Performance in physiology evaluation: possible improvement by active learning strategies

Luis H. Montrezor

Department of Biological Science and Health - Medicine, University of Araraquara, UNIARA, Araraquara, São Paulo, Brazil; Medical Chemistry and Regenerative Medicine Group, QUIMMERA-UNIARA, Araraquara, São Paulo, Brazil; and Undergraduate Education Committee-Brazilian Society of Physiology, São Paulo, Brazil

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Montrezor LH. Performance in physiology evaluation: possible improvement by active learning strategies. Adv Physiol Educ 40: 454–457, 2016; doi:10.1152/advan.00022.2016.—The evaluation process is complex and extremely important in the teaching/learning process. Evaluations are constantly employed in the classroom to assist students in the learning process and to help teachers improve the teaching process. The use of active methodologies encourages students to participate in the learning process, encourages interaction with their peers, and stimulates thinking about physiological mechanisms. This study examined the performance of medical students on physiology over four semesters with and without active engagement methodologies. Four activities were used: a puzzle, a board game, a debate, and a video. The results show that engaging in activities with active methodologies before a physiology cognitive monitoring test significantly improved student performance compared with not performing the activities. We integrate the use of these methodologies with classic lectures, and this integration appears to improve the teaching/learning process in the discipline of physiology and improves the integration of physiology with cardiology and neurology. In addition, students enjoy the activities and perform better on their evaluations when they use them.

the quality of education is associated with, among other factors, the competence to approach complex situations in an appropriate manner. Competence can be defined as an individual’s ability to mobilize cognitive resources to solve complex problems (18). An important goal for teachers is to help students develop skills and acquire knowledge that will result in good performance ratings. However, the analysis of grades or the understanding of concepts alone does not ensure learning success.

Advances in science education research have the potential to improve the way students learn and understand physiology concepts. Students’ evaluations are a common source of information used by instructors and administrators to review and assess faculty performance (1). The evaluation of the learning process can be distressing for teachers who cannot make the learning process extend beyond rote memorization and the collection of facts. The evaluation process is effective when the objectives proposed by the teacher are achieved. Evaluation should avoid an overemphasis on memorization, insufficient standards of proof for correction, and poorly designed questions. Instead, the evaluation process should provide context in the proposed questions and explore the students’ reading and writing capabilities (16). The statement “If you don’t have any goals, you don’t have anything to assess” expresses the close relationship between goals and effective evaluation.

Ramirez (19) hypothesized that frequent attendees would develop higher self-perceptions of learning and obtain higher marks than infrequent attendees and found that male students obtained higher grades and were more confident in their achievements than their female peers despite the similarities in male and female students attendance. Thus, the evaluation processes are complex and should be related to the social and emotional contexts (12) of each course and not just the course’s technical content.

There has been increasing interest among college faculty in the teaching methods variously grouped under the terms active learning and cooperative learning (4). To achieve this, we employed active learning methodologies (11, 12, 14, 15) associated with the classic lectures in a hybrid medical physiology course about physiological systems. We also employed other activities such as computer simulations, videos, and seminars. We believe that integrating active methodologies and theoretical lessons can improve the teaching/learning process for our students. This includes a change in the educational paradigm from one that focuses on teaching (teacher-centered) to one that focuses on learning (student-centered). In a medical school in Turkey that has a hybrid structure of lecture and problem-based learning (PBL), learning style predicted students’ satisfaction with traditional training and success in theoretical block exams, whereas nothing predicted PBL satisfaction and success (7). Luc and Antonoff (9) have discussed perspectives and challenges faced by trainees and surgeons in applying active learning to surgical training. In this way, they helped surgical educators better understand the evaluation of curriculum development, methods of instruction, and assessment. Formative objective structured clinical examinations (OSCEs) were associated with improved performance in subsequent summative OSCEs. The learning style did not improve the overall pass rates for the summative OSCEs, nor did it accurately predict performance (3).

Therefore, the main goal of this study was to analyze the performance of medical students in the physiology, cardiology, and neurology disciplines. The hypothesis was that the use of active methodologies can improve students’ performance. To accomplish our goal, we compared the performance of students who used active methodologies with the performance of students who did not use active methodologies on a cognitive monitoring test (CMT) based on the knowledge of the physiology systems taught in the course.
METHODS

Participants and research design. The study was conducted from 2012 to 2015 with 200 medical school students from four different classrooms. The students were divided according to their semester of attendance: second (group 1), third (group 2), seventh (group 3) and eighth (group 4). Our medical classrooms are composed of 50 students, and all of them participated in the study (n = 50/group). Each group was randomly divided into two subgroups per each semester: a subgroup (n = 25) that completed activities with active methodologies before the CMT and a subgroup (n = 25) that did not perform such activities. The subgroups of students who did not perform activities with active methodologies (control groups) were asked to study the discipline contents in textbooks and scientific articles during the same period (90–120 min) that their peers spent performing the activities. The study evaluated the students’ performance in basic areas (2nd and 3rd semesters) and in clinical areas (7th and 8th semesters). In the first two semesters of the study, the goal was to evaluate the students’ knowledge of basic physiology concepts (membrane potential, action potential, and the physiological basis of electrocardiography, the cardiac cycle, and blood pressure control). In the semesters with a clinical focus, we evaluated the cardiology (7th semester) students’ comprehension and retention of the physiology of the cardiovascular system and the neurology (8th semester) students’ comprehension and retention of the physiology of the nervous system.

The cardiology and neurology disciplines were chosen because of their integration with physiology and the affinity between the teachers. The semesters chosen for the study were those in which the disciplines are offered.

Assessments. The assessment used is part of the medical course evaluation system used at our university. This assessment, the CMT, is applied twice each semester. The contents of the assessment are defined by the teacher responsible for the discipline being assessed. In this study, the CMT was conducted during the first half of each semester (from 2012 to 2015). The CMT is composed of five questions: two open questions and three multiple-choice questions. Students had 30 min for each CMT. Only physiology topics were tested during the second- and third-semester assessments, whereas the seventh- and eighth-semester assessments examined clinical issues (case-based learning) that required a basic understanding of the physiological mechanisms.

All of the students attended lectures (60–90 min) prior to the evaluation. Therefore, all students had been introduced to the content that was evaluated in the CMT.

The students in group 4 were evaluated each semester and over the four semesters. The students in group 3 were evaluated in the seventh, third, and second semesters and throughout these three semesters. The students in group 2 were evaluated in the third and second semesters and throughout these two semesters. Finally, the students in group 1 were evaluated only in the second semester.

The CMT was administered 10 days after the completion of the active methodologies.

Active methodologies. The activities involving active methodologies lasted 90–120 min. The following active methodologies were used: a puzzle on the cardiac cycle (11) in the second semester, a board game on membrane potential and action potential in the third semester, a debate entitled “Physiological Court” in the seventh semester, and a video in the eighth semester. The debate held during the seventh semester was on the physiology of the cardiovascular system, and it focused specifically on the physiological basis of electrocardiography, the cardiac cycle, and blood pressure control. The video presented in the eighth semester was on neurology and focused on membrane potential and action potential. The students in the eighth semester participated in all of the active methodologies activities throughout the study period.

The board game was made with an A3 sheet of plasticized paper (297 x 420 mm). The sheet was divided in half using a projector pen. Along with the board, there were different colored circles (2.5 cm radius) made of plasticized paper, with each color representing a different ion, sodium (Na⁺), potassium (K⁺), and chloride (Cl⁻); a square (2 cm) representing membrane proteins; rectangles (3 x 2 cm) representing Na⁺-K⁺-ATPase pumps; and cylinders (2.5 x 0.5 cm) representing ion channels. Each group was given a board and three envelopes containing the parts, and the teacher provided instructions to the students on how to play the game.

To conduct the “Physiological Court” (debate), the students were informed of the topic 7 days before the activity. On the day of the activity, the group was divided into two subgroups. Each subgroup produced seven questions that were then addressed to the other subgroup. For this step of the activity, the subgroups had 45 min. Alternately, each subgroup asked the opposing subgroup the questions they had produced. Each group had 10 min to answer the questions.

Finally, the video presented to the students demonstrated the electrophysiological membrane, using a frog as an animal model. The video showed the manipulation of the animal step-by-step, including anesthesia, surgery to obtain the nerve, nerve placement in the culture medium and in the electrophysiology devices used for nerve stimulation, feedback of neural signals (especially membrane potential, action potential, and stimulus intensities), and graphs recording neural signals. All of the activities were followed by 30 min of discussion among the students and between the students and the professor.

Evaluation of the CMT scores. Our evaluation system computed grades from zero (0) to 10 (10.00) for the students’ evaluations, and the average grade was seven (7.00). The CMT results were separated into three sets: 0–4.99, 5.00–6.99, and 7.00–10.00. The scores were grouped using this criteria to identify students with scores below 50% (scores from 0 to 4.99), students with scores above 50% (from 5.00 to 6.99) but below the course average of 7.00, and students who scored higher than the course average (scores from 7.00 to 10.00).

Statistical analysis. The results are reported as the means ± SE. The data were analyzed using two-way ANOVA and the Tukey’s test. The scores obtained for the CMT were compared with the differences between the group that completed the active methodologies activities before the CMT and the group that did not perform such activities. Values of P < 0.05 were considered statistically significant.

RESULTS

The results that the medical students obtained on the CMT after participating or not participating in active methodologies during the four semesters are shown in Table 1. The average grades obtained by the second-semester students who performed the active methodologies activity (puzzle) were higher (7.25 ± 0.3) than those of the control group (6.03 ± 0.21). The students in group 2 participated in the puzzle (8.15 ± 0.8) and the board game (9.27 ± 0.4) activities and obtained average CMT scores that were higher than those of the students in the control groups (6.87 ± 1.1 and 7.23 ± 0.9, respectively). The students in group 3 performed three activities with active methodologies prior to the assessment: the puzzle, the board game and the debate. The averages of the group 3 students who completed the puzzle (7.58 ± 0.4) and the board game (8.22 ± 0.9) were significantly higher than those of the control groups (6.39 ± 0.6 and 7.1 ± 0.83, respectively). Finally, the eighth-semester students completed all four active methodologies activities before taking the CMT. The average grades of the students in group 4 who completed the puzzle (8.2 ± 0.8), board game (8.79 ± 0.9) and video (9.4 ± 1.2) were significantly higher than the average grades of the control groups (6.92 ± 0.51, 7.49 ± 0.8 and 8.12 ± 0.78, respectively).

The average grades obtained by the students over the semesters are shown in Table 1. The students in group 2 obtained a...
higher average assessment score after the board game (9.27 ± 0.4) than after the puzzle (8.15 ± 0.8). The students in group 3 obtained a higher average score after the debate (8.74 ± 1.2) and the board game (8.22 ± 0.9) compared with the puzzle (7.58 ± 0.4). Finally, the students in group 4 obtained a higher average after the video (9.4 ± 1.2) compared with the puzzle (8.02 ± 0.8), the board game (8.79 ± 0.9), and the debate (7.39 ± 0.8). Additionally, the average assessment scores obtained after the puzzle and the board game were higher than those obtained after the debate.

**DISCUSSION**

The results of the present study demonstrate that the use of active methodologies before tests had positive effects on medical students during each evaluated semester and across semesters in the disciplines of physiology, cardiology, and neurology.

Student evaluations can be used for formative or summative purposes. Formative purposes of student evaluation involve providing teachers with feedback to improve their teaching or to modify the structure and content of their courses (1). We use the CMT as a formative evaluation, and it is one of the tests that we administer in our medical program. The CMT allows the teachers of each discipline to receive feedback from students in their discipline in the form of a simple and rapid test (30 min).

In addition to the CMT, we also administer theoretical and practical integrative cognitive tests twice per semester. In the theoretical integrative cognitive tests, students answer questions from all of the disciplines in which they are enrolled that semester, which provides proof that all disciplines studied that semester have been integrated. The integrative cognitive test consists of open and multiple-choice questions (an average of 40 questions) based on clinical cases (case-based learning). The total time required to complete each theoretical integrative cognitive test is 4 h, which is divided into two 2-h parts, with a 15-min interval between parts. All of the students included in this study were also evaluated using the integrative cognitive test and obtained better grades than the students in the control group (data not shown). In addition, throughout the semester, the students completed evaluations of their skills and competencies and attitude verifications.

Being an effective teacher involves seeking out the available informal and formal feedback on our efforts. Encouraging student participation, assessing student learning, and evaluating teaching are three sources of this constructive input (21). We used various activities with active methodologies within the physiology discipline of the medical program a few years ago (11, 14, 15), and we realized that students enjoyed and learned more from such methodologies. However, this study provides significant evidence that such activities promoted better performance on tests and retention of information among students. The fact that we showed that active methodologies improved student performance on the CMT does not mean that lectures are bad or ineffective. Brown et al. (2), using a cluster analysis approach, identified students who needed extra instruction, identified which assessments were more effective for discriminating between high-achieving and low-achieving students, and provided quantitative evidence to track student achievement. We use theoretical lessons in all disciplines of our medical school, and theoretical classes are integrated with active methodologies in our physiology course. A well-organized lecture remains one of the most effective ways to integrate and present information from multiple sources on complex topics, such as those often encountered in the teaching of physiology (4, 20). Klegeris and Hurren (8) established that using BPL in addition to didactic lectures in a large classroom setting has several positive outcomes on student satisfaction with the learning process. Ghorbani and Ghavzini (6) established that using the combination of paper presentation breaks and didactic lectures improves the students’ ability to learn physiology.

The educational system requires updates via need-based comprehensive curriculum design and innovative teaching methods (5, 13, 15, 16, 17). Our medical school has a modular and integrated curriculum; the course has a hybrid structure that includes both theoretical classroom methodologies (lectures) and active methodologies. From the first year of study, students are encouraged to think in a manner that integrates the basic areas of study and to comprehend the importance of such areas for clinical education. The results show that the average scores obtained by the students who completed active methodologies activities were higher than those of the control groups in all analyzed semesters. Furthermore, the results show that students in the seventh and eighth semesters in the disciplines of cardiology and neurology, respectively, had better results on the CMT compared with the control groups. Thus, we can infer that the integration of lectures with active methodologies had positive effects on students’ ability to retain basic knowledge of the physiological mechanisms that are necessary in these two clinical areas. In addition to the CMT results, it is important to note that the integration of physiology, cardiology, and neurology encourages students to think in an integrated manner about pathophysiological mechanisms, which, without any doubt, will assist them in clinical disci-
lines and strengthen the importance of basic physiology knowledge in the medical program.

Interestingly in groups 2, 3, and 4, there was a significant increase in the average obtained by the students who performed the activities with active methodologies: the puzzle and board game (group 2); the puzzle, board game, and video (group 3); and the puzzle, board game, video, and debate (group 4). This finding does not mean that one active methodology is better than another, although some students had a greater affinity for one of the applied methodologies; rather, it indicates that the active methodologies led to a better understanding and retention of knowledge of the physiology of the cardiovascular and nervous systems. Learning physiology requires problem-solving ability, the memorization of many facts, and the integration of knowledge to learn complex concepts (6, 10). The use of active methodologies led to a better understanding and retention of knowledge of the physiology of the cardiovascular and nervous systems. Learning physiology requires problem-solving ability, the memorization of many facts, and the integration of knowledge to learn complex concepts (6, 10). The use of active methodologies to reinforce didactic lectures and integration between disciplines is an important pedagogical tool to assist the students in their teaching-learning processes.

DISCLOSURES
The author declares no conflicts of interest, financial or otherwise.

AUTHOR CONTRIBUTIONS
L.H.M. conception and design of research; L.H.M. performed experiments; L.H.M. analyzed data; L.H.M. interpreted results of experiments; L.H.M. prepared figures; L.H.M. drafted manuscript; L.H.M. edited and revised manuscript; L.H.M. analyzed data; L.H.M. interpreted results of experiments; L.H.M. conceived and designed the research; L.H.M. performed experiments; L.H.M. analyzed data; L.H.M. interpreted results of experiments; L.H.M. drafted manuscript; L.H.M. edited and revised manuscript.

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