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Peer instruction enhanced meaningful learning: ability to solve novel problems

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Cortright, Ronald N., Heidi L. Collins, and Stephen E. DiCarlo. Peer instruction enhanced meaningful learning: ability to solve novel problems. *Adv Physiol Educ* 29: 107–111, 2005; doi:10.1152/advan.00060.2004.—Students must be able to interpret, relate, and incorporate new information with existing knowledge and apply the new information to solve novel problems. Peer instruction is a cooperative learning technique that promotes critical thinking, problem solving, and decision-making skills. Therefore, we tested the hypothesis that peer instruction enhances meaningful learning or transfer, defined as the student's ability to solve novel problems or the ability to extend what has been learned in one context to new contexts. 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* ($n = 19$). A randomized crossover design in which students either answered questions individually or during peer instruction was used to control for time and order effects. The first factor that influences meaningful learning is the degree of mastery of the original material. Importantly, peer instruction significantly enhanced mastery of the original material. Furthermore, the student's ability to solve novel problems was significantly enhanced following peer instruction. Thus pausing two to three times during a 50-min class to allow peer instruction enhanced the mastery of the original material and enhanced meaningful learning, i.e., the student's ability to solve novel problems.

active learning; cooperative learning; problem solving skills; knowledge transfer; student attitudes

EMPLOYMENT OPPORTUNITIES in the future will require greater ability to work together to solve novel problems, because much of the knowledge that will be employed in the students' future careers is not known today and therefore must be learned after graduation (24). Furthermore, not all that is known can be taught in 4 yr and not all that is taught can be learned or remembered. Some of what is taught is erroneous and other material will soon be obsolete (24). Students must be capable of working together, gathering evidence, learning from it, and applying the information to novel situations. Without the proper training of the work force for the future, effects on professional research and development, economy, society, and our standard of living will be detrimental. Therefore, it is in the best interest of the nation to raise the level of education of all its citizens in an effort to meet the demands of a challenging society and remain competitive in the scientific and world arenas. However, much of what we do in classes with large numbers of students conflicts with these goals. These activities do not prepare students for solving novel problems because many of these activities encourage memorization of detailed information. Memorization occurs when the learner makes

little or no effort to relate new information to existing knowledge or novel situations. In contrast, meaningful learning (5, 13, 14) occurs when the learner interprets, relates, and incorporates new information with existing knowledge and applies the new information to solve novel problems. Meaningful learning requires multiple opportunities for the student to be actively engaged in the reasoning and application of concepts (5, 13, 14).

Lymna's Think-Pair-Share (11) and Mazur's Peer Instruction (12) provide opportunities for students to be actively engaged in the reasoning and application of concepts (3). Think-Pair-Share occurs two to three times during a lecture when the instructor asks a question or poses a problem. Students spend a minute or two alone thinking about an answer or solution (Think). Subsequently students pair up (Pair) to discuss their answers with each other (Share) (3). Mazur used a very similar approach (12). Two to three times during a lecture the students solve a physics problem, mark down their answer, and rate how confident they feel about the correctness of their answer. For the pair phase, Mazur allows students 1 min to convince their neighbor of their answer. After discussing the problem with classmates, students may revise the answer and again rate their confidence in their second answer. There was a dramatic increase in the confidence level and percentage of correct answers after students discussed the concepts (12).

We recently reported that peer instruction increased medical student performance on quizzes (20). Similarly, we recently reported that collaborative testing, a similar peer instruction procedure, increased medical student performance on quizzes (19) and undergraduate student performance on exams as well as increased student retention of previously learned information (6). Specifically, performances on quizzes and retention of previously learned information were significantly higher when students completed exams in groups than when they completed exams individually. These results document that peer instruction enhances exam performance as well as student retention of previously learned information. Thus peer instruction significantly enhanced mastery of the original material. This is important because the first factor that influences meaningful learning is the degree of mastery of the original material. However, it is unknown if peer instruction enhances meaningful learning. Therefore, we tested the hypothesis that peer instruction enhances mastery of the original material as well as meaningful learning, i.e., the student's ability to solve novel problems.

MATERIALS AND METHODS

Design. All procedures were reviewed and approved by the Institutional Review Board and informed consent was obtained from all students before beginning the study. We borrowed concepts of the Lymna and Mazur peer instruction activities to promote student

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involvement in the learning process and test the hypothesis that peer instruction enhances mastery of the original material as well as meaningful learning (11, 12). Students were divided by the instructor into two permanent equal groups: *group A* ($n = 19$) and *group B* ($n = 19$). Students from the groups were positioned on opposite sides of an aisle that physically divided the classroom in half. It was important that the groups be heterogeneous: diverse in gender, ethnic background, and academic ability. Heterogeneous grouping typically enhances the likelihood of success and permits students to work constructively with varied individuals who bring different strengths and approaches to tasks. Positive interactions with diverse individuals also prepare students for the real workplace and for society. When a group was involved in peer instruction, the students were positioned in clusters of ~4 students. We wanted to have 3–4 students per cluster because this size is large enough to include students of diverse opinions, experiences, and learning styles to assist with the problem solving. In addition, if a group member is absent, the cluster can continue to function smoothly. A group of four is not so large that a student can “hide”; thus all students must carry the load. Finally we used permanent groups so that the students remained together long enough to establish positive working relationships and to develop team building. Classes consisted of two to three short presentations on key points. Each short presentation was followed by a one-question multiple choice quiz. The questions on the quizzes ranged from simple recall to comprehensive questions. The students from both groups were allowed 1 min to formulate the answer. Subsequently, the students from *group A* only were allowed 1 min to discuss their answers with their peers. This process encouraged critical thinking, problem solving, and decision making skill as well as provided a way to assess the level of understanding. Students from the other group, *group B*, were not allowed to consult with peers. After the first exam, students from *group B* followed the peer instruction procedures when responding to questions, and students from *group A* were not allowed to consult with peers. We analyzed these responses to determine the effectiveness of peer instruction on the student performance on quizzes (mastery of the original material).

For the last third of the course, virtually identical procedures were followed to determine the effect of peer instruction on meaningful learning; however, all of the questions involved novel situations. The students were required to interpret, relate, and incorporate new information with existing knowledge and apply the new information to solve novel problems. Students were not exposed to the novel situation; however, they received the material required to solve the novel problem. We analyzed these responses to determine the effectiveness of peer instruction on meaningful learning (the ability to solve novel problems). All problem-solving questions were prepared by an instructor (S. E. DiCarlo) at a different institution who was not formally active in the class. The questions were developed based on the course outline provided by the class instructor (R. N. Cortright). For examples of the problem-solving questions, readers are referred to two recent publications (4, 16). Figures and questions related to the cardiovascular and respiratory sections were taken from these papers.

Procedures. This peer instruction, active learning technique was implemented during the Exercise Physiology class (EXSS 3805) at East Carolina University (Greenville, NC). The class consisted of 38 students. The course, offered through the Department of Exercise and Sport Science (EXSS) must be completed in the third or fourth year in order for EXSS majors to meet the graduation requirements in: 1) Physical Activity and Fitness (BS), 2) Physical Education (BS), 3) Exercise and Sport Science (BA), or 4) Exercise Physiology (BA). Students from other basic science departments could also enroll. The class was lecture based, with laboratories scheduled throughout the semester. The peer instruction technique was used for all classes. Each class of 50 min was divided into two to three short presentations of 15 to 20 min each. Each presentation was followed by a one-question multiple choice quiz on the subject discussed. All students were allowed 1 min to think and to record their answers (see below).

Subsequently students from one group only were allowed 1 min to discuss their answers with classmates. Students were then allowed to change their first answer if desired, and both answers were recorded. Finally, the instructor and students discussed the answer.

To record the student responses, we included five colored sheets of paper labeled A (red), B (white), C (blue), D (green), and E (yellow) in the students' lecture notes. Students use these colored letters to answer questions during the class (7). For example, students answer the question by holding up the appropriate colored letter. All students hold up their choice of colored letter at the same time. These procedures increase class participation as well as allow us to immediately determine whether students understand a particular concept by observing the sea of colors. If the majority of students answer correctly, we feel comfortable moving on. However, if a significant number of students answer incorrectly, the concept is reviewed. Students enjoy this activity and appreciate the opportunity to assess their own understanding as well as participate in class. Furthermore, students report that these activities help to hold their attention. Finally, we get an immediate idea of student learning and record the responses.

After determining the effect of peer instruction on the mastery of original material, we determined the effect of peer instruction on meaningful learning. A randomized, crossover design was again applied to evaluate performance on problem-solving questions. One novel problem-solving question was introduced to each class. Students were allowed ~10 min to answer each question. Students alternated from peer instruction groups (*group A*) to nonpeer instruction groups (*group B*) every class period. Each student participated in an equal number of questions as *group A* or *group B*. Content area was diverse including metabolism, cardiovascular, and respiratory physiology. All students experienced equal numbers of problem-solving questions from all content areas across the study period. Each problem-solving question was worth two points and assessment of meaningful learning was based on the number of points gained for each individual question when operating as *group A* or *group B* participants.

Analysis. All results are presented as means \pm SE. To determine the effect of peer instruction on student performance on multiple choice questions (mastery of original material), we used a Student's paired *t*-test to compare raw scores obtained when all students answered the questions as individuals with raw scores obtained when the students answered the questions in collaboration with others (peer instruction).

To determine the effect of peer instruction on meaningful learning (the ability to solve novel problems) we used a Student's paired *t*-test to compare raw scores on novel problem-solving questions obtained when all students answered the questions as individuals compared with raw scores obtained when the students answered the novel problem-solving questions in collaboration with others (peer instruction). Statistical significance was established a priori as $P < 0.05$.

A questionnaire (Table 1) was used to evaluate the peer instruction procedures. The questionnaire evaluated the goals and objectives, specific procedures, students' attitudes, and personal preferences as well as summary of 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 \pm SE.

RESULTS

Figure 1 presents the effect of peer instruction on student performance on multiple choice questions (mastery of original material). The daily average number of students who participated in peer instruction (answered questions in clusters) was 16.3 ± 0.2 . The daily average number of students who answered questions individually was 17.1 ± 0.4 . The students who interacted with their peers and those who did not answered 2–3 questions per class throughout the first two-thirds of the

Table 1. *Student evaluation of peer instruction*

Questions	Results
1. The purpose of and rationale behind the educational process was fully explained.	4.6 ± 0.09
2. The process was not too lengthy or complex in its format.	4.6 ± 0.11
3. An opportunity to assess an individual's understanding through questions and answers was provided.	4.6 ± 0.09
4. Peer instruction increased my confidence.	4.4 ± 0.11
5. Peer instruction allowed me to go beyond my previous level of knowledge.	4.3 ± 0.12
6. Peer instruction facilitated my learning of the material.	4.3 ± 0.11
7. Every member "pulled their weight" (contributed to the learning process).	4.1 ± 0.14
8. The level of discussion during peer instruction was high.	4.4 ± 0.12
9. I appreciated the immediate feedback afforded by peer instruction.	4.6 ± 0.10
10. It was difficult to convince students of correct answers.	3.1 ± 0.20
11. Peer instruction enhanced my understanding and ability to synthesize and integrate material.	4.4 ± 0.10
12. Peer instruction provided a more positive relationship among students.	4.6 ± 0.10
13. Peer instruction provided a more positive relationship between students and faculty.	4.6 ± 0.09
14. Peer instruction provided a more constructive classroom learning environment.	4.6 ± 0.09
15. Peer instruction provided the opportunity to discuss incorrect answers and fill in knowledge gaps and therefore improve understanding of the material.	4.6 ± 0.09
16. My level of involvement during the discussions was high.	4.2 ± 0.13
17. This method of learning was as effective as any other I have encountered.	4.4 ± 0.10
18. This process was educationally attractive due to the novelty of this style and format.	4.5 ± 0.10
19. I would recommend this process for other content areas.	4.6 ± 0.09
20. I enjoyed peer instruction	4.7 ± 0.08

Results are expressed as means ± SE. Students were given the following instructions to respond to the questions. Circle the number that most accurately defines the way you feel regarding each statement: 1, strongly disagree; 2, tend to disagree; 3, neither agree nor disagree; 4, tend to agree; 5, strongly agree.

course for a total of 34 questions. Without peer instruction, the students answered questions correctly $44 \pm 5\%$ of the time. In contrast, when students were allowed to collaborate with fellow classmates, they answered the questions correctly $59 \pm 6\%$ of the time. This 27% improvement of the raw scores was statistically significant ($P = 0.02$).

Figure 2 presents the effect of peer instruction on meaningful learning (the ability to solve novel problems). The students who interacted with their peers and those who did not answered one problem-solving question per class throughout the last one-third of the course for a total of six questions. When students were allowed to interact with their peers, the level of performance on novel problem-solving questions was significantly greater (47 ± 5 vs. $24 \pm 2\%$, $P = 0.04$) than when they completed novel tasks in the traditional format.

The questionnaire used to evaluate the peer instruction procedures and the students' responses are presented in Table 1. Thirty-four of the 38 students completed the questionnaire; this represents an 89% response rate. Among 20 responses, the students reported that the purpose of and rationale behind the educational process was fully explained (*question 1*, 4.6 ± 0.09). It was clear that the students understood the educational goals and figured out ways to achieve the goals. By understanding the goals, the students were observed becoming more efficient and effective with the discussions. In addition, it was clear that the students understood the nature and value of the activity, which prevented many of the concerns faculty may have about peer activities. Thus when establishing cooperative peer activities, it is important that clear instructions are presented. Students reported that peer instruction facilitated their learning of the material (*question 6*, 4.3 ± 0.11). It was clear that there were many concepts that could not be learned quickly. The time allowed during peer instruction provided the opportunity for students to master several complex concepts. As the authority, the instructor often summarized the lesson and validated the learning that occurred. Students reported that every member "pulled their weight" (contributed to the learn-

ing process) (*question 7*, 4.1 ± 0.14). We observed all students "pulling their weight" as well as students monitoring group behaviors. Students were observed listening, providing constructive feedback, and reflecting on their learning. We observed students developing leadership, decision making, communication, and conflict resolution skills while gaining mutual respect of peers. The peer instruction activities fostered positive interdependence (*question 12*, 4.6 ± 0.10) and individual accountability (*question 7*, 4.1 ± 0.14), because the activity was carefully structured. Students reported that the level of discussion during peer instruction was high (*question 8*, 4.4 ± 0.12). Indeed, students were observed focused and seriously engaged in the discussion. It was clear that the students learned more and better by becoming actively involved with the material. However, activity in and of itself does not result in higher learning. The students invested in the discussion and we observed a high level of involvement from the students (*question 16*, 4.2 ± 0.13), which helped the students make what they were learning meaningful. The students reported that peer instruction provided a more positive relationship between students and faculty (*question 13*, 4.6 ± 0.09) and among students (*question 12*, 4.6 ± 0.10). Interaction between teacher and students and students and students is one of the most powerful factors in promoting learning. The students reported that they enjoyed peer instruction (*question 20*, 4.7 ± 0.08). It was clear that the students were motivated, eager to learn, and having fun. This created a wonderful classroom environment where student's confidence (*question 4*, 4.4 ± 0.11), learning (*questions 3*, 4.6 ± 0.09 and *5*, 4.3 ± 0.12) and involvement (*question 16*, 4.2 ± 0.13) were high.

DISCUSSION

In this study, we examined the effectiveness of peer instruction, a pedagogical method that promotes student participation in class and increases student interaction with each other and with the instructor, on student performance on quizzes (mas-

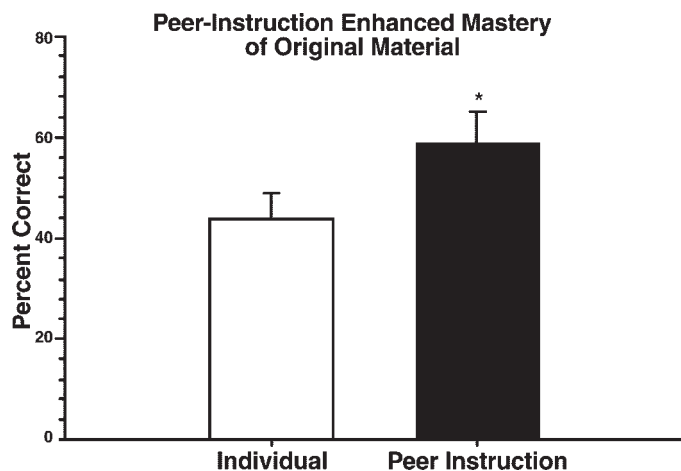


Fig. 1. Effect of peer instruction on student performance on multiple choice questions (mastery of original material). The daily average number of students who participated in peer instruction (answered questions in clusters) was 16.3 ± 0.2 (means \pm SE). The daily average number of students who answered questions individually was 17.1 ± 0.4 . Without peer instruction (Individual), the students answered questions correctly $44 \pm 5\%$ of the time. In contrast, when students were allowed to collaborate with fellow classmates (Peer Instruction), they answered the questions correctly $59 \pm 6\%$ of the time. This 27% improvement in raw scores was statistically significantly ($*P = 0.02$). Values are means \pm SE.

tery of original material). In addition, we examined the effectiveness of peer instruction on meaningful learning, defined as the learner interprets, relates, and incorporates new information with existing knowledge and applies the new information to solve novel problems. Results from this study confirm previous reports documenting that peer instruction and collaborative group test taking enhanced student performance on quizzes. Specifically, previous studies (6, 15, 19, 20, 21) have documented that student performance on examinations is significantly higher when students completed the same exam in groups than when they completed the examinations individually. The new finding from this study is that peer instruction enhanced meaningful learning. That is, peer instruction provided a learning experience that lead to transfer, defined as the ability to extend what has been learned in one context to new contexts (2, 22). Quality learning experiences should lead to transfer. All learning experiences can appear equivalent when measures of learning are focused on the ability to repeat previously taught facts. However, quality learning experiences (learning with understanding) can be identified when tests of transfer are used. Thus because peer instruction leads to transfer, this study documents that peer instruction provides a quality learning experience.

Mastery of the subject is essential for meaningful learning (e.g., for the successful transfer of knowledge to solve novel problems). Without an adequate level of initial learning, transfer cannot be expected (5). Thus transfer is affected by the degree to which students learn with understanding rather than merely memorize sets of facts (5). Learning with understanding requires time to allow for practice. Faculty must be realistic about the amount of time required to learn complex concepts and provide the practice time to achieve the goal. Students need to take time to explore underlying concepts and to generate connections to other information. Students must have time to “grapple” with specific information relevant to the

topic. Thus learning cannot be rushed; the complex cognitive activity of information integration requires time (5). It is important to recognize that time alone will not result in the benefit seen with peer instruction. Rather it is the practice and the feedback provided by peer instruction that enhances the mastery and transfer of knowledge. As stated more succinctly by a quote attributed to world-renowned physiologist and medical historian Horace Davenport, “There is a great difference between teaching and learning. There is too much teaching and not enough learning.” (9, 23). In this context, I taught George, my cat, to fetch the remote to my sound system; however, he has failed to learn this task. Importantly, peer instruction provides the time for students to test existing knowledge and apply it to novel situations in a safe, supportive, environment. This quality learning experience allows students to evaluate their concepts and experiences while providing feedback about their progress.

A questionnaire (Table 1) was used to evaluate the peer instruction procedures. The questionnaire evaluated the goals and objectives, specific procedures, 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 the students developed a better understanding of the material and in the process gained more self confidence (*questions 4 and 6*). Furthermore, the questionnaire documented that peer instruction resulted in more positive relationships among students (*question 12*) and between students and faculty (*question 13*), more positive psychological well being (*questions 4-6*), and a more constructive classroom-learning environment (*question 14*).

The results of the questionnaire are important because the students also reported that they enjoyed the procedures (*question 20*) and would recommend this process for other content areas (*question 19*). It is well documented that motivation affects the quality of the learning experience and that high levels of motivation increase learning with understanding (8). According to the ancient Greek scholar Plato, “Bodily exercise,

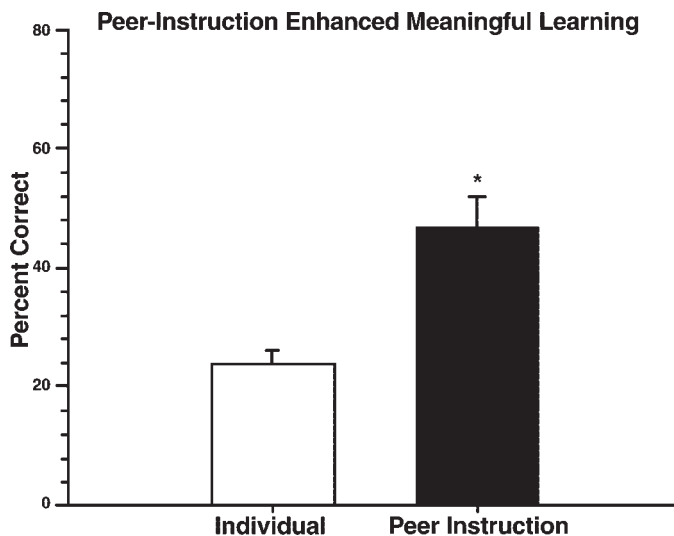


Fig. 2. Effect of peer instruction on meaningful learning (the ability to solve novel problems). When students were allowed to interact with their peers (Peer Instruction), the level of performance on novel problem-solving questions was significantly greater (47 ± 5 vs. $24 \pm 2\%$, $*P = 0.04$) than when they completed novel tasks in the traditional format (Individual). Values are means \pm SE.

when compulsory, does no harm to the body; but knowledge which is acquired under compulsion obtains no hold on the mind." (17). Peer instruction motivates students! Furthermore, learning with understanding and transfer requires the student to actively choose and evaluate strategies, consider resources, and receive feedback.

By actively involving students in peer instruction activities, the student's attention span may be greatly increased. It has been reported that students in a lecture-based college classroom are not attentive ~40% of the time (18). During sustained lectures, student attention decreases with each passing minute. Furthermore, sustained lectures appeal only to auditory learners and tend to promote lower level learning of factual information. Finally, sustained lecturing assumes that all students learn the same information at the same pace (10). Thus by incorporating peer instruction, active learning activities may increase student's attention.

Faculty are often reluctant to incorporate active learning activities in the class. The reasons most often advanced for not including these active learning activities include not being able to cover as much content in the time available and the excessive preparation time required for devising strategies promoting active learning (1). In terms of preparation time, minimal extra time is required for this active approach. Furthermore, the minimal extra time pays dividends in understanding and retention of material (6). As stated by Mazur (12), using time for peer instruction greatly improves student's level of understanding with relatively little effort and no capital investment.

Although little additional time is required in preparation for the peer instruction activities, the instructor has several important roles during the process. For example, the instructor must model appropriate social skills, including listening and providing constructive feedback or eliciting more in-depth responses through probing questions. The instructor must also reinforce these positive behaviors by publicly commenting on the ways students use them effectively.

In conclusion, pausing two to three times during a 50-min class to allow peer instruction of concepts enhanced the student's level of understanding and ability to synthesize and integrate material. Specifically, peer instruction enhanced the mastery of original material and meaningful learning. It is possible to create an effective active learning environment with relatively little effort by implementing peer instruction technique. We would be wise to heed the words of British mathematician, logician, and philosopher Alfred North Whitehead who said, "So far as the mere imparting of information is concerned, no university has had any justification for existence since the popularization of printing in the fifteenth century." (25).

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