The efficacy of interactive lecturing for students with diverse science backgrounds

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Ernst H, Colthorpe K. The efficacy of interactive lecturing for students with diverse science backgrounds. Adv Physiol Educ 31: 41–44, 2007; doi:10.1152/advan.00107.2006.—Learning is an active process, and, as such, interactive lectures are considered as the educational best practice. This study investigated the efficacy of interactive lecturing in a module of eight respiratory physiology lectures in a second-year Physiology course with two distinct subcohorts: students with strong science backgrounds and those without. The comparison of student performance in the summative examinations of respiratory physiology allowed us to evaluate the efficacy of interactive lecturing for each subcohort. Formal teaching evaluations were used to gauge the students’ perception of interactive lectures. To further validate our findings, we repeated the study in the following year. The introduction of interactive lecturing significantly improved learning outcomes, with this improvement being maintained for the period of this study. Furthermore, students with limited prior knowledge, who had typically performed very poorly in this module, achieved a similar learning outcome to those students with a good science background. From these summative results and the students’ perceptions, we concluded that students that are alert, motivated and interested in the subject, and engaged in learning activities and that are being encouraged to think and receive constant feedback on their progress will become confident in their learning abilities and have improved learning outcomes.

active learning; learning outcomes; motivation; self-efficacy

Learning is an active process (10), and, as such, interactive lectures are considered as educational best practice. Participants at the International Union of Physiological Sciences Teaching Workshop in April 7–10, 2005 in Pali Mountain, CA, agreed that students needed to actively participate in lectures to maintain their engagement with the content (5). It is clear from recent research that students prefer to be taught by interactive lectures (15), and, therefore, it is not surprising that traditional, information-imparting lectures are characterized by poor attendance rates (8). In physiology education research, there is evidence for the efficacy of interactive lectures, and, as a result, many physiologists have developed various techniques that increase interactivity in their lectures and lead to increased student satisfaction and better learning outcomes (3, 6, 7, 9, 11, 13, 14, 16, 17).

This study investigated the effects of interactive lecturing in a module of eight respiratory physiology lectures in a second-year Physiology course offered by the School of Biomedical Science at the University of Queensland. The students undertaking this course represented two rather different subcohorts: 1) speech pathology and occupational therapy students and 2) physiotherapy students. While the entrance requirements for each of these programs were identical, the students entering physiotherapy had a much higher likelihood of entering the program with a strong science background compared with the speech pathology and occupational therapy students. That is, proportionally many more physiotherapy students had completed three or more of the fundamental sciences (chemistry, biology, and physics or mathematics) in the final year of their secondary education. For example, in an average year, ~60% of the physiotherapy students would have completed physics and 67% would have completed chemistry in their final school year, whereas only 25% of the speech pathology and occupational therapy students would have completed physics and 39% chemistry, respectively. It had been noted that in previous years, the physiotherapy students performed satisfactorily in the course, but the speech pathology and occupational therapy students struggled with physiological concepts, especially in respiratory physiology. The average student performance in the end of the semester exam for this subcohort was only 43.8% in 2003. It appears that understanding this topic requires some prior knowledge of the fundamental sciences that is often deficient in these students, which may lead to a lack of confidence and a failure to engage with the topic. We believe that active learning activities will help students apply newly presented information and key physiological concepts, therefore promoting knowledge construction. These activities should also provide them with an opportunity to develop problem-solving skills, building their confidence to tackle new problems. Furthermore, as these students often do not appear to recognize the relevance of physiology toward their professional program, activities that use clinical scenarios may increase their awareness of content relevance.

Exposing two different subcohorts to the same educational interventions at the same time allowed us to investigate the effect of interactive lectures to large audiences with diverse backgrounds and educational standards.

Our research questions were as follows:

1. Will students benefit from interactive lecturing by acquiring a better understanding of respiratory physiology, as measured by improved exam results?
2. Will students who have limited prior scientific knowledge benefit more from interactive lecturing than students with a good science background?

METHODS

We introduced active learning activities in a module of eight respiratory physiology lectures given in a second-year Physiology course for speech pathology, occupational therapy, and physiotherapy students with 249 students in the first semester
of 2004. To further validate our findings, we repeated the study with 243 students in the first semester of 2005. The comparison of student performance in the respiratory physiology component of summative examinations, over the 3-yr period from 2003 to 2005, allowed us to evaluate the efficacy of interactive lecturing for each subcohort. During the same 3-yr period, student performance in the cardiovascular physiology component of summative examinations was used to control for any cohort variations. The course content, teaching staff, and scope of the examinations did not change from 2003 to 2005.

In 2003, the respiratory physiology module was delivered using didactic lectures. In 2004 and 2005, the lectures of this module were redesigned into interactive lectures. These lectures consisted of 10-20-min-long didactic sections, each concentrating on one content focal point, with the breaks between these sections used for active learning activities such as short buzz groups and whole class discussions. Two-minute buzz groups were triggered by questions about physiological concepts that were new for students, thus testing prior knowledge and introducing the next lecture section. An example of this is “What factors determine lung volume?” Alternatively, the questions required understanding and application of physiological concepts taught in the section(s) before; an example is “Why do emphysema patients have an increased residual volume?” Another example would be “Prematurely born babies often present with infant respiratory distress syndrome due to insufficient pulmonary surfactant production. Pulmonary surfactant deficiency leads to...?” The questions were projected on the screen, and students were encouraged to discuss possible answers with the student(s) next to them. After 2 min, students were encouraged to volunteer their answers. The questions, often posed in multiple parts, normally led to whole class discussions: the questions posed generated a variety of responses from the students, allowing other students to provide further input until a consensus was reached. During these discussions, student answers were either repeated over the microphone so that all the students were able to hear the answer or, if the answering student was sitting close to an aisle, the microphone was handed over to the student. Some demonstrations and audiovisual material were also used to reinforce, visualize, or introduce physiological concepts or specific physics topics. Overall, each lecture contained at least three active learning activities, which constituted between 25% and 35% of the total lecture time.

The lecture notes for respiratory physiology were published on the course home page before the lectures. They did not contain any answers to any of the questions. After each lecture, another version of the lecture notes was published with all the questions and their answers raised during the lecture.

Learning outcomes were quantified by summative results for respiratory physiology and cardiovascular physiology short-answer questions in the end-of-semester examination. For each year of the study, new exam questions were written and marked by the same teaching staff member. The degree of difficulty of the questions and the total number of marks allocated to each topic remained the same. Each year, the questions were designed to test the students’ ability to apply physiological concepts to clinical scenarios and to predict outcomes. The results were collated in Microsoft Excel for each subcohort. Statistical analysis of summative results was performed in Instat (GraphPad Software) comparing results between years and subcohorts using unpaired *t*-tests and ANOVA. Results were considered to be significant if *P* < 0.05.

Student responses in formal teaching evaluations in 2004 and 2005 were used to gauge student perception of interactive lecturing; this information was not available for 2003. Student responses to the open-ended questions “What are this staff member’s strengths in teaching?” and “What improvements would you suggest?” were coded into major themes independently by three investigators. Interrelator reliability was calculated as a correlation coefficient for the coding by the three investigators across all themes. Correlation for agreement between investigators was high, with a correlation coefficient of 0.97 for investigator 1 and investigator 2, 0.93 for investigator 1 and investigator 3, and 0.91 for investigator 2 and investigator 3.

RESULTS

**Summative results.** In 2003, the speech pathology and occupational therapy students performed poorly in respiratory physiology with an average mark considerably below the pass mark (Table 1). They were significantly worse in respiratory physiology than the physiotherapy students (*P* < 0.001), who performed reasonably well in this topic.

Overall student performance in 2004 was high, with students achieving an average of 70.6% of possible marks in the respiratory physiology component of the end-of-semester exam compared with 49.5% in 2003. Overall, this represented a highly significant increase of over 20% (*P* < 0.01). Student performance in 2005 in respiratory physiology remained at a similar high level.

When separated into their subcohorts, the performance of the speech pathology and occupational therapy students showed an extremely significant increase (*P* < 0.001) of 25%, from 43.8% of possible marks in 2003 to 68.8% in 2004, and remained at a similarly elevated level in 2005 with 67.8% (Table 1). The performance of the physiotherapy students also

### Table 1. Average student performance in the end-of-semester exams from 2003 to 2005

<table>
<thead>
<tr>
<th></th>
<th>Physiotherapy Students</th>
<th>Speech Pathology and Occupational Therapy Students</th>
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<tbody>
<tr>
<td></td>
<td><em>n</em></td>
<td>Respiratory physiology</td>
</tr>
<tr>
<td>2003</td>
<td>98</td>
<td>59.2 ± 2.7</td>
</tr>
<tr>
<td>2004</td>
<td>88</td>
<td>73.8 ± 2.5</td>
</tr>
<tr>
<td>2005</td>
<td>86</td>
<td>79.2 ± 2.6</td>
</tr>
</tbody>
</table>

Values are means ± SE and expressed as percentages of possible marks; *n*, total number of students.
increased significantly ($P < 0.05$) although by a lesser extent (14.6%), from 59.2% in 2003 to 73.8% in 2004, and remained at a similar although slightly higher level in 2005, with an average of 79.2% (Table 1).

Student performance in the cardiovascular physiology module (which had comparable content with the respiratory module) did not change markedly from 2003 to 2005 for either of the subcohorts apart from a small decrease in the performance of physiotherapy students in 2004 (Table 1).

Student responses. Student responses from both subcohorts in the formal teaching evaluations of the interactive lecture series are shown in Table 2. Most student responses to the question “What are this staff member’s strengths in teaching?” clustered around four themes: engagement, attention, inspiration, and understanding.

Typical responses in the theme of engagement were as follows: “He allows a great deal of interaction, so that we are involved in [the] learning process,” “Involves students,” “Great class involvement,” “The lecturer made me think,” “He engages students,” “Encourages group discussions and interactions,” “Good interaction with students,” “Encourages thinking,” and “Motivates students to participate.”

Typical responses in the theme of attention were as follows: “Interesting lectures that keep you listening,” “Good pacing,” “Made it easier to keep focus and concentration,” “Maintained interest levels throughout the lecture. I could actually stay awake!” and “Enjoyable lectures, he keeps everyone awake.”

Typical responses in the theme of inspiration were as follows: “Very inspiring lectures,” “His enthusiasm made me enthusiastic about what he was teaching,” “Inspiring and challenging,” and “Lots of encouragement for further studying.”

Typical responses in the theme of understanding were as follows: “. . . heavy/difficult topic(s) was taught in such a way that is easy/easier to understand,” “Taught in a manner that allowed you to understand the material,” and “Checked our understanding.”

Some further responses were made in regard to the lecture notes, clear explanations, and approachability. These responses were grouped together into the theme of “other.”

A few students responded to the question “What improvements would you suggest?” Most of these students suggested to improve the lecture notes and to slow down the pace of lecturing.

### Table 2. Coded student responses in formal teaching evaluations in 2004 and 2005

<table>
<thead>
<tr>
<th></th>
<th>Physiotherapy Students</th>
<th>Speech Pathology and Occupational Therapy Students</th>
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<tbody>
<tr>
<td></td>
<td>2004</td>
<td>2005</td>
</tr>
<tr>
<td>$n$</td>
<td>25</td>
<td>53</td>
</tr>
<tr>
<td>“What are this staff member’s strengths in teaching?”</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engagement</td>
<td>46.7 ± 5.8</td>
<td>59.7 ± 4.5</td>
</tr>
<tr>
<td>Attention</td>
<td>40.0 ± 4.6</td>
<td>38.4 ± 4.4</td>
</tr>
<tr>
<td>Inspiration</td>
<td>68.0 ± 4.0</td>
<td>49.1 ± 0.0</td>
</tr>
<tr>
<td>Understanding</td>
<td>32.0 ± 8.0</td>
<td>32.7 ± 1.7</td>
</tr>
<tr>
<td>Other</td>
<td>24.0 ± 4.6</td>
<td>8.8 ± 5.0</td>
</tr>
<tr>
<td>“What improvements would you suggest?”</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Improved lecture notes</td>
<td>26.4 ± 1.9</td>
<td>11.4 ± 2.6</td>
</tr>
<tr>
<td>Slower pace</td>
<td>8.2 ± 0.6</td>
<td>14.4 ± 2.0</td>
</tr>
<tr>
<td>Other</td>
<td>20.0 ± 6.1</td>
<td>13.9 ± 3.5</td>
</tr>
</tbody>
</table>

Values are means ± SE and are expressed as percentages of students responding, as identified by the 3 investigators; $n$, number of students responding to the questions.

**DISCUSSION**

This study suggests that students benefited more from interactive lectures than from traditional didactic lectures. Importantly, this study also shows that this effect was more profound for those students that tended to have a limited science background. The introduction of interactive lecturing significantly improved learning outcomes, with this improvement being maintained for the period of this study. This result is unlikely to be due to differences between cohorts over the years of study, given the consistency of results from the cardiovascular module. It would have been beneficial to have used identical examination questions throughout the 3 years, but this was impossible as they were made available to students in the following year. To minimize the effect of variability, the questions used each year were focused on understanding the core concepts presented in the lectures and applying this knowledge to a given scenario. Importantly, teaching staff and course content did not change over the period of this study. Therefore, the large change in examination results seems unlikely to be entirely attributable to either a cohort effect or variations in the course itself.

The formal teaching evaluations used in this study asked students to comment on the staff member’s strengths in teaching. As the feedback given was primarily centred on the interactive lecturing style used by the staff member, we believe that these student responses are therefore indicative of their perceptions of interactive lecturing. While we do not wish to repeat here a discussion as to why interactive lecturing promotes good learning outcomes, as has been thoroughly discussed in the educational literature by many authors, as summarized by Bligh (2), we would like to highlight a few significant points that are apparent from the student feedback and that are consistent with the findings of earlier studies.

- Students enjoy being actively involved in the lecture theatre.
- The change in pace of interactive lecturing breaks the monotony of the lecture resulting in heightened attention. Students in fact said they “could actually stay awake.”
- Engagement and attention leads to a developing interest in the subject matter.
- Students that are alert, motivated and interested in the subject, and engaged in learning activities and that are...
being encouraged to think and receive constant feedback on their progress will become confident in their learning abilities and have improved learning outcomes.

The most important finding of this study is that interactive lecturing seems to have a particularly profound effect on students without strong science backgrounds. However, the reasons for this are somewhat unclear, and the student feedback did not offer any clues as to why it occurred. Both student subcohorts, those that tended to lack a strong science background and those that had a good science background, responded very positively in the formal teaching evaluations, with similar responses from each subcohort. This comes to no surprise since both subcohorts demonstrated increased learning outcomes; but, unlike in previous years, students without strong science backgrounds were in fact now able to develop a satisfactory understanding: their learning outcomes increased more than those of the students with a good science background so that both subcohorts had a very similar level of achievement. Hence, their attitudes, and therefore their responses at completion of the module, were very similar.

So why does interactive lecturing seem to have such a profound effect on students without strong science backgrounds? We suggest that the students from different backgrounds have differing attitudes toward physiology, and often those without strong science backgrounds find it difficult to recognize the relevance of the topic toward their professional program. Interactive lecturing may challenge the attitudes of these students more than normal and increase their awareness of content relevance by linking the content to clinical scenarios. It is recognized that increased student engagement leads to changes in attitudes and learning outcomes (1). Student feedback in our study undoubtedly indicates that heightened engagement and attention leads to a developing interest in physiology for those students, countering the tendency of students to withdraw from the learning process based on their subjective but, for them, very real feelings of intimidation when confronted with physiology. In addition, interactive lecturing lightens the lecture atmosphere, which may also help such students overcome their fear of science. Furthermore, the whole class discussions that develop in interactive lectures highlight and address common misconceptions held by students, allowing the more-challenged students to follow the lines of argument. Taken together, these factors may assist in keeping these students engaged in the learning process and develop confidence in their own learning ability. Students’ self-efficacy, that is, their expectation of success, is linked to academic achievement (12). The opportunity to apply key concepts to questions posed during the lecture clearly demonstrates both the techniques required to solve the problems and allows the students to recognize that they are capable of finding the solutions. This, most importantly, appears to increase their confidence, which in turn increases their expectation of success. This supports the findings of Wilke (16), who showed that active learning increases self-efficacy in nonmajor students studying human physiology, and those of Goldberg et al. (4), who found that interactivity increases the educational value of lecture time.

In conclusion, it is clear that students greatly benefit from interactive lecturing. Even the introduction of interactive lecturing in a short module within a course can be of significant benefit to the students. This supports the argument that wherever possible, interactive lecturing should be introduced. Furthermore, students with poor prior knowledge are able to overcome the disadvantage of their limited science background and achieve similar learning outcomes to those students with good science backgrounds. Given the increasing diversity of student cohorts, it is important to promote interactivity, so that all students have the opportunity to reach their full potential.

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REFERENCES