HOW WE TEACH | Classroom and Laboratory Research Projects

Effect of a small-group, active learning, tutorial-based, in-course enrichment program on student performance in medical physiology

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Powell JM, Murray IVJ, Johal J, Elks ML. Effect of a small-group, active learning, tutorial-based, in-course enrichment program on student performance in medical physiology. Adv Physiol Educ 43: 339–344, 2019; doi:10.1152/advan.00075.2017.—Physiology is one of the major foundational sciences for the medical curriculum. This discipline has proven challenging for students to master due to ineffective content acquisition and retention. Preliminary data obtained from a survey completed by “low-performance” students (those maintaining a grade average below the passing mark of 70%) at Morehouse School of Medicine reported that students lacked the ability to adequately recognize and extract important physiological concepts to successfully navigate multiple-choice assessments. It was hypothesized that a specially designed, small-group, active learning, physiology in-course enrichment program would minimize course assessment failure rates by enhancing the ability of low-performance students to effectively identify important course content, successfully perform on multiple-choice assessments, and, thereby, improve overall course performance. Using self-report surveys, study skills and test-taking deficiencies limiting successful comprehension of course material and examination performance were identified. Mini-quiz assessments and assignments in formulating multiple-choice examination questions were given to help students recognize and solidify core concepts and improve test-taking ability. Lastly, self-report surveys evaluated the effectiveness of the enrichment program on overall course performance. Results showed a marked improvement in student confidence levels with regards to approaching multiple-choice assessments, and a significant improvement in grades achieved in the physiology component of the first-year curriculum, as 100% of participants achieved a final passing grade average of ≥70%. It was concluded that students became more proficient in identifying, understanding, and applying core physiological concepts and more successful in mastering multiple-choice questions.

INTRODUCTION

Physiology is one of the major foundational sciences for the medical curriculum, and a sound understanding of this discipline underpins good medical practice (2, 11). A study completed by Michael (7) reported that 48% of students found physiology “hard to learn,” and several students also confirmed it to be one of the most challenging courses in their medical curriculum (7, 9). Many professors have also noted that too few of their students manage to master physiology at an acceptable level and have discovered that students require extra support in understanding basic physiological concepts (7). The ultimate goal of physiology education is to help students gain sufficient mastery of this discipline so that it can be applied in the clinical setting (10).

During the first year of medical school, students are faced with a number of significant challenges that often limit their success in achieving this goal of proficiency in physiology. Aside from a demanding course load, compounding this challenge is the excessive volume of material presented in a very short time frame. As such, the manner in which most students approach learning physiology has been a major obstacle (10). Students are unsure about what information they are expected to understand and master long after the course is complete (7). This problem has also been encountered at the Morehouse School of Medicine (MSM). Given that first-year students enter medical school with very diverse academic backgrounds and learning styles, it becomes difficult for many to comprehend what information is significant and how to learn and retain it effectively. At MSM, many students were unable to successfully pass the physiology portion of their examinations, which was likely due to ineffective content acquisition and retention. It was noted that 67% of our “low-performance” students (those maintaining a grade average below the passing mark of 70%) prepared for their examinations by simply reading their notes and/or textbooks once over, whereas 30% admitted to cramming the night before a quiz or examination (unpublished data). While these students reported that they felt sufficiently prepared to successfully pass their examinations, studies have shown such approaches to the acquisition of knowledge do not adequately and actively engage students in the learning process nor allow long-term retention to occur (1, 4). It was also noted that ~95% of our low-performance students lacked the ability to recognize and extract important physiological concepts to successfully navigate multiple-choice questions (unpublished data).

Several studies document that an effective way to help students learn physiology is through active learning processes, whereby students take ownership over their learning and be-
come more focused and engaged in the process (1, 5, 8). Although this learning approach may promote the development of students’ skills in critical thinking and motivate students toward further learning, it does not teach the student specifically how to learn important course information. The development of study and learning skill strategies to assist students in becoming more proficient in identifying core physiological concepts and successful in approaching and mastering multiple-choice examination questions (MCQs) is a critical educational issue that needs to be addressed. To reduce failure rates and preserve the integrity and objectives of the physiology component of our first-year medical curriculum, we designed a small-group, active learning, tutorial-based, in-course enrichment (ICE) program for low-performance students to help adjust their learning and test-taking behaviors with the goal of solidifying their recognition, comprehension, and application of important physiological concepts and improving their performance on multiple-choice assessments, so as to reduce assessment failure rates and successfully pass the physiology course.

The intention of the present study was to investigate the impact of ICE sessions on improving student performance and successful completion of the physiology component of the first-year medical curriculum at MSM. It was hypothesized that this specially designed ICE program would minimize course assessment failure rates by enhancing the ability of low-performance students to effectively discern and apply significant course information, improve performance on multiple-choice examinations, and, thereby, successfully improve overall course performance.

MATERIALS AND METHODS

Originating as informal tutorial sessions to assist students with their understanding of challenging physiological concepts, these sessions became formalized into an official ICE program. Through iterative student feedback processes, such as informal interviews and survey evaluations, along with the identification of effective teaching methods and the introduction of various learning and test-taking strategies, the ICE program was further developed to also effectively minimize student failure rates on course assessments. These 2-h weekly interactive, nonlecture-based, small-group sessions were conducted by one professor, in a conference room, and operated congruently with the traditional lecture-based physiology curriculum over the course of the full academic year, August to May. The average total class size was 50 students, and the average ICE group size ranged from 7 to 8 students over the years of this study. The majority of students who attended these sessions were of African-American descent, and students’ participation was voluntary. Data were collected from MSM medical students from 2006 to 2009, all identifying information was kept confidential, and all data presented were aggregated. Although this study involved the use of educational tests, interviews, and survey procedures, it was not considered to be research, as determined by the Institutional Review Board committee.

Session Participants/Student Selection

Initially, low-performance students were identified from the traditional lecture-based physiology course based on physiology grades achieved on both quiz 1 and examination 1. Grades from those two assessments were evaluated, and only those first-year medical students whose average physiology grade fell below the passing mark of 70% received a confidential invitation via e-mail to attend the ICE sessions. Due to ethical considerations, there was no non-ICE comparison group, as those students with failing grades could not be knowingly excluded. All students who received an ICE invitation were able to opt out at any time; however, all students voluntarily attended with a 100% compliance rate for the entire academic year-long duration of the course.

Student Self-Evaluation Pre-Survey to Identify Weaknesses

A self-report survey regarding confidence levels, test preparation, and study habits was administered to each student (see the APPENDIX). We should note that not all participants completed the survey. In addition to personal comments, Likert-style ratings (extremely good, good, average, poor, extremely poor) were used. Examples of survey questions included:

1. Describe your level of understanding physiological concepts.
2. Describe your level of confidence on passing the physiology course.
3. Briefly describe your studying habits before attending session (i.e., studied in the mornings or late night; crammed before exams or studied daily).

Using MCQs to Identify Important Test-Taking and Knowledge-Based Concepts

Mini-quizzes. At the beginning of each session, students were administered a practice mini-quiz consisting of 10–20 MCQs, designed to include core concepts and terminology relating to the physiology content for that corresponding week, in a simulated test-taking environment. Approximately 40 assessments were administered over the course of the yearly ICE program. The MCQ mini-quizzes were developed based on difficult concepts as identified from student feedback, as well as personal experience and observations as a student, peer-tutor, and professor. Selected answer choices were analyzed, and assessments of knowledge base and preparatory effectiveness were made. The mini-quizzes were used as formative assessments, whereby performance was neither graded nor recorded; however, feedback scores acquired from mini-quizzes based on difficult concepts were used for concrete experience and self-reflection for further improvements.

Formulating MCQs. Students were also required to formulate their own MCQs based on course material covered during the previous week. A paradigm for designing poor, good, and exemplary questions was explained from personal experience in creating summative assessments. Each student was then required to construct one question and develop it from a poor to good or exemplary question. Student-generated MCQs were then presented during the session, critiqued by peers and the professor. The practice of creating MCQs was to incorporate active learning techniques in assessing the student’s depth and scope of physiology knowledge and their ability to apply content knowledge and to enable students to compare the quality of their questions to standardized questions.

Final Assessment and Exit Survey

Objective and subjective measures were implemented to determine the overall effectiveness of attending ICE sessions. Student performance in ICE was assessed using their final grade in the lecture-based physiology course in comparison to their grade on entry into the program. On completion of the physiology course, students were asked to complete a self-reporting exit survey evaluating their session experience and its effectiveness in enhancing their learning skills and ability to successfully navigate through the medical physiology course (APPENDIX). Despite 43 students having participated in the ICE program, only 24 students were compliant in completing the requested surveys. Results determined positive or negative changes in studying habits and confidence levels. In addition to personal comments, Likert-style ratings (strongly agree, agree, neutral, disagree, strongly disagree) were used. The following are examples of survey questions to be included:

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1. The sessions improved my studying habits.
2. The sessions improved my test-taking confidence.
3. The sessions improved my understanding of physiological concepts.
4. The sessions improved my physiology grades.

Statistical Analysis

Sample size was sufficiently large (n = 43) enough to use a one-sample t-test to assess statistical significance of the observed improvement in scores. Since all students began the course failing (grade point average < 70%), postintervention scores were compared with a hypothetical preintervention mean of 69%.

Because preintervention scores were not available, a paired t-test was impossible. Because of this and because many students' true preintervention grade point average was lower than 69, this test was likely to underestimate, rather than overestimate, statistical significance of results. However, we chose to maintain a conservative P value for significance of 0.05.

RESULTS

Figure 1A shows that, on entering the ICE program, none of the students was passing the physiology course. Despite main-

A

Initial Grade (Rank)

B

Understanding Concepts (%)

C

Confidence of Passing Course (%)

Fig. 1. A: academic performance before attending enrichment program. Number of students are shown with physiology course grades below D (<70%) before participating in the program (2006–2009 survey respondents: n = 24). This is expected as only students at risk of failing the course were entered into the program. B: level of understanding physiological concepts before attending enrichment program. Approximately 17% of students self-reported by survey to having a poor knowledge of physiological concepts before participating in the program (2006–2009, survey respondents: n = 24). However a large proportion (83%) overestimated their capability. C: level of confidence in passing course before attending enrichment program. Approximately 29% of students self-reported by survey their level of confidence in passing the physiology course as poor or average (2006–2009 survey respondents: n = 23). However a large proportion (72%) overestimated their confidence of success.

taining failing grade averages <70%, overall, 83% and 71% of the students self-reported that they were confident in their ability to understand the physiological concepts and successfully pass the course, respectively (Figs. 1, B and C). Considering pre-ICE grade averages were <70%, statistical analysis shows a significant improvement in physiology course grades after attending the ICE program (Fig. 2, P < 0.0001). Figure 2 and Table 1 both show that, of those students enrolled in ICE, 100% successfully passed the physiology course with a final grade of >70% after completing the program. Although our results showed the average final grade scores of ICE students to be less than those of the non-ICE students at 77% and 82%, respectively, indicating that they were weaker students overall, our results also demonstrated the value of the ICE program in helping students pass the physiology course (Fig. 2). Students evaluated their level of improvement with regards to their study habits, test-taking confidence, understanding of concepts, and overall grade averages. The median responses for the Likert ranking “strongly agree” or “agree” per the total responses, as well as the sum of all positive responses (agree and strongly agree categories) are shown in Table 2. Table 2 also shows that 95.6% of student participants “agreed” and “strongly agreed” that completing the program was useful in helping to improve their level of understanding physiological concepts, as well as their level of confidence in their test-taking ability. Additionally, 87.5% of students found the program helpful in improving their study skill habits, as well as their overall academic performance. Figure 3 and Table 3 show that 100% of student participants “agreed” or “strongly agreed” on the usefulness and effectiveness of the ICE program in improving their overall academic performance and would recommend the program to incoming first-year students. The results are summarized in Figs. 1–3 and Tables 1–3.

Table 1. Failure rate pre- and postintervention

|               | Intervention | Post (n = 43) |
|---------------|--------------|--------------|
| ICE students failing (grade below D, 60–69%), % | 100 | 0 |

n = 43 Students who participated in the in-course enrichment (ICE) program; n = 24 students who completed the requested surveys. All students who entered the program were failing the physiology course with grades <70%. After attending the enrichment program, no student failed the physiology course. Pre, before ICE; Post, after ICE.
Table 2. *Student-evaluated improvements*

| Improved Study Habits | Improved Test-Taking Confidence | Improved Understanding of Concepts | Improved Grades |
|-----------------------|---------------------------------|-----------------------------------|-----------------|
| Median, $n$           | 11/24                           | 16/23                             | 12/24           | 11/24           |
| Strongly Agree        |                                 | Agree                             | Agree           | Agree           |
| Sum of positive responses |                              | %                                 |                  |                  |
|                       | 21/24                           | 16/23                             | 12/24           | 11/24           |
| $n$                   | 87.5                            | 95.6                              | 95.8            | 87.5            |

Students evaluated their improvement in the different categories shown. Values are the no. ($n$) of median responses for the Likert rankings Strongly Agree or Agree out of the total no. of responses, as well as the percentage of all positive responses (Agree and Strongly Agree categories), along with the no. ($n$) of positive responses out of the total no. of responses.

**DISCUSSION**

The present study investigated the impact of a supplementary active learning, tutorial-based ICE program on improving student academic performance, reducing course failure rates, and enabling successful completion of the physiology component of the first-year medical curriculum. As hypothesized, the ICE program did enhance the ability of low-performance students to identify, understand, and apply important physiological concepts, perform successfully on multiple-choice examinations, and significantly improve overall academic performance to successfully pass the physiology course.

Several studies have examined the utility of small-group-based supplemental instruction programs in increasing student academic success in the medical education setting and reported findings consistent with those from our study. Recent investigations found that students who participated in voluntary medical physiology small-group-based supplemental tutorial sessions scored significantly higher on class quizzes compared with their pretutorial scores (3). Earlier research also confirmed positive effects after the implementation of a voluntary supplemental instruction small-group program at the University of Southern California School of Medicine for at-risk first-year medical students, concluding that voluntary supplemental instruction significantly increased mean examination scores and reduced the failure rate for those at-risk students by 46% (13).

Before attending our ICE program, all low-performance students were failing the course, with grade averages < 70%, likely due to a difficulty in identifying and applying important physiological concepts on multiple-choice assessments. Although student participants entered the ICE program with failing grades, most felt they had an average to good understanding of the physiological concepts and felt quite confident in their ability to pass the course without intervention, suggesting an over-optimistic belief in their aptitude. In following Kolb's learning style (4), a concrete experience of completing MCQs, followed by reflective observation of the experience, allowed for the identification of important physiological concepts. These active learning skill-building exercises were able to enhance student recognition of relevant course content, identify any ensuing knowledge gaps, and reinforce the application of difficult and/or important theoretical concepts on multiple-choice assessments.

The physiology course began with the neurophysiology and gastrointestinal modules, with the introduction of the more difficult modules, cardiovascular, pulmonary, and renal, toward the second half of the curriculum. While attending the program for the duration of the full academic year, students showed a marked improvement in their level of understanding and applying physiological concepts on MCQ assessments, as well as an increased level of confidence in their refined studying habits and test-taking abilities. With the integration of active-learning skill approaches, an improved theoretical understanding, along with increased self-confidence to perform effectively on assessments, the positive impact of consequent academic success and/or absence of academic failure seemingly played an important role in the students' successful completion of the physiology course. Additionally, the quality and effectiveness of our weekly small-group ICE sessions may have been due, in part, to the number of students participating in the sessions. Recent studies found that smaller groups, consisting of 8–10 students, may be preferred for team-based learning groups (15). The group of students attending the ICE program was of a similar number, and it was our experience that this intimate group size fostered a cooperative rather than competitive interactive teaching environment, thereby encouraging and strengthening classmate collegiality. As such, this

Fig. 3. Usefulness of the enrichment program and student recommendation. 100% of surveyed student participants agreed or strongly agreed that the enrichment program was useful for improving academic performance and would recommend its use to incoming first-year medical students (10 students strongly agree, 14 students agree; survey respondents: $n = 24$).

Table 3. *Overall effectiveness of enrichment program on improving academic performance*

| Student Evaluation of ICE | Rank |
|---------------------------|------|
|                           | 4 ± 0.7 |

Value is mean ± SD; $n = 24$ student evaluations. The ranking was on a Likert scale from 1 to 5, with 5 being the highest. Approximately 80% of students considered the program to be very or extremely effective in helping them improve their overall physiology course performance. ICE, in-course enrichment.
aspect may have contributed to how highly rated these sessions were among medical physiology students at MSM.

Although the average final grade scores of those who attended the enrichment program were lower than those of students who were not invited to join the sessions, the ICE students began as the weaker cohort within the class, with failing grades, yet still managed to successfully navigate and pass the physiology course. With an increased level of confidence in their enriched study skill techniques, enhanced ability to identify, understand, and apply difficult physiological concepts, and refined test-taking ability, all 100% of student participants found the ICE program to be effective in improving their overall academic performance in physiology and would recommend the program to incoming first-year medical students. These outcomes were consistent with previous studies that showed that, as medical students progress through their studies, they become more receptive toward small-group learning and better appreciate its effectiveness (12). Currently, there exists a sufficient amount of data that support the use of small-group learning to supplement medical curriculum at the basic sciences level, as well as the notion that those small-group sessions, similarly to our ICE program, are meaningful tools to significantly enhance medical student performance in various first-year subjects, including physiology.

A limitation of this study was that a nonstandardized survey was used to assess learning behaviors and anxiety levels. Thus our survey data cannot be effectively replicated in other studies. Additionally, the survey results may have been influenced by the fact that they were administered in the conference room with all students present. The solution to this is that, in future studies, the use of the published and validated Kolb Learning Style Inventory and the State-Trait Anxiety Inventory surveys would allow for those factors impeding successful student performance to be identified in a more standardized fashion (4, 14). Additionally, the initial and final surveys should also be administered using an online platform to maintain confidentiality. Using a standardized and validated instrument for assessing study skills, such as the Learning and Study Strategies Inventory, or the Motivated Strategies for Learning Questionnaire, would also allow for comparisons between different educational institutions (6).

The ICE program was designed to focus on teaching students how to organize, prioritize, and memorize relevant course material to overcome limited comprehension and application of course material, as well as increase test-taking confidence to overcome compromised performance on course assessments. Our findings suggest that the small-group, active learning, tutorial-based ICE program was an extremely valuable resource for enhancing the ability of low-performance students to effectively identify, understand, and apply difficult and/or important physiological concepts and improve performance on multiple-choice assessments, thereby reducing academic failure and enabling students to successfully navigate physiology and significantly improved their overall course performance. As a result of our investigation, we anticipate that students will become more proficient in identifying, understanding, and applying core physiological concepts and become successful in mastering multiple-choice assessments, thereby achieving academic success. Conclusions from this study may provide a strong basis for the implementation of similar ICE programs as an academic support, not only in other medical school courses within MSM’s first-year curriculum, but in all medical institutions worldwide.

APPENDIX: PHYSIOLOGY ICE PROGRAM SURVEY

Physiology Session Questionnaire

Before Attending Sessions:

1. What was your physiology grade before receiving an invitation to attend session? (Please circle one) (<60%) (60–62%) (63–65%) (66–69%) (70–72%) (73–75%) (76–79%) (80–82%) (83–85%) (86–89%) (90–92%) (93–95%) (96–99%) (100%)
2. Describe your level of understanding physiological concepts. Extremely Good Good Average Poor Extremely Poor
3. Describe your level of confidence on passing the Physiology course. Extremely Good Good Average Poor Extremely Poor
4. Describe your level of confidence on passing the Physiology course. Extremely Good Good Average Poor Extremely Poor
5. Do you feel able to effectively recognize and extract important physiological concepts to successfully navigate multiple-choice questions? (Yes/No)

After Attending Sessions:

6. During which academic year did you participate in session? (Please circle one) 2005–6 2006–7 2007–8 2008–9 2009–10
7. How many days a week did your sessions occur? 2 3 4 5 6 7
8. Approximately how long was each session? 2 hours 3 hours 4 hours 5 hours 6 hours
9. Did you attend sessions throughout the entire academic year? Yes No
10. Did you attend sessions on a consistent basis? Yes No
11. Did you pass the Physiology course? Yes No
12. What was your final Physiology grade? A B C D E F G
13. The sessions improved my studying habits:
   - Strongly Agree
   - Agree
   - Neutral
   - Disagree
   - Strongly Disagree
14. The sessions improved my test-taking confidence:
   - Strongly Agree
   - Agree
   - Neutral
   - Disagree
   - Strongly Disagree
15. The sessions improved my understanding of physiological concepts:
   - Strongly Agree
   - Agree
   - Neutral
   - Disagree
   - Strongly Disagree
16. Describe your level of understanding physiological concepts. Extremely Good Good Average Poor Extremely Poor
17. The sessions improved my physiology grades:
   - Strongly Agree
   - Agree
   - Neutral
   - Disagree
   - Strongly Disagree
18. The sessions were useful overall:
   - Strongly Agree
   - Agree
   - Neutral
   - Disagree
   - Strongly Disagree
19. You would recommend these sessions to future first-year students: Strongly Agree
20. Describe what you liked most about session. (Please give an example.)
21. What aspects would you recommend keeping? (Please give an example.)
22. Describe what you liked least about session. (Please give an example.)
23. What aspects would you change and improve upon? (Please give an example.)
24. On a scale of 1–5 (with 5 being the highest and 1 being the lowest), please rate the overall effectiveness of these sessions.

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Disclosures

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AUTHOR CONTRIBUTIONS

J.M.P. conceived and designed research; J.M.P. performed experiments; J.M.P., I.V.M., and M.L.E. analyzed data; J.M.P., I.V.M., J.J., and M.L.E. interpreted results of experiments; J.M.P. and I.V.M. prepared figures; J.M.P., I.V.M., J.J., and M.L.E. drafted manuscript; J.M.P., I.V.M., J.J., and M.L.E. approved final version of manuscript.

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