STUDENT RETENTION OF COURSE CONTENT IS IMPROVED BY COLLABORATIVE-GROUP TESTING

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We recently reported that collaborative testing (i.e., group test taking) increased student performance on quizzes. It is unknown, however, whether collaborative testing improves student retention of course content. Therefore, this study was designed to test the hypotheses that collaborative-group testing improves student retention of course content. To test this hypothesis, our undergraduate exercise physiology class of 38 students was randomly divided into two groups: *group A* ($n = 19$) and *group B* ($n = 19$). During *exam 1*, students from both groups answered questions in the traditional format as individuals. Immediately after completing the exam as individuals, students from *group A* answered a randomly selected subset of questions from *exam 1* in groups of two (1 group had 3 students) to test the effectiveness of collaborative-group testing on test performance and level of student retention. On the next exam (*exam 2*, 4 wk later), students from both groups answered questions in the traditional format as individuals *and* responded to the same subset of questions from *exam 1*. The subset of questions was analyzed to determine the level of retention of the original test material. In addition, immediately after completing the exam as individuals, students from *group B* answered a randomly selected subset of questions from *exam 2* in groups of two (1 group had 3 students). Finally, on the next exam (*exam 3*, 4 wk later), students from both groups answered questions in the traditional format as individuals *and* responded to the same subset of questions from *exam 2*. This protocol followed a randomized crossover design to control for time and order effects. Student retention of course content was reduced when students completed the original examinations individually. In sharp contrast, student retention was improved ($P < 0.05$) when students completed the original examinations in groups. Results suggest that collaborative testing is an effective strategy to enhance learning and increase student retention of course content.

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Richardson (8) recently reported that, compared with naive students, experienced students who had completed an elementary physiology course did not have a greater knowledge level of physiology or perform better in an upper-division physiology course. In short, a previous course in physiology did not en-

hance performance on a precourse test or on a postcourse test (8). These results document that student retention of course content is short-lived. Importantly, we (7) recently reported that collaborative testing (i.e., group test taking) increased student performance on quizzes. Specifically, performance on quizzes was significantly higher when students completed the quizzes in groups than when they completed the quizzes individually. These results document that collaborative testing enhanced student test performance. It is unknown, however, whether collaborative testing improves student retention of previously learned course content. Therefore, we tested the hypothesis that collaborative testing improves student retention.

METHODS

Design. This study was designed to test the hypothesis that collaborative testing improves student retention of previously learned course content. To test this hypothesis (Fig. 1), our undergraduate exercise physiology class of 38 students was randomly divided into two groups: *group A* ($n = 19$) and *group B* ($n = 19$). During *exam 1*, students from both groups answered questions in the traditional format as individuals. Immediately after completing the exam as individuals, students from *group A* answered a randomly selected subset of questions from *exam 1* in groups of two (1 group had 3 students) to test the effectiveness of collaborative-group testing on test performance and level of student retention. On the subsequent exam (*exam 2*, 4 wk later), students from both groups answered questions in the traditional format as individuals *and* responded to the same subset of questions from *exam 1*. The subset of questions was analyzed to determine the level of retention of the original test material. In addition, immediately after completing the exam as individuals, students from *group B* answered a randomly selected subset of questions from *exam 2* in groups of two (1 group had 3 students). Finally, on the next exam (*exam 3*, 4 wk later), students from both groups answered questions in the traditional format as individuals *and* responded to the same subset of questions from *exam 2*. This protocol followed a randomized crossover design to control for time and order effects.

Subjects. The undergraduate exercise physiology class, titled The Physiology of Exercise, EXSS 3805, is the basic exercise physiology course that all students from the Department of Exercise and Sport Science must complete in their third or fourth years to meet the graduation requirements as majors in either *1*) Physical Activity and Fitness (BS), *2*) Physical Education (BS), *3*) Exercise and Sport Science (BA), or *4*) Exercise Physiology (BS) at East Carolina University, Greenville, NC. Students from other basic science departments as well as students in the biomedical sciences program could also enroll. The class was lecture based, with laboratories scheduled throughout the semester. All exams were a combination of single best type multiple-choice questions (MCQs), fill in the blanks, and short-answer essay questions. Informed consent was received from all participants before commencement of the study, and recruitment and procedures were approved by the Institutional Review Board at East Carolina University.

Analysis. To determine the level of student retention of course content, we used a Student's paired *t*-test to compare the scores obtained when all students completed an exam *in the traditional format as individuals* (original scores) with the scores obtained when all students answered a subset of the *same* questions *in the traditional format as individuals* 4 wk later (repeat scores, Fig. 2)

To determine whether collaborative testing increased student performance on exams, we used a Student's paired *t*-test to compare the scores obtained when all students answered the questions *in the traditional format as individuals* (individual scores) with the scores obtained when all students answered a subset of the same questions in *groups* (group scores, Fig. 3).

To determine whether collaborative testing improved student retention of course content, we used a Student's paired *t*-test to compare repeat scores (scores on the subset of questions) when all students answered the original subset of questions individually (individual repeat scores) with the repeat scores obtained when all students answered the subset of questions in *groups* (group repeat scores, Fig. 4).

A questionnaire (Table 1) was used to evaluate the collaborative testing procedures. The questionnaire evaluated the goals and objectives, specific procedures, students' attitudes, and personal preferences

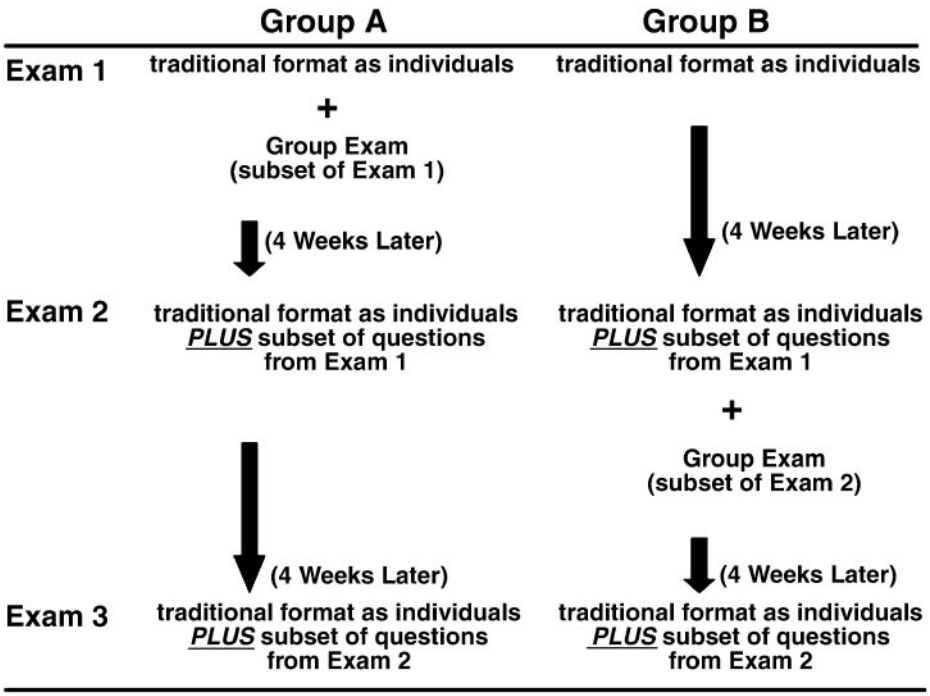

FIG. 1.

Flow diagram presenting experimental design used to test the hypothesis that collaborative testing improves student retention of previously learned course content. To test this hypothesis, our undergraduate exercise physiology class of 38 students was randomly divided into two groups: *group A* (n = 19) and *group B* (n = 19). During *exam 1*, students from both groups answered questions in the traditional format as individuals. Immediately afterward, students from *group A* answered a randomly selected subset of questions from *exam 1* in groups of 2 (1 group had 3) to test effectiveness of collaborative-group testing on test performance and level of student retention. On *exam 2* (4 wk later), students from both groups answered questions in the traditional format as individuals *and* responded to the same subset of questions from *exam 1*. The subset of questions was analyzed to determine the level of retention of the original test material. In addition, immediately afterward, students from *group B* answered a randomly selected subset of questions from *exam 2* in groups of 2 (1 group had 3). Finally, on *exam 3* (4 wk later), students from both groups answered questions in the traditional format as individuals *and* responded to the same subset of questions from *exam 2*. This protocol followed a randomized crossover design to control for time and order effects.

as well as summary and recommendations. The students completed the evaluation at the end of the course. Results from the questionnaire were analyzed using descriptive statistics and are expressed as means ± SE.

RESULTS

All values are expressed as means ± SE. Figure 2 presents the percentage of correct responses the first time all students answered the questions in the traditional format as individuals (original score) and the percentage of correct responses on a subset of the same questions the subsequent time the students answered the questions in the traditional format as individuals 4 wk later (repeat score). Originally, the students answered 63.5 ± 1.9% correctly. In sharp contrast, 1 mo later, the students answered 46.0 ± 2.6% correctly. This reduction in questions answered correctly was statistically significant ($P < 0.05$). Thus student retention of course content is short-lived.

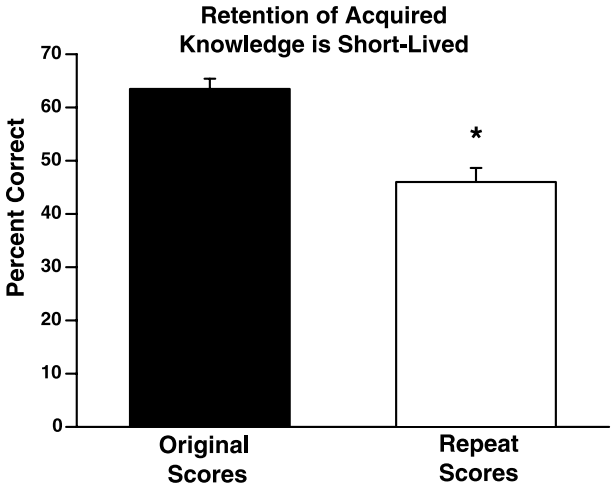

FIG. 2.

Student retention of course content is short-lived. Figure presents percent correct responses the first time all students answered the questions individually (original score) and percent correct responses on the same questions the next time the students answered the same questions individually 4 wk later (repeat score). Originally, students answered 63.5 ± 1.9% correctly. In sharp contrast, 1 mo later, students answered 46.0 ± 2.6% correctly. This reduction in questions answered correctly was statistically significant. Thus student retention of course content is short-lived. Values are means ± SE; *$P < 0.05$.

Figure 3 presents the percentage of correct responses when the students answered the questions in the traditional format as individuals (individual scores) and when the students answered a subset of the same questions in groups (group scores). The percentage of correct answers when students completed the examinations in groups (81.3 ± 2.0%) was significantly higher ($P < 0.05$) than when the students completed the examinations individually (63.5 ± 1.9%). Thus collaborative testing increased student performance on examinations.

Figure 4 presents the repeat scores (percent correct responses on the subset of questions) when the students answered the original subset of questions individually (individual repeat score) and when the students answered the original subset of questions in groups (group repeat scores). Student retention of course content (percent correct answers on the repeat examination) was significantly lower (46.0 ± 2.6%, $P < 0.05$) when the students answered the original questions individually than when the students answered the original questions in groups (52.9 ± 3.3%).

The questionnaire used to evaluate the collaborative-testing procedure and the students' responses are presented in Table 1. Thirty-four of the 38 students completed the questionnaire; this represents an 89% response rate. Overall, the students reported that the collaborative-testing procedure enhanced their understanding of the material and improved relationships among students and faculty and that everyone "pulled their weight."

DISCUSSION

The results from this study confirm previous reports documenting that student retention of previously learned material is short-lived (Fig. 2). Specifically, previous studies (2, 4, 8, 10) have documented that, after a short time, students forget much of what they learned. Importantly, collaborative-group test taking enhanced student test performance and improved student retention. Thus collaborative-group test tak-

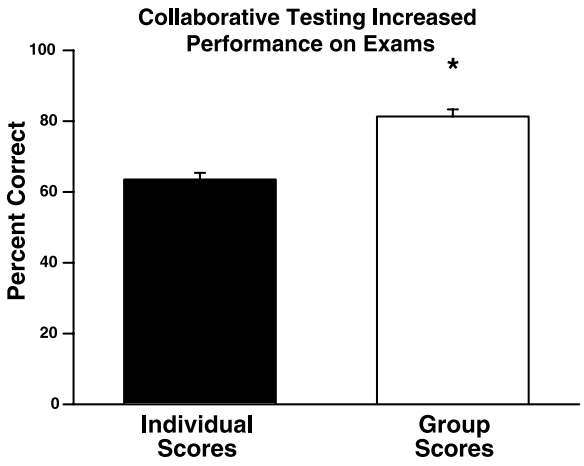

FIG. 3.

Collaborative testing increased student performance on exams. Figure presents percent correct responses when students answered the questions individually (individual scores) and when the same students answered the same questions in groups (group scores). Percent correct answers when students completed exams in groups (81.3 ± 2.0%) was significantly higher than when students completed examinations individually (63.5 ± 1.9%). Thus collaborative testing increased student performance on exams. Values are mean ± SE; *$P < 0.05$.

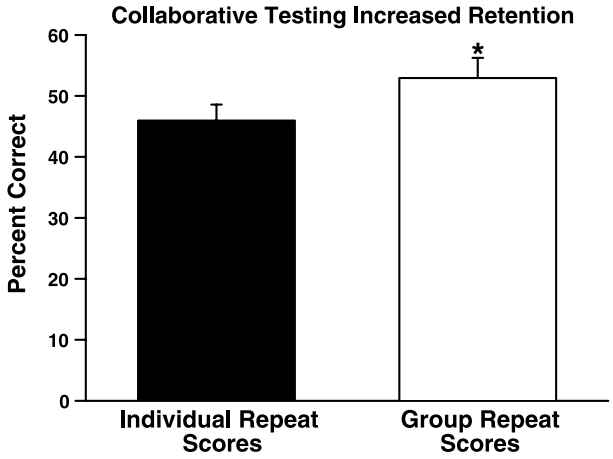

FIG. 4.
Collaborative testing increased student retention of course content. Figure presents repeat scores (percent correct responses on subset of questions) when students answered the original subset of questions individually (individual repeat score) and when students answered the original subset of questions in groups (group repeat scores). Student retention of course content (percent correct answers on repeat examination) was significantly lower (46.0 ± 2.6%, $P < 0.05$) when students answered the original questions individually than when students answered the original questions in groups (52.9 ± 3.3%). Thus collaborative testing increased student retention of course content. Values are mean ± SE; *$P < 0.05$.

ing is useful for assessing as well as enhancing student learning and improving retention.

The results from this study also confirm previous studies documenting that student performance on examinations is significantly higher when students completed the same examination in groups than when they completed the examinations individually (Fig. 3). Interestingly, the increase in group test scores was 18%. The 18% increase was more than expected and much greater than that reported for other disciplines (5, 9). Thus the higher performance for the group effort supports the concept that cooperative activities facilitate student learning (7).

The new finding from this study is that collaborative testing improves student retention of course content (Fig. 4). The pedagogical value of a test should emphasize its instructional merit for both students and teacher. However, educators often view examinations simply as a basis for grades. Too often, little emphasis is placed on using exams to help teachers teach and students learn. However, exams should be used as a mechanism for evaluating performance as well as en-

Table 1
Student evaluation of collaborative testing

Questions	Results
1. The purpose of and rationale behind the educational process was fully explained.	4.5 ± 0.14
2. The process was not too lengthy or complex in its format.	4.2 ± 0.17
3. An opportunity to assess an individual's understanding through questions and answers was provided.	4.2 ± 0.15
4. Group testing increased my confidence.	4.3 ± 0.15
5. Group testing allowed me to go beyond my previous level of knowledge.	4.2 ± 0.15
6. Group testing facilitated my learning of the material.	4.2 ± 0.17
7. Every group member "pulled their weight" (contributed to the learning process).	3.7 ± 0.20
8. The level of discussion during group testing was high.	4.2 ± 0.16
9. I appreciated the immediate feedback afforded by group testing.	4.2 ± 0.16
10. It was difficult to convince students of correct answers.	2.5 ± 0.18
11. Group testing enhanced my understanding and ability to synthesize and integrate material.	3.9 ± 0.17
12. Group testing provided a more positive relationship among students.	4.2 ± 0.14
13. Group testing provided a more positive relationship between students and faculty.	4.1 ± 0.15
14. Group testing provided a more constructive classroom learning environment.	4.3 ± 0.16
15. Group testing provided the opportunity to discuss incorrect answers and fill in knowledge gaps and therefore improve understanding of the material.	4.5 ± 0.12
16. My level of involvement during the discussions was high.	4.2 ± 0.14
17. This method of learning was as effective as any other I have encountered.	4.1 ± 0.15
18. This process was educationally attractive due to the novelty of this style and format.	4.4 ± 0.15
19. I would recommend this process for other content areas.	4.6 ± 0.12

Student evaluation of collaborative testing process. Results expressed as mean ± SE. Students were given the following instructions in order to respond to the questions: Please circle the number that most accurately defines the way you feel regarding each statement. Scale: 1, strongly disagree; 2, tend to disagree; 3, neither agree nor disagree; 4, tend to agree; 5, strongly agree.

hancing learning (6). Results from this study document that using exams as learning tools during collaborative testing increases student performance and retention.

A questionnaire (Table 1) was used to evaluate the collaborative testing procedures. The questionnaire evaluated the goals and objectives, specific procedures, and students' attitudes and personal preferences, as well as summary and recommendations. The students completed the evaluation at the end of the course. The questionnaire documented that students developed a better understanding of the material and in the process gained more self-confidence (*questions 4* and *12*). Furthermore, the questionnaire documented that collaborative testing resulted in more positive relationships among students (*question 12*) and between students and faculty (*question 13*), more positive psychological well-being (*questions 2 4, 5,* and *6*), and a more constructive classroom learning environment (*question 14*).

Some educators may be concerned that less-prepared students will be "carried" by the more industrious ones. However, the students reported that every group member "pulled their weight" (*question 7*), that the level of discussion during group testing was high (*question 8*), and that their level of involvement during the discussion was also high (*question 16*). Thus this potential concern appears unwarranted. Finally, current evidence suggests that students feel a responsibility for the group's success and that group members tend to ensure that everyone is doing their share (6). Therefore, it is unlikely that students will be carried along in the process.

In contrast to individual exams (3), group testing provides an opportunity for students to discuss their reasoning for an answer as well as receive immediate feedback of their performance (*questions 3* and *9*). Group testing provides an opportunity to discuss incorrect answers and fill in knowledge gaps. In this situation, the understanding of the material is enhanced. Therefore, immediate feedback is very important for learning, especially in large classes.

Students rated this format (individual followed by group performance) superior to the traditional method. Students reported that the group efforts promoted an understanding of the material as well as providing an opportunity to improve their scores. Students also reported that they did not mind the additional time required to complete both the individual and group efforts.

Limitations. Both great needs and great possibilities exist for research in teaching and learning. The challenge is formidable, especially with the inherent limitations associated with pedagogical research (1). That is, most classroom environments present a number of obstacles to tightly controlled research, and thus this study has a few limitations. First, as an additional control, when students from one group were paired and repeated a subset of the original questions from an exam, it might have been better for the students from the other group to repeat the same questions as individuals to control for the repeated exposure to the questions. This additional control might have provided a mechanism/reason (e.g., increased exposure to the questions) for the positive effects of collaborative testing on exam performance and retention. In addition, it is impossible to control for the certain discussion among students regarding the design and hypotheses of the study. Such discussions have the potential to affect the outcome. However, it is important to note that most variables were tightly controlled in this study. For example, individual test scores documented that all students in the collaborative testing setting improved their scores. Furthermore, there were no differences in individual scores between groups. Thus, within the confines of the classroom environment, we are confident with our results.

Summary and conclusion. Collaborative-group testing immediately after the traditional individual examination enhanced students' understanding of the material (Fig. 3) and improved student retention (Fig. 4). In addition, this approach provided students with immediate feedback which is an important component for understanding. Finally, cooperative learning may result in higher academic achievement, a more positive relationship among students and instructors, more positive psychological well-being, and a more constructive classroom environment, all which may serve to produce professionals who are self-sufficient, critical thinkers, and life-long learners.

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