Impact of Online Learning Modules on Medical Student Microbiology Examination Scores

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Medical students have a limited amount of time in which to acquire working knowledge of an enormous amount of information, and this is especially relevant for microbiology. One large midwestern medical school is unique in having medical microbiology taught at nine regional campuses using a single core curriculum. A committee of statewide course directors writes a licensure board-style final examination that is referenced to the core and used at all campuses. To prepare for the final examination, students traditionally utilize print-based board examination review books. The purpose of the present study was to determine whether students who train using web-based quizzes score differently as a group on this statewide examination than students who do not utilize the materials online for exam preparation. The study included 71 learners from two different campuses who were taught by the same instructor and were admitted to medical school with similar exemplary credentials. Results were aggregated for three consecutive years. A standard medical microbiology textbook was used to assign the same suggested readings for all students and similar laboratory sessions were provided for all learners. The independent variable was use of the web-based quizzes to prepare before examinations, as indicated by student web usage logs. The dependent variable was score on the statewide final examination. Results support the hypothesis that students who use preparation modules online score higher on the final examination than students who do not. Moreover, students who prepared online scored higher on questions designed to test synthesis of knowledge and analysis of data. The significant difference in final examination outcome \( P < 0.002 \) using a two-tailed unpaired \( t \) test indicates that online preparation for high-stakes examinations could improve student performance in medical microbiology.

One goal of any teaching strategy is to help students become effective learners. Many persuasive educators have suggested that the time-honored lecture is not the most productive mode for many students to learn new material (1, 7, 19, 22). Several studies have shown that instructional methods designed to actively engage learners improve learning outcomes (4, 11, 13). Frequent quiz administration at the undergraduate university level has been shown to maintain learner engagement and to promote student study effort (5, 16). By contrast, other studies have reported that students derive no benefit from frequent, low-stakes testing and conclude that conventional review sessions may be a more successful strategy for enhancing the academic performance of postsecondary learners (3, 10). Few studies provide evidence for the benefits of computer-assisted instruction supplements of any kind to promote medical student learning (5, 8).

Medical microbiology is taught at one large state-supported medical school at geographically separated campuses using a common core curriculum set by a committee of the course directors who teach at each of the regional sites. All faculty members agree to directly teach 80% of the core materials during their respective courses. The committee also prepares a comprehensive licensure board-style final examination that is mapped to the core curriculum and administered to all medical students in the school. The statewide multiple-choice exam is evaluated annually for flaws and has a stable reliability of 0.8 for any given year, as determined using the Cronbach-alpha formula (6).

In order to enhance students’ preparation for course examinations, the study author created “preparation quizzes” as an optional tool beginning in 1993. At the start, these quizzes were pencil and paper copies of multiple-choice questions derived from a bank of questions accumulated over a number of years. In 1999 the author converted all quizzes to an electronic, web-based format using the ANGEL Learning Management System (LMS) (21). Most questions were linked to patient case-based vignettes. The resulting online learning quiz modules contained additional review charts, summaries, and images and were offered to students as supplemental learning materials. The quiz modules did not have a direct bearing on the students’ course grades, but were freely available for medical students at the campuses where the author was medical microbiology course director. The quizzes provide a means of self-assessment by giving students a method to gauge their own level of understanding and preparation before each examination. After completing each quiz, students are provided with an overall score, a performance summary, and the reasons why the selectors are correct or incorrect.

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An analysis of final examination outcomes for 2003 and 2004 revealed a bimodal class distribution: students who utilized the optional online quiz modules before each exam during the semester performed better on the comprehensive final examination than students who did not take advantage of this opportunity to prepare online. The results prompted a more systematic analysis of resource utilization.

A study of student use of online quizzes and learning materials was performed over three terms. The purpose of the study was to determine whether students who train using web-based quiz modules score differently as a group on the statewide comprehensive examination than students who choose not to complete the learning modules online. The results showed an interesting trend in utilization of online course materials and its correlation with high level performance on a group-normed examination.

METHODS

Course management system. The ANGEL LMS was used for routine class reading assignments and interactions, as well as electronic quiz delivery (21). Quizzes were scored automatically, and students received immediate feedback on their performance as well as the rationale behind the correct and incorrect responses. The LMS reporting feature was also used to analyze online resource utilization by each student.

Standard course elements. The same medical microbiology textbook (17) was used to assign suggested readings for all students. Similar supplemental laboratory sessions were also provided for all students at both instructional sites for every student group. The final examination administered for students at both sites was an evaluation instrument developed by a statewide committee of microbiology faculty. The examination has a reliability of 0.8 using the Cronbach coefficient alpha formula,

\[ \alpha = \frac{N \cdot r}{1 + (N - 1) \cdot r} \]

where \( N \) is the number of test items and \( r \) is the average inter-item correlation among the items (6).

Although the final examination used for each of the three years was not identical, many of the questions used were repeated and retained through validity testing using more than a thousand medical students’ responses (data not shown).

Study design. The study included 71 medical students from two geographically separated campuses who were taught by the same instructor using a hybrid of traditional didactic and web-based course materials and quiz modules. Results were aggregated for three consecutive years. The independent variable was the way in which the web-based multiple choice quiz modules were used by students to prepare before each examination during the semester. Quiz scores were not a factor in the course grading scheme. The dependent variable was student score on the norm-referenced statewide final examination. The average student time-on-task utilizing online course resources was evaluated using electronic tracking features in the LMS (Web Log analysis; see Fig. 1) (21). Students were divided into two groups based on utilization of online resources. Quizzes taken online were scored electronically. Electronic scores for student online quizzes and comprehensive final examination were compared as course outcomes for the two groups (Fig. 2). Subsets of exam questions were grouped into categories according to content complexity with a rubric developed using Bloom’s taxonomy of cognitive domain. Student scores on questions within those three subsets were also compared for the two groups (Fig. 3).

Statistical analysis. SPSS 14.0 for Windows XP operating system was used for statistical calculations (20). A two-tailed, unpaired t test was used to compare group averages. For examination item category analysis, a 3 by 2 factorial analysis of variance for independent samples using standard weighted means was performed. Mean group differences associated with ANOVA procedures were interpreted using Tukey’s HSD (honest significant difference). Post hoc analysis was performed using a one-tailed, unpaired t test.

Institutional review board. This work was approved by the Institutional Review Board as an exempted study #EX0610-28.

FIG. 1. Web log analysis for online learning in microbiology. The ANGEL LMS allows students to take quizzes online and receive feedback on their performance through automatic electronic grading. Students are provided with correct answers and explanations of microbiology concepts. The ANGEL LMS reports feature allows analysis of student time spent utilizing online resources. Student time spent for online quizzes is shown in Fig. 1A, grouped according to comprehensive exam outcome. This comparison was significant using a two-tailed, unpaired t test at \( P < 0.005 \). Students with lower online quiz scores spent less time overall utilizing online learning materials in the days leading up to examinations during the semester (an example time log is shown in Fig. 1B).
FIG. 2. Final examination score correlated with online quiz utilization. Students self-selected into two groups based on utilization of online instructional materials. Students with low quiz scores also scored lower on a comprehensive final examination. The mean final exam score for the high quiz score group was significantly higher than the mean score for the low quiz score group, as measured by a two-tailed unpaired t test, $P < 0.0001$.

**FIG. 3.** Final examination item level of complexity correlated with online quiz scores. Students who achieved the highest online quiz scores also performed better on questions testing analytical thinking skill ($^* p < 0.003$). Categories were developed based on Bloom’s taxonomy of cognitive domain.

**RESULTS AND CONCLUSIONS**

Students were aggregated into two groups based on the use of online resources as indicated in Fig. 1. Quiz scores varied in proportion with the total amount of time students spent online using LMS-based lecture materials, taking the quizzes, and/or reviewing the explanations for correct versus incorrect question responses.

Results support the hypothesis that students who consistently use quiz modules online, repeating the process until a high quiz score is achieved (78.1% average quiz score; $n = 38$), also score higher on the final examination than students who do not use this preparation strategy (46.7% average quiz score; $n = 33$). The average score on a norm-referenced final examination used in all 3 years of the study was 75.1 ± 7.8% for students in the high quiz score group and 68.27 ± 9.9% for students in the low quiz score group ($P = 0.002$). Students who had low quiz scores also spent significantly less time online as indicated by quiz web usage logs (Fig. 1A; 0.93 hours ± 0.1 for high scorers, compared with 0.52 hours ± 0.07 for low scorers; $P < 0.005$). The difference in final examination outcome ($P < 0.002$; Fig. 2) indicates that quiz modules used online in preparation for high-stakes examinations, as intended, could improve medical student exam performance. Students who are “print-oriented” (as indicated by brief access and log-off resource utilization patterns) do not derive the benefit of online quiz delivery to identify topics for which greater preparation is needed (12).

Students who use LMS-based resources online challenge their understanding of course content in real-time, simulating the proctored examination environment (12, 14). Student use of optional quizzes in an online mode was positively correlated with academic achievement as measured by performance on a standardized final exam ($r = 0.62$). The LMS quiz tool records low quiz scores even when print-oriented students access and download the exam questions along with the correct answers and discussion items (21). Thus, student results using paper-and-pencil are not recorded and were not a part of the study analysis.

It is not clear whether online use of the preparation quizzes resulted in improved achievement or whether unmeasured factors such as student desire to challenge their own preparation may play an important role. However, the two groups compared in this study were homogeneous with regard to academic preparation for medical school, as indicated by Medical College Admissions Test (MCAT) scores and overall undergraduate grade point averages. The high quiz score group had an MCAT average of 29.24 ± 2.8 in comparison with the low performing group MCAT average of 28.26 ± 2.9 (no significant difference; $P = 0.202$). The two groups were also similar when undergraduate grade point average was considered as an indicator of aptitude for microbiology learning (3.71 ± 0.2 for the high quiz score group versus 3.70 ± 0.22 for the low quiz score group, no significant difference; $P = 0.86$). There was no difference in class attendance between the two groups; overall attendance ranges from 90% to 100% for medical schools divided into small classes held at regional campuses (data not shown).

Cognitive theory suggests that active processing of information is necessary in order to achieve higher-order learning (2). Students who study independently using web-based materials have an opportunity to integrate information differently than other learners. The interactive format
of LMS-based online materials and quiz modules provides a different context than reading a paper text or jotting notes on a printed copy (21). The time spent on-task during a quiz session is qualitatively different than other study formats (9). The present study was not designed to include consideration of learner background or learning style as factors in the effectiveness of online module utilization. However, the potential for differences in these areas may be important because several investigators have found that learners in higher education diverge in visual-verbal and intuitive-sensing learning style dimensions (5, 12, 15). Future studies will be designed to explore the relationship between such factors and student utilization of LMS-based online learning resources.

In order to investigate the possibility that enhanced analytical thinking skill could be detected for students who scored higher on the online quizzes, an analysis of questions drawn from the final examination item bank was performed. The questions selected for this analysis formed a subset of exam items that were repeated across all 3 years of the study. These questions were ranked by the instructor for difficulty and cognitive level (2). Bloom’s taxonomy of cognitive domain was used to categorize the questions into three levels, following the method of Rao and DiCarlo (18). Each category contained a similar number of questions (range 28 to 35 questions per level). The “recall level” category grouped together single-concept, factual questions that tested a student’s ability to retrieve information. The “application level” category contained questions that assessed comprehension of more complex concepts and reasoning skill. Higher-order thinking was tested in the third category, an “analysis level” where questions always included patient case information, vital signs, laboratory values, and organism identification details. Level 3 questions required evaluation and synthesis to support the selection of a correct answer. As shown in Fig. 3, students who made use of online training exercises to prepare for the challenge of the final examination were better able to address the Level 3 analytical problems than the other learners. The two student groups performed equally well on the recall level questions (no significant difference, \( P = 0.46 \)). However, the high-scoring online quiz group showed a trend towards improved performance on application questions \( (P = 0.12) \) and achieved significantly higher scores on the analysis category problems that required synthesis of information and higher order thinking \( (P < 0.003) \).

The use of electronic quizzes represents a method to emphasize critical material in an active and challenging mode within an interactive format. Interactive methods of enhancing the delivery of educational materials have been associated with improved student learning in many disciplines (1, 3-5, 8, 9, 11, 13). The online, web-based delivery system provides a learning environment that is accessible from nearly any location at any time of the day or night (8, 19).

In the present study, a positive correlation between medical students’ use of online learning materials and performance on a comprehensive examination suggests that independent study using the “challenge mode” available only with the active learning provided through an electronic interface may enhance both knowledge retention and higher-order thinking skills. Immediate feedback is an important feature of the online delivery system, underscoring learning areas that require greater focus. In particular, the results indicate that preparation for high-stakes examinations utilizing an online mechanism is more effective than paper and pencil practice. Repetitive training using online quizzes represents an important and underutilized resource to help medical students improve their performance in medical microbiology.

REFERENCES


