For question 2:
   1. voltage-gated calcium channels open; 2. action potential arrives at the axonal terminal; 3. neurotransmitter is released by exocytosis into the synaptic gap; 4. neurotransmitter is reabsorbed by the axonal terminal; 5. calcium ions enter the neuron
   2. For what happens at the axonal terminal of a neuron, what is the order of steps?
   A. 2, 3, 15, 6, 2, 4, 3, 1, 5, 4, 2, 3
   3. Plants often use changes in day length (photoperiod) to trigger events such as dormancy and flowering. It is logical that plants have evolved this mechanism because photoperiod changes
   A. are more predictable than air temperature changes; B. alter the amount of energy available to the plant; C. are modified by local temperature changes; D. are independent of the biological clock; E. depend on moisture availability
   4. Which of the following would lead to increased resistance to blood flow in a blood vessel?
   A. a shorter pathway for flow; B. loss of plasma (water) from the bloodstream; C. a wider blood vessel; D. multiple branches for the flow to enter; E. none of the above
   5. Which type of gastrointestinal function is most likely controlled by the sympathetic nervous system (left or right system)?
   A. secretion of juice; B. peristaltic waves; C. rhythmic segmentation; D. constriction of sphincter muscles; E. activation of enzymes
   6. Why do blood cells normally stay inside the capillaries?
   A. They are attached to the capillary walls; B. They don’t ever get into the capillaries; C. They are too big to cross the capillary walls; D. They are kept inside the capillary by an electrical attraction; E. They move so fast through the capillary that there is no time to leak out.

Take time to reflect, then write your best answer. You may write on the backs of any pages. Brief answers are all that are required.

7. How does a lizard regulate its body temperature? What is your evidence?
8. Why is the pituitary gland sometimes called the “master gland”?
9. Why does someone with untreated diabetes mellitus need to urine frequently?
10. Where would you find receptors for water-soluble hormones in cells? Where would you find receptors for lipid-soluble hormones? Justify your answer.
11. Using physiological examples, briefly describe the differences between negative and positive feedback loops. What are the advantages of each?
12. What are the advantages of having a four-chambered heart? What evidence led you to this answer?

Fig. 2. Questions used for the pre- and posttest examinations (the same questions) for all students at the beginning and end of the course with no discussion or grading in between.

experimental group wore name tags for a short time at the beginning of the course until they could be identified by the faculty member and were called on by name in class. However, the same lecture material and the same active-learning activities were used in the small separate lectures and in the large lecture class. The most common kinds of active learning exercises used in both lectures were think-pair-share activities; open-ended questions; and minicase studies with open-ended questions. In addition, handouts were available to both groups of students with the individual student learning objectives for each chapter listed (for example, see Fig. 1), and the PowerPoint presentations of graphs and figures used during the lecture time were available to all students via web access. Sometimes the first offering of the lecture was to the experimental group and sometimes it was to the control group depending on the day of the week.

Students in both groups were given a pretest of comprehension-level multiple choice and essay-type questions about physiological principles during the first laboratory of the course and a posttest of the same questions during the last laboratory of the course (see Fig. 2 for the entire 12-question test). Tests were not graded and returned to the students after the pretest, and there was no direct discussion of the test material during the course. Tests were graded by B. E. Goodman after the completion of the course using a grading sheet for the multiple choice questions and a rubric for the essay questions. Neither the identity of the student nor whether the test was the pretest or the posttest was known when the essay questions were graded. Since the pre- and posttests were identified with the names of the students (on the front of the test but not on the part that was hand graded), a comparison of group mean changes in pre- vs. posttest scores and correlation with course final grades were both possible. In addition to the pre- and posttest analysis of student learning, students in both groups were asked to fill in a custom-designed class satisfaction survey with questions using a Likert scale (scale of 5 choices for each answer) for answers. The class satisfaction survey (see Fig. 3 and Table 1) was designed by B. E. Goodman with the assistance of P. L. Redinius who served as the educational psychology and statistical consultant. Data were collected from pre- and posttest scores, student final course scores, and the 24-item, 5-point Likert course satisfaction surveys.

RESULTS

The purpose of the data collection was to compare both student learning and student satisfaction with the small vs. the large lecture formats, both of which incorporated active learning components. First, the student knowledge results will be reported followed by student satisfaction.

Group means were calculated for pretest, posttest, and for final course scores. Table 2 shows the results.

The group means on the pretest indicate the entering knowledge of the experimental small class group may have been slightly higher than for the control large lecture group. The posttest scores are nearly identical for both the experimental and control groups, demonstrating that the post-
test may not have been robust enough to detect differences in group performance or that there were no differences. The final course grades did show an increase in mean score of the experimental group over the control group.

A one-way ANOVA was calculated to determine the contribution of group membership to pretest scores, posttest scores, and final course grades. Table 3 shows there was not a statistically significant difference between group means in the posttest scores. The \( P \)-values approached significance in detecting differences in course grade and pretest scores. Thus experimental small class group success in the course grade cannot be confidently attributed to the intervention.

The student satisfaction survey (Fig. 3) addressed such issues as clarity of course objectives, handouts, laboratory, Biopac experiments, treatment of the students, and overall impressions of the course. A \( \chi^2 \) analysis was conducted to identify which satisfaction scale items demonstrated a difference between the control large lecture and the experimental small class groups (see Table 1). This section will begin with the satisfaction scale items rated statistically significantly higher by the experimental group, followed by the satisfaction survey items rated statistically significantly higher by the control group.

The survey items with statistically significant differences that were scored higher by the experimental small class group include:
1. “The number of students in the lecture portion of the course was distracting to my learning.” \( (P < 0.01) \),
2. “The number of students in the laboratory portion of the course was distracting to my learning.” \( (P < 0.01) \),
3. “Conducting experiments and preparing laboratory reports helped me to learn about the scientific method and to apply physiological concepts.” \( (P = 0.014) \).

One satisfaction survey item was rated statistically significantly higher by the large lecture control group, “The number of students in the lecture portion of the course was distracting to my learning.” \( (P < 0.01) \).

Table 1. Mean, standard deviation, and \( \chi^2 \) results for the satisfaction survey by group

<table>
<thead>
<tr>
<th>Survey Question</th>
<th>Control</th>
<th>Experiment</th>
<th>( \chi^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>The course objectives were clearly stated.</td>
<td>4.35 ± 0.58</td>
<td>4.58 ± 0.51</td>
<td>2.55 ± 0.28</td>
</tr>
<tr>
<td>The course was organized well.</td>
<td>4.17 ± 0.69</td>
<td>4.32 ± 0.48</td>
<td>3.22 ± 0.36</td>
</tr>
<tr>
<td>The handouts and audiovisual materials were useful to my learning.</td>
<td>4.21 ± 0.67</td>
<td>4.16 ± 0.60</td>
<td>0.69 ± 0.88</td>
</tr>
<tr>
<td>The laboratories helped me to understand the major concepts of physiology.</td>
<td>4.02 ± 0.72</td>
<td>3.95 ± 0.91</td>
<td>3.83 ± 0.43</td>
</tr>
<tr>
<td>The questions asked during lecture helped me to think about physiological concepts.</td>
<td>4.14 ± 0.73</td>
<td>4.05 ± 0.62</td>
<td>1.43 ± 0.69</td>
</tr>
<tr>
<td>The questions and think-pair-share activities helped me to understand the major concepts of physiology.</td>
<td>4.29 ± 0.75</td>
<td>4.42 ± 0.51</td>
<td>2.02 ± 0.73</td>
</tr>
<tr>
<td>The mini-case studies during class helped me to understand the relevance of physiological concepts.</td>
<td>4.34 ± 0.70</td>
<td>4.42 ± 0.61</td>
<td>0.56 ± 0.90</td>
</tr>
<tr>
<td>The number of students in the lecture portion of the course was appropriate for learning.</td>
<td>3.65 ± 0.94</td>
<td>4.74 ± 0.45</td>
<td>27.70 ± 0.00</td>
</tr>
<tr>
<td>The number of students in the laboratory portion of the course was appropriate for learning.</td>
<td>4.35 ± 0.57</td>
<td>4.63 ± 0.60</td>
<td>7.14 ± 0.01</td>
</tr>
<tr>
<td>Conducting experiments and preparing laboratory reports helped me to learn about the scientific method and to apply physiological concepts.</td>
<td>3.78 ± 0.76</td>
<td>4.16 ± 0.96</td>
<td>3.83 ± 0.27</td>
</tr>
<tr>
<td>The development of the Biopac experiments helped me to understand the major concepts of physiology and the scientific method.</td>
<td>3.41 ± 0.76</td>
<td>3.63 ± 0.83</td>
<td>3.62 ± 0.46</td>
</tr>
<tr>
<td>The preparation of the poster for the Biopac experiments helped me to understand how scientists communicate.</td>
<td>3.33 ± 0.99</td>
<td>3.79 ± 0.79</td>
<td>3.87 ± 0.42</td>
</tr>
<tr>
<td>Comparisons of animal and plant strategies for living helped me to understand major concepts of physiology.</td>
<td>3.94 ± 0.76</td>
<td>3.95 ± 0.91</td>
<td>1.29 ± 0.52</td>
</tr>
<tr>
<td>The course challenged me intellectually.</td>
<td>4.33 ± 0.54</td>
<td>4.47 ± 0.51</td>
<td>3.06 ± 0.54</td>
</tr>
<tr>
<td>The exams evaluated how well I understood the material.</td>
<td>3.80 ± 1.10</td>
<td>4.17 ± 0.51</td>
<td>6.68 ± 0.71</td>
</tr>
<tr>
<td>The professors displayed a thorough knowledge of the subject matter.</td>
<td>4.63 ± 0.55</td>
<td>4.68 ± 0.48</td>
<td>3.96 ± 0.27</td>
</tr>
<tr>
<td>I felt that my professors wanted to help me to learn physiology.</td>
<td>4.37 ± 0.78</td>
<td>4.74 ± 0.45</td>
<td>2.17 ± 0.54</td>
</tr>
<tr>
<td>I felt comfortable contacting my professors about the course.</td>
<td>4.07 ± 0.87</td>
<td>4.37 ± 0.68</td>
<td>1.54 ± 0.46</td>
</tr>
<tr>
<td>The students were treated with respect.</td>
<td>4.47 ± 0.61</td>
<td>4.63 ± 0.50</td>
<td>1.42 ± 0.38</td>
</tr>
<tr>
<td>The number of students in the lecture portion of the course was distracting to my learning.</td>
<td>2.50 ± 0.97</td>
<td>1.53 ± 0.61</td>
<td>24.70 ± 0.00</td>
</tr>
<tr>
<td>The number of students in the laboratory portion of the course was distracting to my learning.</td>
<td>1.95 ± 0.80</td>
<td>1.58 ± 0.61</td>
<td>3.83 ± 0.43</td>
</tr>
<tr>
<td>This was a worthwhile course.</td>
<td>4.19 ± 0.79</td>
<td>4.53 ± 0.61</td>
<td>4.09 ± 0.25</td>
</tr>
<tr>
<td>I would recommend this course to others.</td>
<td>4.07 ± 0.78</td>
<td>4.37 ± 0.76</td>
<td>4.64 ± 0.33</td>
</tr>
<tr>
<td>Overall, this course was a valuable learning experience for me.</td>
<td>4.18 ± 0.69</td>
<td>4.53 ± 0.51</td>
<td>4.64 ± 0.33</td>
</tr>
</tbody>
</table>

CV, coefficient of variation.
How We Learn

CLASS SIZE AND BIOLOGY STUDENTS

Table 3. ANOVA analysis of group means for pretest, posttest, and course grade

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between groups</td>
<td>70,228</td>
<td>1</td>
<td>70,228</td>
<td>2.669</td>
<td>0.11</td>
</tr>
<tr>
<td>Within groups</td>
<td>2,709.779</td>
<td>103</td>
<td>26.309</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>27,800.007</td>
<td>104</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Posttest</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between groups</td>
<td>0.641</td>
<td>1</td>
<td>0.641</td>
<td>0.023</td>
<td>0.88</td>
</tr>
<tr>
<td>Within groups</td>
<td>2,824.808</td>
<td>103</td>
<td>27.425</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>2,825.448</td>
<td>104</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Course grade</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between groups</td>
<td>258.999</td>
<td>1</td>
<td>258.999</td>
<td>3.137</td>
<td>0.08</td>
</tr>
<tr>
<td>Within groups</td>
<td>8,504.115</td>
<td>103</td>
<td>82.564</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>8,763.114</td>
<td>104</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

There was no statistical significant difference between group means in the posttest scores. P values approached significance in detecting differences in course grade and pretest scores.

DISCUSSION

The experimental small class group was randomly chosen based on those students who signed up for a particular laboratory session before the first day of the course. It is possible, based on pretest scores and final course grades, that the average Tuesday afternoon laboratory student was a stronger (or weaker) student than the average student in the large lecture class. There is no known reason why this would be the case, but potential conflicting classes may have had an impact on a student’s choice of laboratory time. However, the differences in pretest and posttest scores did not reach a level of statistical significance between groups. If the intervention of the small class group with personal attention from the teaching faculty had improved student learning, one would expect that both posttest scores and course grades might be significantly higher for the experimental group. Thus, at least in this introductory biology course taught with many active learning opportunities, a small-size lecture class and personal attention from teaching faculty did not significantly improve student learning.

The student satisfaction surveys did find some significant differences between the experimental small class group and the large lecture control group. More students in the experimental group thought that the number of students in the lecture portion of the small class was appropriate for learning and more students in the control group thought that the number of students in the lecture portion of the large class was distracting to learning. Thus the students did appreciate being in a smaller class to learn even if there was no evidence that their learning was actually enhanced by being in the smaller class. It is interesting to note that students in the experimental group appreciated learning about scientific method and applying physiological concepts that they achieved by conducting experiments and preparing laboratory reports significantly more than the students in the control group. An explanation for this difference could be that having the expert teaching faculty facilitating their work in the laboratory might have helped them understand physiological concepts better than having only a biology graduate TA in the lab. If simply being in the small lecture/laboratory with the teaching faculty did help them learn better (as they perceived), then the assessment tools used in the course must not have accurately evaluated enhanced long-term student learning. The number of students in the laboratory portions of the course were not very different, with 20 students in the experimental lab (only 18 were in the separate lectures due to scheduling conflicts) and a range of 9 to 18 students in the labs for the control group in the large lecture portion of the course. Thus it is difficult to explain why students in the experimental group appreciated the size of enrollment in their laboratory significantly more than the students in the control group.

Literature about the effects of class size in college courses on student learning and student preferences for courses highlights some interesting aspects. Litke (3) reviewed the literature on teaching and learning in large college classes and investigated student attitudes toward effective and ineffective teaching strategies in the large classes. The author states that many faculty members believe that increased class size equals decreased student learning and satisfaction. However, student views of large classes may differ from faculty perceptions. Students state that the quality of instruction (not the size) determines a successful class and that a good teacher can teach any size class (3). A second perception is that large classes need to be taught differently than small classes (3). To address this perception, Litke provides suggestions to faculty to make large classes “feel smaller.” A final perception of faculty is that student ratings of instructors are lower in large classes; however, this perception is not necessarily true (3). Thus according to Litke, five key areas of concern about large classes are: their impersonality, the extent of active learning, how to solicit class participation, effects on student evaluation, and predominant reliance on lectures. All five of these areas are addressed in the article with helpful suggestions. In addition, student views on teaching and learning in large classes were solicited via surveys from 134 students in a course on communication theory at California State University at Northridge (Northridge, CA) (3). There was a clear preference among the students for smaller classes, but 33% of the students were favorable to large classes. Students reported that they can learn in large classes and that quality teaching is possible in large classes with numerous active and engaging learning opportunities.

Williams et al. (7) published an extensive meta-analysis of student performance on objectively scored general education tests compared with section size for 305 sections from 24 different courses with section sizes of 13 to 1,006 students at Brigham Young University. Only courses that met in a regular lecture format and had a common test across sections were included in the study. Fifteen different content areas were represented, and student performance on 16,230 tests was analyzed. Their results suggested that for college-level students, class size may have less effect on student learning than thought by some faculty. The data indicated that increasing class size from 30 to 40 to several hundred did not affect
college student achievement. However, the authors did question whether there was a possibility that class size has less impact on student recall of facts than on student development of thinking and problem-solving skills. This possibility was not investigated or analyzed by the authors (7).

Other studies have analyzed college student preferences for small vs. large classes and how those preferences affect student ratings of faculty. Many faculty and departments feel that undergraduate students need to experience small classes sometime during their academic training; thus generally after the anonymity of the large first- and second-year classes, upper-division students take smaller classes. Feigenbaum and Friend (2) compared student preferences for small vs. large psychology classes at State University of New York at Stony Brook (Stony Brook, NY). They asked first-year compared with upper division students to state preferences for 16 class structures that differed in class size (small with discussion or large without), workload (moderate or heavy), type of exam (multiple choice or essay), and average grade in class (C or B). They found that students taking large classes generally adapt to them and prefer them to small classes. In fact, in their study, upper-division students preferred classes with moderate workloads and easier grading, implying that workload and a good GPA become more important as students advance. Thus their results essentially contradicted the way courses are normally taught at the college level in that first-year students preferred small classes and upper-division students preferred large classes (2). While this may be an approach to education for numerous students, our goals have always been to interest students in lifelong learning and to help students learn physiological concepts by understanding instead of memorizing.

Toby (6) studied chemistry students in small vs. large classes at Rutgers (New Brunswick, NJ) to see if class size was related to student evaluations of faculty. Students' (>35,000) overall ratings of instructors from 420 classes taught by 36 different professorial chemistry faculty over a 5-yr period were analyzed compared with class sizes that varied from a few to several hundred students. The student pool included majors and nonmajors, first-year students through seniors, and graduate students. For 25 faculty, the larger the class, the lower the instructor ratings; for 8 faculty, instructor ratings were independent of class size; and for 3 faculty there was no correlation between instructor rating and any tested variable. Thus class size was important for student ratings of some faculty and was irrelevant for others. Toby also noticed a time effect on instructor ratings for the teaching of several faculty in several large courses, indicating that teaching large classes successfully might require skills that some instructors have developed early in their careers and that others require more time to develop (6).

To evaluate agreement or disagreement between this study and the deleterious outcomes of large class size teaching proposed by Cuseo (1), we will clarify for which outcomes there may be new information from our study. In our study, comparing small vs. large classes for Cuseo's eight deleterious outcomes reveals that increased faculty reliance on lecture–our lecture component was the same; 2) less active student involvement—of all of our students do small group think-pair-share activities, etc.; 3) reduced frequency of instructor interaction with and feedback to the students–TAs interact with both groups of our students but teaching faculty provide more face-to-face feedback to those in the experimental group; 4) lower depth of student thinking while in class—higher level active-learning activities found in both classes (but students may feel more or less vulnerable in the small class); 5) lower Bloom's taxonomy level of learning objectives and learning strategies—our course and system learning objectives are mostly at the comprehension level or higher (see Fig. 1), student study strategies were not evaluated; 6) lower levels of academic achievement of students—the mean course grades were the same; 7) lower level of course satisfaction with learning—our students in the small class appreciated the value of fewer students and our students in the large class thought there were distractions in the lecture hall; and 8) lower student evaluations at the end of the course—this aspect was not evaluated using the standard University course evaluation forms; however, there were no significant differences in this on the custom-designed class satisfaction survey. Based on his analysis of the literature, Cuseo (1) discusses how to provide more effective education to today's undergraduates; what an optimal class size is; how administrative decision making can take into account enhancing student learning by providing a variation of class sizes to each student each term; providing instructional delivery resources to maximize small group and individual learning opportunities to students in large classes; and how institutional mission, priorities, and values might need to be readjusted to value teaching that enhances student learning.

In our study, the teaching faculty used the same lectures and the same active-learning activities in both the large lecture class with small separate laboratory sections taught by graduate TAs and the small group lecture/lab classes taught by a graduate TA assisted by the teaching faculty. Our results indicate that while the students may have appreciated that the size of the small class was appropriate for learning and the size of the large class was distracting to learning, there were no significant differences in either pre- vs. posttest results or course grades for the students in the experimental group compared with those in the control group. This could either mean that with active learning techniques, large lecture classes can “feel smaller” and thus enhance student learning just as well as small, personal classes, or that we studied the wrong parameters to identify differences in long-term understanding of physiological principles.

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REFERENCES