INSTRUCTIONAL DESIGN AND ASSESSMENT

Expanding Voluntary Active-learning Opportunities for Pharmacy Students in a Respiratory Physiology Module

Hardy Ernst, PhD, and Kay Colthorpe, PhD

Submitted June 5, 2007; accepted August 23, 2007; published April 15, 2008.

Objectives. To expand voluntary active-learning opportunities for bachelor of pharmacy students enrolled in a third-year human physiology and pharmacology course and determine whether the additional course components improved learning outcomes.

Design. Additional voluntary active-learning opportunities including a large-class tutorial, additional formative assessment, and an online discussion were added to the Respiratory Physiology Module of the course. Examination scores were compared with those from previous years. A questionnaire was administered to assess students' perception of the active-learning components.

Assessment. Mean examination scores increased from 69.3% $\pm$ 24.4% in 2003 to 88.9% $\pm$ 13.4% in 2004 and 86.9% $\pm$ 17.6% in 2005, after the addition of the active-learning components. Students' overall perception of the value of the active-learning activities was positive.

Summary. The addition of voluntary active-learning course components to a required pharmacy course resulted in improved student examination scores, and decreased failure rate, and were accomplished at low cost and with little additional staff time.

Keywords: active learning, respiratory, online discussion forum, formative assessment

INTRODUCTION

Learning is an active process.¹⁻³ *Active learning* is defined as "the process of having students engaging in some activity that forces them to reflect upon ideas and how they are using those ideas."⁴ Active learning can occur when students become actively engaged in the learning process by participation in activities that require them to consider their understanding and incorporate new information into their personal conceptual framework. Furthermore, interactive respiratory physiology lectures with embedded active-learning activities have been shown to significantly improve learning outcomes.⁵⁻⁷

Accordingly active learning had been incorporated into the third-year human physiology and pharmacology course of the bachelor of pharmacy degree program at the University of Queensland, Australia. However, despite the active-learning activities included in 5 lectures and 1 laboratory class, there was high variability in student performance in the summative assessment of this module, and over 20% of students did not achieve a passing grade. The active-learning activities within the interactive lectures and the laboratory class, while tremendously valuable, offered only a limited time for the students to apply newly presented information and key physiological con-

cepts, thereby limiting the effectiveness of these activities in promoting knowledge construction and developing problem-solving skills. In order to decrease the number of underachieving students and further improve learning outcomes, we redesigned the module to include additional voluntary course components that offered the students further opportunities for active learning outside the lectures and the laboratory class. The objective of this intervention was to determine whether the introduction of voluntary active-learning activities outside the official contact hours decreased the number of underachieving students.

DESIGN

The human physiology and pharmacology course we selected for this study is the last of a series of 3 integrated physiology and pharmacology courses in a 4-year bachelor of pharmacy degree program. It is offered concurrently with 5 other courses in the second semester of the third year of the program. The course contains 4 main content modules: treatment of infection, cancer chemotherapy, respiratory physiology, and respiratory pharmacology. Students' mastery of all 4 modules is assessed in an end-of-semester examination, with respiratory physiology comprising approximately 30% of that examination.

In 2003 the respiratory physiology module was delivered by five 50-minute interactive lectures to all

Corresponding Author: Dr Hardy Ernst, PhD, The University of Queensland, St Lucia, Queensland Australia. E-mail: h.ernst@uq.edu.au

students and one 2-hour laboratory class, which was repeated 3 times to a smaller class size of approximately 60 students. These lectures were designed to maximize active-learning opportunities for the students and were similar to the interactive lectures described by Ernst and Colthorpe.⁵ The lectures consisted of 10- to 15-minute didactic sections each concentrating on one content focal point, interspersed with activities such as 2-minute buzz groups and/or whole class discussions. These were triggered by questions that required understanding and application of physiological concepts that were taught in the preceding section(s). The questions, often posed in multiple parts, generated a variety of responses from within small groups of learners which expanded to whole class discussions. Facilitator encouragement of these class discussions enabled other students to provide further input until the collaborative learning activity enabled whole group understanding of the issues. Each lecture contained at least 3 active-learning activities, which constituted between 25% and 35% of the total lecture time. In the laboratory class, students were introduced to spirometry, and working in pairs, students tested their own lung volume and lung function using a vitalograph spirometer and a flow-volume loop. Following this, students were asked to form small groups to predict how the test results might differ in a range of patient case scenarios, including in patients with large airway obstruction disease, asthma, emphysema, and fibrosis. At the end of the laboratory class each clinical scenario was discussed, and a detailed learning resource was uploaded on the course web site.

In 2004, in addition to the lectures and the laboratory class, we included additional voluntary components, an online discussion forum, additional formative assessment, and a 50-minute large-class tutorial. To further validate our findings, we repeated the study in 2005. In 2006, due to changes beyond our control, we were no longer able to offer the additional components and reverted to the original lectures/laboratory class format.

The web-based on-line discussion forum was hosted on the discussion board of the course web site and accessible throughout the duration of the courses in 2004 and 2005. The students were familiar with these types of web-based discussion boards as they have used them in previous courses. This forum allowed anonymous postings and students could answer other students' questions. Each discussion thread was initiated by a student posting. To counteract "learned helplessness," student postings that sought information readily available in the learning resources such as the textbook were simply referred back to the appropriate learning resource. Postings seeking clarification in understanding were only addressed by teaching staff if students did not reply within 1 week or

if developing discussions revealed misunderstandings that needed to be rectified.

Formative assessment was available by access to past examination papers. In 2004 and 2005, additional formative assessment was published online 2 weeks before the large-class tutorial for the students to prepare for the tutorial. The formative assessment was comprised of 5 multipart questions that tested the students' ability to apply physiological concepts to clinical scenarios and to predict outcomes.

Approximately 50% of students participated in the 50-minute large-class tutorials. During the tutorials, students presented an answer to a question posed in the formative assessment in front of their peers. Other students were encouraged to volunteer their agreement or disagreement and their reasoning. This led to further discussions involving more of the class until a consensus was reached. The teaching staff member acted primarily as a facilitator for the discussions and only intervened when the consensus reached was incorrect or incomplete. Model answers were published online after the tutorial, allowing students who did not participate in the tutorial to also test their understanding.

The additional voluntary components were designed to enable students, with less time/place constraints, to reflect on their knowledge, to practice knowledge application, and to discuss their understanding with others online⁸ and in person. The modifications also offered students opportunities to assess their learning progress and anonymously verify their understanding. Overall, these additional opportunities for active learning should promote meaningful learning and therefore a deeper understanding of the topic.¹

The institutional resources required to implement this design in 2004 and 2005 were the use of a large room for the tutorial, additional computer access time for the students, and additional staff time of approximately 7 hours per year to convene the online discussion forum, prepare the formative assessment, and to facilitate the tutorial. We particularly set out to develop a design that could be easily adapted to other physiology modules, was cost efficient, and did not unduly increase the teachers' workload, as it is recognized that a lack of implementation of active-learning activities is often due to a perceived increase in workload.⁹

The efficacy of the redesigned module was evaluated by comparison of student performance in the respiratory physiology section of the summative examinations over the period of the study. During the same 3-year period, the student performance in the respiratory pharmacology section of the same summative examinations was used to control for any cohort variations as the respiratory

pharmacology module did not change throughout the study period. As previous examination questions were available to the students for formative assessment, it was necessary to write new examination questions for each year of the study. These questions were written and marked each year by the same teaching staff members for both the respiratory physiology section and the respiratory pharmacology section. Care was taken to ensure that the standard and degree of difficulty for questions in each topic remained the same. All questions were case-based and in short answer format, with respiratory physiology contributing approximately 20%, and respiratory pharmacology approximately 12% of the total assessment. The course content, teaching staff, and scope of the examinations did not change from 2003 to 2005. Summative results were collated in Microsoft Excel. Statistical analysis was performed in Instat (GraphPad Software, San Diego, Calif), comparing results between years using unpaired *t* tests and analysis of variance. Results were considered to be significant if $p < 0.05$. In 2006, the respiratory pharmacology results could no longer be used to control for any cohort variation as both teaching staff and assessment mode for this module were markedly changed.

Students' perception of the respiratory physiology module was evaluated in 2004 and 2005 by a questionnaire sent out via e-mail at the end of each course, prior to the students receiving their grades. The questionnaire was comprised of 4 open-ended questions, including: "Why do you think you were successful in understanding Respiratory Physiology?" and "What helped you most, lectures, the laboratory class, the tutorial, the on-line discussion forum, the practice questions, or other resources?" Student responses were coded into different categories independently by 3 investigators. If students mentioned more than 1 category, they were also included in the additional category of "combination of some or all of the course components." Interrater reliability was calculated as a correlation coefficient for the coding by the 3 investigators across all categories. Correlation for agreement between investigators was high, with a correlation coefficient of 0.92 for investigator 1 and investigator 2; 0.95

for investigator 1 and investigator 3; and 0.94 for investigator 2 and investigator 3.

ASSESSMENT

The bachelor of pharmacy program at the University of Queensland consistently has a high proportion of international students, particularly from Asian countries. Generally, the students in this course consistently achieve good learning outcomes as demonstrated by their grade point averages (GPAs). For example, the students undertaking this course in 2006 entered with a mean GPA of 5.66, on a scale of 1-7, with a standard deviation of 0.6, which equates to a mean of $80.8 \pm 8.9\%$ of the highest achievable grade in the pharmacy program. The number of students enrolled in the third-year human physiology and pharmacology course varied slightly during the period of the study, with 177 students in 2003, 153 students in 2004, 137 students in 2005, and 160 students in 2006.

The online discussion forum had over a hundred queries and discussion threads posted each year. Each query or discussion thread triggered a further 1 to 10 responses. Convening of the online discussion forum required approximately 1 hour/week of teaching staff time, spread throughout the week.

In 2003 the students performed reasonably well in the respiratory physiology section of the summative examinations with a mean score of 69.3%, but with a relatively large standard deviation of 24.4%, suggesting that there was significant variation in the performance of the students within the cohort (Table 1). Thirty-nine students did not achieve a passing grade (below 50%) in this module; this represents 22.2% of the students undertaking the course in that year (Figure 1). During 2004 and 2005, when the additional voluntary course components were included, the mean student performance increased to 88.9% and 86.9%, respectively (Table 1). This represents a highly significant difference from 2003. Furthermore, in these years, the standard deviation fell to 13.4% in 2004 and 17.6% in 2005, suggesting that the extent of the variation in student performance within each cohort was markedly reduced compared to that for 2003 (Table 1). The number of students that did not achieve a passing

Table 1. Average Student Performance in the Summative Assessment From 2003 to 2005

Year	No. of Students	Respiratory Physiology Mean Score (SD), %	Respiratory Pharmacology Mean Score (SD), %
2003	177	69.3 (24.4)	74.9 (17.1)
2004	153	88.9 (13.4) ^a	79.6 (21.9)
2005	137	86.9 (17.6) ^a	76.4 (23.8)

Values are means $\pm$ SD and expressed as percentage of possible marks (maximum 100%); *n*, total number of students

^a $p < 0.001$ compared to 2003

Figure 1. Individual student performance in respiratory physiology in 2003-2005 grouped in 10 percentile bands.

grade also fell markedly to just 4 in 2004 and 8 in 2005, representing 2.6% and 5.8%, respectively, of the students undertaking the course in those years (Figure 1). Further, in 2004 and 2005 the majority of students scored more than 90% on their summative examination. There was no significant difference between the summative results for respiratory pharmacology in 2003, 2004, and 2005 (Table 1).

Twenty-five students responded to the voluntary e-mail questionnaire in 2004, and 18 students in 2005, which constituted 16% of the student cohort in 2004 and 13% of the student cohort in 2005. Most students did not address each individual question but volunteered their thoughts in paragraph(s). The majority of responding students indicated that no single course component helped them most in understanding respiratory physiology. Instead, they mentioned several items and stressed that they benefited from the combination of different course components (Table 2).

Table 2. Coded Student Responses to the Question: "What helped you most: lectures, the laboratory class, the tutorial, the on-line discussion forum, the practice questions, or other resources?"

Response	Percent 2004 Students, ^a Mean (SE)	Percent 2005 Students, ^b Mean (SE)
Lectures	56.7 (3.5)	75.9 (0.8)
Laboratory class	24.0 (1.1)	33.3 (0.7)
Tutorial	41.3 (1.5)	55.6 (0.0)
On-line discussion forum	16.0 (0.7)	18.5 (0.6)
Formative assessment	36.0 (2.3)	31.5 (0.8)
Combination of some or all of the course components	58.7 (2.3)	83.3 (1.3)

Abbreviations: SE = standard error

^an = 25

^bn = 18

Some students offered explanations as to why they thought they were successful in understanding respiratory physiology. One student responded "I think it was the combination of learning styles that you made available to us that really helped us to understand your section – lectures followed by practice questions and a prac[tical] and availability to ask questions on the discussion forum. It tied together really well, so the repetition and the different ways of looking at it helped us understand it." Interestingly, there were some comments that suggested that not only a combination of the different course components were important, but also the attitude of the teaching staff: "It seemed as though you really cared about how we were understanding respiratory physiology, and you emphasized thinking and problem solving rather than just memorising information."

Typical responses in the lectures category were: "The subject matter requires understanding rather than rote learning. Your lecturing style enforced this requirement from the onset in that you made us think and answer questions in the classes. I left the classes exhausted from thinking but satisfied with my application." and "I found that you often didn't just give us answers, but questions, and then helped us work through them as a group, so we were proactive in our learning and also learnt from our mistakes. I had no trouble at all understanding your lectures and I've found that I even understand and remember it now while many other subjects I have already forgotten."

Typical responses in the tutorial category were: "I understood the lectures but had great difficulty in applying that knowledge, until the day of the tut [tutorial], and then everything made sense." and "It reinforced my knowledge."

Typical responses in the formative assessment category were: "The practice questions were really useful, because it gave everyone a clear idea of what level of understanding was expected of us." and "I think that [the] practice questions are incredibly useful. I know for me that the practice questions are what tied everything together, far better than just reading and reading, it actually makes your brain think about it and put it into practice."

Typical responses in the category discussion forum were: "The discussion forum enabled me to learn from others' questions and to be able to ask questions without feeling silly." and "The fast and constant feedback on the discussion forum really helped me."

Typical responses in the category laboratory class were: "I found that the prac[tical] was most helpful, we were able to use info in the prac[tical] to relate back to the lecture material." and "The format of the prac[tical] was

such that it became easy to understand, especially as we went through how the changes came about step by step.”

DISCUSSION

Students greatly benefited from the addition of voluntary course components that offered further opportunities for active-learning outside the official contact hours and that were cost efficient and not unduly time consuming for the teaching staff. When additional formative assessment, an online discussion forum, and a large-class tutorial were introduced, there was a marked decrease in the number of underachieving students and also a significant improvement in the results of summative assessment. However, due to the voluntary nature of the additional course components, we could not ensure that each student participated or benefited equally from these components. This improvement, maintained over the 2 years, is unlikely due to any cohort variations between the years given the consistency of results in respiratory pharmacology. Nor are they likely to be due to differences in summative assessment as the teaching staff and course content did not change over the period of this study and examination questions, although newly written each year, were of similar standard and required understanding of core concepts introduced in the respiratory physiology module. Further, to our knowledge, there were no additional outside influences to which this improvement may have been attributed. Interestingly, in 2006, when the additional course components were withdrawn, learning outcomes and the number of underachieving students reverted to levels similar to those of the control cohort in 2003. However, this compelling finding (although apparently supporting the result of this study) could not be verified as we were unable to control for any cohort variation in that year due to the changes in the respiratory pharmacology module. Overall, these findings add to the growing body of evidence that active learning works, recently comprehensively reviewed and discussed in relation to physiology education.¹ Furthermore, this suggests that students will take advantage of voluntary active-learning opportunities outside the official contact hours and benefit from them.

Students’ perception of the additional course components was positive, with students particularly favoring the additional formative assessment and voluntary tutorial. The responses indicated that the students valued the additional opportunities to apply physiological concepts to clinical scenarios, even though such opportunities were frequently offered during the interactive lectures and the laboratory class. Although not explicitly stated by the students, the questions used for the interactive lectures, laboratory class, and formative assessment may also have

reassured students about the validity of the learning objectives, demonstrating that assessment was based on physiological concepts. Surprisingly, only a few responding students thought that the online discussion forum helped them most in their learning, despite the fact that the discussion forum during the respiratory physiology module was well utilized, with over a hundred postings each year. Those students who did comment on the online discussion forum stressed the importance of its anonymous nature. In fact, not one student who utilized the online discussion forum in 2004 or 2005 revealed his/her identity. While students clearly favored the anonymous nature of the discussion forum, it did present a limitation of the study as we were unable to determine how many or which students were using the online discussion forum.

The interactive lectures and the laboratory class were an integral part of the respiratory physiology module. For that reason we have included the students’ perception of these activities, although the focus of this study is on the additional course components. The student responses suggest that these components, in particular the interactive lectures, were important in enhancing their understanding. This positive perception of interactive lectures is consistent with previous findings.^{5,10,11} Further, as students are encouraged to think during the interactive lectures, students perceive interactive lectures as fulfilling but exhausting learning activities.

The majority of responding students did not favor a single course component. Instead, students perceived coherence within the respiratory physiology module between all the different course components, as each activity reinforced and repeated the core physiological concepts. Therefore, this coherence may have allowed students repeated opportunities for knowledge construction. Further, it may have fostered the creation of an effective learning community in which students and teaching staff experienced a purposeful, coherent, and integrated learning environment where all engage with each other to acquire knowledge and share understanding.¹²

Previous studies have found that the majority of students tend to have a broad range of learning style preferences, implying that they benefit from a wide variety of teaching modes.^{13,14} However, a few students strongly preferred just one of the learning styles.⁶ The limited variety of learning activities offered in respiratory physiology prior to this study may have been insufficient to address the diverse needs of all students. Lunjan and Dicarolo⁷ have suggested that active-learning activities cater to all types of learners in the visual, auditory, reading/writing, and kinaesthetic scheme. The additional active-learning activities introduced in this study may have contributed to the reduction in underachieving students

by appealing to the different learning styles of students that may not have been catered to well by lectures and laboratory classes. Furthermore, the high-achieving students in this study, while already coping with the limited variety of learning activities, may also have benefited from the increased variety of learning activities and resources by utilizing additional learning styles.

SUMMARY

Additional voluntary course components that offer students further opportunities for active learning outside official contact hours were introduced. They included a large-class tutorial, additional formative assessment, and an online discussion. When additional course components were introduced, there was a marked decrease in the number of underachieving students and a significant improvement in summative assessment results. The new design appears to allow for more opportunities for knowledge application and construction, and may foster the development of an effective learning community. Furthermore, the additional course components do not unduly increase cost or teaching staff workloads. Given the good learning outcomes and low cost, the adaptation of this design to other physiological modules should be encouraged.

ACKNOWLEDGEMENT

We would like to thank Dr. Jon Good for coding the responses to the student feedback questionnaire and for proofreading the manuscript.

REFERENCES

1. Michael J. Where's the evidence that active learning works? *Adv Physiol Educ.* 2006;30:159-67.
2. Michael JA and Modell HI. *Active Learning in Secondary and College Science Classrooms.* Mahwah, NJ: Lawrence Erlbaum, 2003.
3. Odedina FT, Clemmons CD, Nikita Dukes D. Multifaceted active-learning approach to teaching pharmacy health care and behavior. *Am J Pharm Educ.* 2001;65:276-83.
4. Collins JW 3rd, O'Brien NP, eds. *The Greenwood Dictionary of Education.* Westport, Conn: Greenwood; 2003.
5. Ernst H, Colthorpe K. The efficacy of interactive lecturing for students with diverse science backgrounds. *Adv Physiol Educ* 2007;31:41-4.
6. Rao SP, DiCarlo SE. Active learning of respiratory physiology improves performance on respiratory physiology examinations. *Adv Physiol Educ.* 2001;25:55-61.
7. Reddy IK. Implementation of a pharmaceuticals course in a large class through active learning using quick-thinks and case-based learning. *Am J Pharm Educ.* 2000;64:348-54.
8. Taradi SK, Taradi M. Expanding the traditional physiology class with asynchronous online discussions and collaborative projects. *Adv Physiol Educ.* 2004;28:73-8.
9. Silverthorn DE, Thorn PM, Svinicki MD. It's difficult to change the way we teach: lessons from the Integrative Themes in Physiology curriculum module project. *Adv Physiol Educ.* 2006;30:204-14.
10. Goldberg HR, Haase E, Shoukas A, Schramm L. Redefining classroom instruction. *Adv Physiol Educ.* 2006;30:124-7.
11. Wilke RR. The effect of active learning on student characteristics in a human physiology course for nonmajors. *Adv Physiol Educ.* 2003;27:207-23.
12. Gabelnick F, MacGregor J, Matthews RS, Smith, B. Learning communities: creating connections among students, faculty, and disciplines. In: *New Directions for Teaching and Learning, No. 41.* San Francisco: Jossey-Bass, 1990
13. Fleming ND. I'm different; not dumb. Modes of presentation (VARK) in the tertiary classroom. In: Zelmer, ed. *A Research and Development in Higher Education. Proceedings of the 1995 Annual Conference of the Higher Education and Research Development Society of Australasia;* 1995;18:308-13.
14. Lujan HL, DiCarlo SE. First-year medical students prefer multiple learning styles. *Adv Physiol Educ.* 2006;30:13-6.