ACTIVE LEARNING OF RESPIRATORY
PHYSIOLOGY IMPROVES PERFORMANCE ON
RESPIRATORY PHYSIOLOGY EXAMINATIONS

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Active involvement in the learning process has been suggested to enhance creative thinking, judgement, interpretation, and problem-solving skills. Therefore, educators are encouraged to create an active-learning environment by incorporating active-learning strategies into the class. However, there is very little documentation of the effectiveness of active-learning strategies. Furthermore, faculty are often reluctant to incorporate new strategies without documentation of the effectiveness of these strategies. To address this concern, we compared the performance of two individual classes on an identical respiratory physiology examination. One class was taught respiratory physiology using active-learning strategies. The other class was taught respiratory physiology using the traditional lecture format. The results document that students who learned using active-learning strategies did significantly better \( P < 0.05 \) on the respiratory physiology examination than students who learned by the traditional lecture format (61 ± 2.2 vs. 86 ± 1.0). Thus, by actively involving students in the learning process, academic performance is enhanced.


Key words: peer instruction; role-playing; models; games

Students learn more when they are actively involved in learning than when they are passive recipients of instruction (8). Students must do more than just listen: they must read, write, discuss, and be engaged in solving problems. Students must also be actively involved in higher-order thinking tasks including synthesis and evolution (5). It has been suggested that strategies promoting active learning are comparable with lectures in promoting the mastery of content but superior to lecture in promoting the development of thinking and writing skills (3). Active-learning strategies encourage students to become an active integral part of the educational process. Thus, if we want our students to learn thinking, reasoning, problem-solving, and decision-making skills, then it is essential to use active-learning strategies in the classroom.

Active-learning strategies reach all types of learners in the visual, auditory, kinesthetic, and tactile schemes. It has been reported that 60% of students have a practical rather than a theoretical orientation toward learning (23). Grinder noted that in every group of 30 students, an average of 22 are able to learn effectively as long as the teacher provides a blend of visual, auditory, and kinesthetic activities. The remaining eight students, however, prefer one of the modalities over the other two so strongly that they struggle to understand the subject matter unless special care is taken to present it in their preference mode. To meet
these needs, teaching should be multisensory and filled with variety (11). To achieve this goal, it becomes important to use active-learning strategies. With active-learning strategies, visual learners are targeted by the presence of models and demonstrations. Auditory learners are reached through discussion during peer instruction (20), debate (22), games (1, 16, 17, 19), and answering questions. Manipulating models (4, 15, 26) and role playing (14) satisfies kinesthetic and tactile learners.

Cooperative-learning exercises, role playing, simulations, models, debates, and games are active-learning strategies that can be used effectively in large classrooms. These active-learning strategies expose students to stressful, unfamiliar, and complex situations by creating circumstances that are momentarily real, thereby letting students develop and practice skills necessary for coping (9). These activities also promote working in groups and generate high levels of motivation and enthusiasm (7). This is important because employment opportunities in the future will require employees to work cooperatively to solve problems and develop solutions. Furthermore, investigators have reported an increase in students’ achievement with the use of simulations and games, and students usually expressed positive feeling about the experiences (28). For all these reasons, active-learning strategies may be superior to the traditional lecture format in promoting thinking, reasoning, problem-solving, and decision-making skills.

However, active-learning strategies are not often used in large classrooms. Instructors often cite limited class time, a possible increase in preparation time, and a lack of needed resources as reasons for not incorporating these activities in the classroom (3). Instructors are also reluctant to change what has worked for them without documentation that a different method is more effective. However, there is very little documentation on the effectiveness of active-learning strategies.

We have addressed this last concern by comparing the performance of two individual classes on an identical respiratory physiology examination. One class was taught respiratory physiology using active-learning strategies. The other class was taught respiratory physiology using the traditional lecture format. Specifically, the effectiveness of active-learning strategies in a large classroom was examined by comparing the performance on an identical respiratory physiology examination of a class of 252 students that were taught using active-learning strategies with a class of 84 students that were taught using the traditional lecture format.

METHODS

Design

Faculty in the department of physiology teach in two virtually identical physiology courses. One physiology course is for medical students, and the other physiology course is for graduate students. Most faculty are responsible for the same component of each course and teach virtually the same material. For example, the individual responsible for the cardiovascular component of the physiology courses teaches the same material to both medical and graduate students. A similar situation exists for the other components of the physiology courses. However, the respiratory component of the physiology course is an exception. That is, two different professors teach the respiratory component of the physiology courses. One professor is responsible for the medical class, and the other professor is responsible for the graduate class. Although two different professors teach the respiratory component, the content for the two courses is virtually identical; however, the teaching approach is different (active-learning vs. traditional lecture format). This scenario provides an opportunity to compare the effectiveness of active-learning strategies with the traditional lecture format. To compare the effectiveness of the active and traditional approaches, students from both courses (medical and graduate) took an identical respiratory physiology examination. That is, we requested volunteers from the graduate course (traditional group) to take the respiratory physiology examination that was taken by the medical students (active-learning group). Thirty-eight of the eighty-four traditional group students completed the respiratory physiology examination that was developed for the active-learning group.

This approach is not perfect. Concerns about equating the motivation and ability of the students are valid. Furthermore, only volunteers from the traditional group completed the respiratory physiology examina-
tion developed for the active-learning group. However, the content of the two courses was virtually identical, thus within the confines of these limitations, this approach produced valid data.

**Procedures**

The respiratory component of the medical physiology class, presented to 252 first-year medical students, consisted of 10 classes of 50 min each and one 3-h laboratory session. Each class incorporated active-learning strategies. The active-learning techniques included peer instruction (13, 20), models (4, 15, 26), interactive games (1, 16, 19), debates (22), simulations, and role playing (Table 1) (14).

For the peer instruction active-learning strategy, each class of 50 min was divided into three or four short presentations of 12–20 min each. Each presentation was followed by a one-question multiple-choice quiz on the subject discussed. Students were allowed 1 min to think and to record their first answer. Subsequently, students were allowed 1 min to discuss their answers with their classmates and possibly correct their first response (13, 20).

Several concepts in respiratory physiology were presented using models (4, 15, 26). For example, the concept of surface tension was demonstrated using two microscopic slides. The slides were initially pulled apart without difficulty. However, after water was placed between the slides, it was impossible to pull the slides apart. Students were also asked to expand a balloon before and after water was injected into the balloon. Of course, it was much more difficult to expand the balloon after water was injected due to the surface tension. Thus these two models demonstrated the concept of surface tension. The concept of Boyle’s law and how the contraction of the diaphragm causes expansion of the alveoli by creating a negative pressure was also demonstrated by constructing a model. The model consisted of a chamber that had an opening at the top through which a glove was hung inside representing the alveoli. The bottom of the chamber was covered with rubber sheeting that represented the diaphragm. When the rubber sheeting was pulled downward, negative pressure was created inside the chamber causing the expansion of the glove representing the alveoli. A similar model consisting of a syringe and plunger was also used (4). The concept of ventilation/perfusion ratio was also demonstrated with a model (18). Several additional models were also used to demonstrate concepts (26).

Many concepts were also presented during role playing (14). For example, control of ventilation was presented by having students act as different receptors, centers, and effectors. The receptors, centers, and effectors were connected by strings. The students acted out the entire process of the control of respiration by controlling each other with the help of the strings.

Interactive games (1, 16, 19) were used to review material previously presented in class. A “Who Wants To Be A Physician” game was constructed based loosely on the popular television show “Who Wants To Be A Millionaire” (17). This game was constructed in the form of a manual consisting of a bank of questions in various areas of pulmonary physiology: basic concepts, pulmonary mechanics, ventilation, pulmonary blood flow, pulmonary gas exchange, gas transport, and control of ventilation. Detailed answers were included in the manual to assist the instructor or player in comprehension of the material. The “Who Wants To Be A Physician” game is an active-learning exercise because answering the questions requires not only knowledge of fundamental pulmonary concepts previously presented in class, but tests the student’s ability to apply this information as well.
Another professor presented virtually identical content to 84 graduate students using the traditional lecture format. The graduate class consisted of 12 lectures of 50 min each. This scenario provided an opportunity to compare the effectiveness of the active-learning strategies with the traditional lecture format.

To compare the effectiveness of the active-learning strategies with the traditional lecture format, the traditional group students were requested to take the same respiratory physiology examination that the active-learning group took in addition to their traditional (graduate) respiratory physiology examination. Thirty-eight traditional group students volunteered to take both the traditional (graduate) and active (medical) respiratory physiology examination. The performance of the traditional group was compared with the performance of the active-learning group.

The active (medical) respiratory physiology examination consisted of 33 single-best type multiple-choice questions, which were constructed by the professor who taught the active-learning group. A one-way ANOVA was used to evaluate differences on the examination in each of the three conditions: graduate students on the traditional (graduate) respiratory physiology examination \( (n = 84) \), volunteer graduate students on the active (medical) respiratory physiology examination \( (n = 38) \), and medical students on the active (medical) respiratory physiology examination \( (n = 252) \). Graduate students represented the traditional learners, whereas medical students represented active learners. Pairwise group differences were evaluated using the Bonferonni post hoc test.

**RESULTS**

Figure 1 presents the percentage ± SE of correct answers on the multiple-choice examinations of the traditional (graduate) and active-learning (medical) group for the respiratory component of the physiology courses. The mean percentage of correct answers of the traditional group \( (n = 84) \) on the traditional (graduate) respiratory physiology examination and the traditional volunteer group \( (n = 38) \) on the respiratory physiology examination developed for the active-learning group was 60 ± 1.5 and 61 ± 2.2, respectively. There was no significant difference on the performance of the traditional group on the traditional (graduate) respiratory physiology examination and the traditional volunteer group on the active (medical) respiratory physiology examination. These results suggest that the traditional (graduate) and active (medical) respiratory physiology examinations were similar in content and difficulty. However, the mean percentage of correct answers for the active-learning group \( (n = 252) \) on the active (medical) respiratory physiology examination was 86 ± 1.0. The active-learning students performed significantly better \( (P < 0.05) \) than the traditional group students on the same examination.

**DISCUSSION**

In this study, we compared the effectiveness of active-learning strategies with the traditional lecture format on the respiratory component of two individual physiology classes. The major finding of this study is that students who learned respiratory physiology using active-learning strategies did significantly better on the respiratory physiology examination than the students who learned respiratory physiology using the traditional lecture format.

The enhanced performance on the respiratory physiology examination of the students who learned using active-learning strategies may be due to an enhanced attention during the class. One of the concerns associated with the traditional lecture format is an inability of many of the students to listen effectively over a sustained period, no matter how skillful the lecturer may be (3, 6). The progressive fall in concentration may be due to fatigue of the teacher and/or students, student boredom, or lack of variety in the teaching method. For this reason, Stuart and Rutherford (27) suggested that lectures of 25–30 min may be more appropriate than the conventional 50 min. Thus, in the active class, each 50-min session was organized into three or four short presentations of 12–20 min (20). Each presentation was followed by a one-question multiple-choice quiz on the topic discussed. Students were allowed 1 min to think and to record their first answer. Subsequently, students were allowed 1 min to discuss their answers with their classmates and possibly correct their first response. The opportunity to discuss questions with classmates enhanced students’ attention and facilitated understanding of ma-
Ruhl and colleagues (21) also reported increased performance on quizzes when the instructor paused for 2 min to allow discussion.

Active-learning strategies reach all types of learners in the visual, auditory, and kinesthetic and tactile schemes. This could be another reason for the better performance of the active learners on the examination. The traditional lecture format assumes that all students acquire the same information, presented orally at the same pace without dialogue with the presenter (6, 12). In addition, the traditional lecture format assumes that students are auditory learners and have a high memory capacity (12). However, learning style is not the same for every student. Some students learn best by observing. Other students learn mainly by direct involvement in the activity (25). In this study, the active group used models, demonstrations, and discussions. Models and demonstrations assure that visual learners are taught in their preferred mode. Auditory learners were reached during discussion, debate, games, and by answering questions. Kinesthetic learners understood the material by manipulating the models and role playing. Thus targeting all types of learners with different active-learning strategies increased student’s involvement in the educational process.

Active-learning strategies assure that students are actively involved in the educational process. When students are actively involved in the educational process, students enhance their ability to utilize cognitive skills, creative thinking, judgement, interpretation, and problem-solving skills. When students are actively
engaged with the subject and learning process, they are more likely to undertake a deep approach to learning and improve their academic performance (10, 24). Thus the better performance by the active learners on the respiratory physiology examination was achieved by creating an active-learning environment in the classroom. It has been suggested that students who are actively involved in the learning process not only show better academic performance, but also develop an intellectual passion for wanting to understand and know the material. This fosters an attitude on the part of the student consistent with lifelong learning (24).

Limitations
Research is the key to unlocking the potential of teaching as a profession. The future of teaching as a profession may depend, in part, on our scholarly pursuit of educational research. Shall we be technicians or shall we be professionals with a scientific basis to our work (2)? Can we perform research that will directly improve teaching and learning? Can we document the effectiveness of our strategies by professional level research, or are we doomed to being second-class citizens in the academic community? Both great needs and great possibilities exist for research in teaching and learning. The challenge is awesome, even with its usually accepted limits. Unless major efforts are made in educational research, students are doomed to learning with strategies where the science behind them is not as strong as the faith, and teachers will fall short of their potential. To address this issue, we designed a study to determine the effectiveness of active-learning strategies. It is important to note, however, that our approach and experimental design have limitations. There are a number of limitations because it is difficult to compare classes of different students and teachers. Specifically, it is difficult to equate the abilities and motivational levels of the students and teachers. Therefore, results must be interpreted with these limitations in mind. Furthermore, only volunteers from the traditional group (38 of 84 students) completed the active (medical) respiratory physiology examination. Because the volunteer students were not identified, the performance of the volunteer traditional group was compared with the entire traditional group. Although this is a limitation, it was done this way because we felt that students would not volunteer if they were required to reveal their identity.

Another limitation of this study is that the active-learning group did not take the traditional group examination. This prohibited an important comparison. Practical problems associated with scheduling the examinations prevented us from doing this comparison. It is also possible that the active-learning students were better performers on multiple-choice examination than the traditional group students. This may have caused an enhanced performance of the active-learning students on the respiratory physiology examination. However, there is no documentation supporting this hypothesis. This issue could have been indirectly addressed by comparing the performance of the volunteer traditional group students on another section of the course with the performance of the active-learning students on that portion of the course. However, pragmatic difficulties involved in equalizing the examinations prevented us from performing this comparison.

Despite these difficulties, we compared the performance of students from two different programs. Although students from two different programs were compared, the content of the two courses was virtually identical. It is important to note that the mean percentage of correct answers of the traditional group on the traditional (graduate) respiratory physiology examination and the traditional volunteer group on the respiratory physiology examination developed for the active-learning group was 60 ± 1.5 and 61 ± 2.2, respectively. These results suggest that the traditional (graduate) and active (medical) respiratory physiology examinations were similar in content and difficulty. In addition, the difference in the performance of the active learners and the traditional learners on the respiratory physiology examination was striking (~25 points). This large difference in the performance on the same examination suggests that at least part of the enhanced performance of the active learners could be due to active involvement in learning.

In conclusion, by creating an active-learning environment in the classroom, student involvement in the educational process is increased. By increasing
students' involvement, academic performance is improved. In addition, by actively involving the students in the educational process, students may recognize and accept their responsibility for lifelong learning and continued professional development.

We thank Michael F. Copado, audio/visual technician, for expert technical assistance during the year.

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Received 21 August 2000; accepted in final form 20 March 2001.

REFERENCES


