# Use of unsupervised online quizzes as formative assessment in a medical physiology course: effects of incentives on student participation and performance

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**Kibble J.** Use of unsupervised online quizzes as formative assessment in a medical physiology course: effects of incentives on student participation and performance. *Adv Physiol Educ* 31: 253–260, 2007; doi:10.1152/advan.00027.2007.—Online quizzes were introduced into a large Medical Physiology class to provide students with formative assessment before midterm and final summative examinations. Use of unsupervised online quizzes was chosen to provide a flexible supplementary learning tool for students without overwhelming a small faculty. Several quiz models were applied, which varied in the availability of course credit points for participation and performance. The aims of the study were to investigate if participation in formative assessment was associated with improved course outcomes, if offering incentives for completing quizzes affected student participation, and if quiz performance was predictive of summative examination outcomes. Results showed that students who elected to use online quizzes performed better in summative examinations. Offering course credit of between 0.5% and 2% per quiz increased student participation. However, evidence was found for widespread inappropriate use of unsupervised online quizzes when incentives for participation were applied. Predictive validity of online quizzes could be demonstrated when comparing the first of several quiz attempts with subsequent summative examination scores.

web based

FORMATIVE ASSESSMENT is intended to foster learning, helping students to develop under conditions that are nonthreatening. Providing feedback is an important element of formative assessment, and this should ideally include guidance about how to improve performance (17). Formative assessment should be available early in the learning process for feedback to be most effective (2). Well-designed formative assessment tools should be informative for students in answering the question "How am I doing?" (14). Summative assessment requires students to demonstrate the sum of their learning in terms of knowledge, skills, and attitudes. It is generally a formal and mandatory assessment given at the end of a period of instruction. From a student perspective, summative assessment answers the question "How did I do?" (14).

The concept of formative assessment is firmly established in higher education, generally, and also in medical education, specifically. For example, the United States Licensing Committee on Medical Education (LCME), standard ED-26, states that "The directors of all courses and clerkships must design and implement a system of formative and summative assess-

ment evaluation of student achievement in each course and clerkship." Improved learning outcomes with formative assessment have been demonstrated, especially when accompanied by individual feedback and remedial action (16). Other studies (3, 19) have shown that the use of formative assessment before summative assessment increases grade points. On the other hand, Peat and Franklin (12) found no relationship between the outcome of formative quizzes and the subsequent performance on summative assessments for inexperienced biology students, although a positive effect of formative assessment was established later in their program (13). This emphasizes the importance of auditing use and effectiveness of formative assessment tools.

The Medical Physiology course at St. George's University serves a heterogeneous student cohort in large classes of ~350 students. In recent years, we have introduced formative assessment in the form of unsupervised online quizzes to meet the general trend of increasing student expectations for support. Online quizzes were adopted as a tool that could provide flexible student support without overwhelming a small faculty. Several different presentations of formative online quizzes were used over a period of five semesters, which varied in the amount of course credit available and in the criteria used to award credit. A retrospective analysis of the data was undertaken to address several hypotheses: *1*) use of formative assessment is associated with improved outcomes on summative assessment, *2*) providing incentives for unsupervised online quizzes increases student participation, and *3*) unsupervised online quizzes have predictive validity for summative examinations. In addition to addressing these hypotheses, the study revealed unexpected student behaviors in response to providing credit for participation in quizzes, which may be meaningful to others intending to adopt this type of formative assessment.

## METHODS

### Background

St. George's University offers a 4-yr medical program in which basic medical sciences are taught during the first 2 yr. Medical Physiology is taught twice a year to cohorts of ~350 students. It is a five-credit hour course, delivered over 18 consecutive weeks, consisting of 75 h of lecture and 12 h of formal small-group teaching. Curricular content is based on the American Physiology Society Medical Physiology Objectives Project. The course runs during the second academic semester, concurrently with Neuroscience, Genetics, Immunology, and Medical Parasitology courses. The Medical Physiology course follows the Anatomy and Biochemistry course and precedes courses that include Pathology, Pharmacology, and Pathophysiology.

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*Learning Management System*

A campus-wide learning management system (ANGEL) was introduced at St. George's University in late 2004, and faculty members were encouraged to develop online tools to support learning by the Curriculum Committee. Our use of online quizzes stemmed from this initiative together with the consistent request by students to provide more formative assessment in their course evaluation. All quizzes were administered through ANGEL, which students accessed using their personal username and password. The grade book feature within ANGEL was used to record quiz use.

*Online Quiz Presentation*

Medical Physiology students were assessed using the aggregate score from a summative examination after 9 wk and another after 18 wk. Each summative examination consisted of 80 multiple-choice questions. Two online quizzes were offered during the learning period before each summative examination. The two quizzes offered in each block were presented sequentially, separated by ~2 wk. The second quiz in a pair included new course material to provide ongoing feedback as the teaching progressed. Each online quiz consisted of 20–30 multiple-choice questions designed to match the style and difficulty of summative examinations. Students were made aware of quizzes in the course syllabus and by milestones posted in their personal calendar within ANGEL. Different quiz presentations were applied to five student cohorts between 2004 and 2006, in which there were variations in the amount of course credit available, in the ways of earning credit, and in the length of time quizzes were open to students. These variations reflected ideas of faculty members aiming to encourage student participation and to help students pace their studies. Each model described below was applied once throughout a single semester (Table 1). A given cohort of students was held to the same online quiz policy throughout their semester. Feedback pertaining to quiz items and suggestions about remedial action were available through face-to-face meetings with faculty members on student request.

*Model 1.* In *model 1*, no course credit was given for taking online quizzes. Each of the two quizzes, made available prior to a summative examination, was open for 1 wk, during which time students could take a given quiz only once before the database was closed and accumulated data were downloaded. Students were encouraged to use the quiz during the 1-wk window as a means of helping them keep up with their studies. After data collection, each quiz was then made available for unlimited review until the summative examination.

*Model 2.* In *model 2*, total course credit available for each online quiz was set at 0.5%. Credit was awarded for taking a quiz, irrespective of the score obtained. Students could take a given quiz an unlimited number of times leading up to the summative examination. The database was closed immediately before the summative examination.

*Model 3.* In *model 3*, total course credit available for each online quiz was set at 1.0%. Credit was awarded on an all-or-none basis to students scoring 30% or more on a given quiz. A 1-wk window was provided to complete a given quiz for credit, and unlimited attempts were allowed during that week. The database was closed at the end of

the quiz week, and accumulated data were downloaded for later analysis. The quiz was then again made available for unlimited review until the summative examination.

*Model 4.* In *model 4*, total course credit available for each online quiz was set at 1.0%. Credit was allotted as a function of the actual quiz score attained from the better of two attempts. After the first attempt, students were provided with a list of questions answered incorrectly along with their original responses. Students were encouraged to review the questions before completing the quiz a second time. Students had a 1-wk window to complete a given quiz for credit, after which time the database was closed and accumulated data were downloaded. Each quiz was then made available for unlimited review until the summative examination.

*Model 5.* In *model 5*, the same design as for *model 4* was used except that the total course credit available for each quiz was set at 2%.

*Data Analysis*

Data analysis was conducted retrospectively for all semesters at the end of the Fall 2006 semester. Approval was granted by the St. George's University Institutional Ethics Review Board. A sampling approach was used to manage data analysis because of the large volume of data produced. Within each model, one pair of quizzes and their associated summative examination were selected at random for analysis. Comparison of quizzes within any given pair showed consistent patterns of student responses. There were no significant differences between mean quiz scores within any given pair of quizzes. For this reason, pooled data from quiz pairs were used for presentation.

On first inspection, quiz performance appeared different for students who took an online quiz only once compared with students who accessed a quiz several times. These data are presented separately for *models 2–5*, in which quizzes could be taken more than once. Student performance on each quiz or examination is reported as a percentage, and data are expressed as means $\pm$ SE. Statistical comparisons between mean online quiz scores and summative examinations within each semester were made using ANOVA followed by post hoc $t$-tests with Bonferroni correction and 5% significance level. Use of alphanumeric student codes allowed anonymous correlation between individual online quiz scores and summative examination scores.

*Student and Faculty Member Surveys*

The student survey shown in Table 2 was presented to student cohorts in *models 4* and *5* at the end of their course. The survey was available online, and the student response was both voluntary and anonymous. The purpose of the student survey was to gauge how useful and acceptable students perceived online quizzes to be. The faculty member survey shown in Table 3 was e-mailed to 120 full-time faculty members involved in teaching in the medical curriculum to gain insight into their views on the purpose and implementation of online quizzes across the wider curriculum. Four-point Likert Scales were used to omit a neutral response and encourage a clear response to questions (7).

Table 1. *Key features of different quiz models and resulting student participation rates*

| Model No. | Course Credit Available Per Quiz, % | Criteria for Earning Quiz Credit | Student Participation, % |
|---|---|---|---|
| *1* | 0 | | 52 |
| *2* | 0.5 | Login only | 87 |
| *3* | 1.0 | Score >30% | 92 |
| *4* | 1.0 | Actual quiz score, best of two attempts | 97 |
| *5* | 2.0 | Actual quiz score, best of two attempts | 98 |

Table 2. *Student survey*

| Survey Question | Strongly Agree | Agree | Disagree | Strongly Disagree |
|---|---|---|---|---|
| *1.* I used online quizzes to give me feedback about my learning. | 68 | 28 | 4 | 0 |
| *2.* Online quizzes helped me to identify areas of weakness. | 42 | 44 | 12 | 2 |
| *3.* Results of online quizzes were helpful to direct my review before major exams. | 35 | 45 | 16 | 4 |
| *4.* Online quizzes motivated me to study. | 34 | 41 | 22 | 3 |
| *5.* Online quizzes were a valuable learning activity. | 50 | 41 | 5 | 4 |
| *6.* I completed online quizzes because course credit was given for them. | 59 | 33 | 7 | 1 |
| *7.* Online quizzes are an adequate replacement for formal in class pen and paper quizzes. | 58 | 34 | 6 | 2 |
| *8.* Which of the following study aids did you use while taking online quizzes? | | | | |
|    Lecture notes | | | 93 | |
|    Textbook | | | 31 | |
|    Discussion with peers | | | 63 | |
|    Internet | | | 21 | |
|    E-mail | | | 3 | |

Data shown are percentages of responses in each category and for *question 8*, percentages used by the students. Surveys were offered to students in *models 4* and *5* at the end of their course. Responses from the 2 cohorts were very similar, and data were pooled; 378 of 688 students (55%) responded.

**RESULTS**

*Student Participation Rates*

Table 1 shows the percentage of students who participated in online quizzes for each model. Higher student participation was observed with increasing credit value of quizzes.

*Models*

*Model 1.* The mean online quiz score in *model 1* did not differ significantly from the mean summative scores. However, individual quiz scores showed a significant positive correlation with corresponding summative examination scores, and students who elected not to use the online quizzes performed significantly worse on the associated summative examination ($75.7 \pm 0.6\%$, $n = 167$ students) than those who used at least one ($80.2 \pm 0.5\%$, $n = 179$ students). Of the students taking online quizzes, 160 students used both quizzes and 19 students only one of the pair. There were no differences in the summative examination scores between students taking both online quizzes ($80.3 \pm 0.5\%$, $n = 160$) and those taking only one quiz ($79.4 \pm 0.7$, $n = 19$). Data from these two groups were pooled for presentation and are shown in Fig. 1.

For quiz *models 2–5*, students could take an online quiz more than once during the specified time windows. In *models 4* and *5*, 96% of students scored between 95% and 100% on their first quiz attempt, did not then take the second quiz, and

did not sustain the high level of performance of quizzes on the summative examination. This suggests the inappropriate use of quizzes to gain credit rather than to provide a form of formative assessment. As a result, data from students using a single attempt at any given quiz were expressed separately for *models 2–5*. Correlation analysis was also restricted to students who used online quizzes more than once and addressed whether the first quiz performance was related to the summative examination performance.

*Model 2.* The mean quiz score for students using only one attempt ($82.9 \pm 1.1\%$, $n = 356$ quiz scores) was significantly greater than the first effort of students who subsequently repeated a quiz ($72.2 \pm 1.6\%$, $n = 284$ quiz scores; Fig. 2). There were no significant differences in summative examination scores for students who used a quiz only once ($80.2 \pm 0.5\%$, $n = 356$ scores) compared with students who repeated an online quiz ($81.6 \pm 0.6\%$, $n = 284$ scores). Individual scores from the first of several quiz attempts showed a significant positive correlation with corresponding summative examination scores. The mean summative examination score of the 49 students who did not post any online quiz scores was significantly lower ($76.3 \pm 0.5\%$, $n = 49$ students) than the average for students taking at least one quiz ($80.8 \pm 0.5\%$, $n = 333$ students).

*Model 3.* The mean quiz score for students taking a quiz only once ($86.8 \pm 0.7\%$, $n = 516$ quiz scores) was significantly greater than the first effort of students who subsequently repeated a quiz ($77.8 \pm 1.6\%$, $n = 108$ quiz scores; Fig. 3).

Table 3. *Faculty member survey*

| Survey Question | Strongly Agree | Agree | Disagree | Strongly Disagree |
|---|---|---|---|---|
| *1.* Online quizzes help students to keep up with their studies. | 41 | 55 | 4 | 0 |
| *2.* Online quizzes help students learn course material. | 26 | 65 | 9 | 0 |
| *3.* Online quizzes provide useful feedback to students about their mastery of learning objectives. | 40 | 53 | 7 | 0 |
| *4.* Giving credit for quizzes makes it more likely students will take them. | 43 | 55 | 2 | 0 |
| *5.* Online quizzes are an adequate replacement for formal in-class quizzes. | 21 | 35 | 35 | 9 |
| *6.* Online quizzes should be compulsory for students. | 12 | 55 | 29 | 4 |
| *7.* The goal of setting an online quiz is: | | | | |
|    Formative | | | 36 | |
|    Summative | | | 0 | |
|    Mixture | | | 64 | |

Data are percent responses in each category and for *question 7*, percent responses to the descriptions. The survey was given after *model 5*. No student outcome data were given to faculty members from the present study; 44 full-time teaching faculty members from basic medical sciences responded from a possible 120 faculty members (37%).
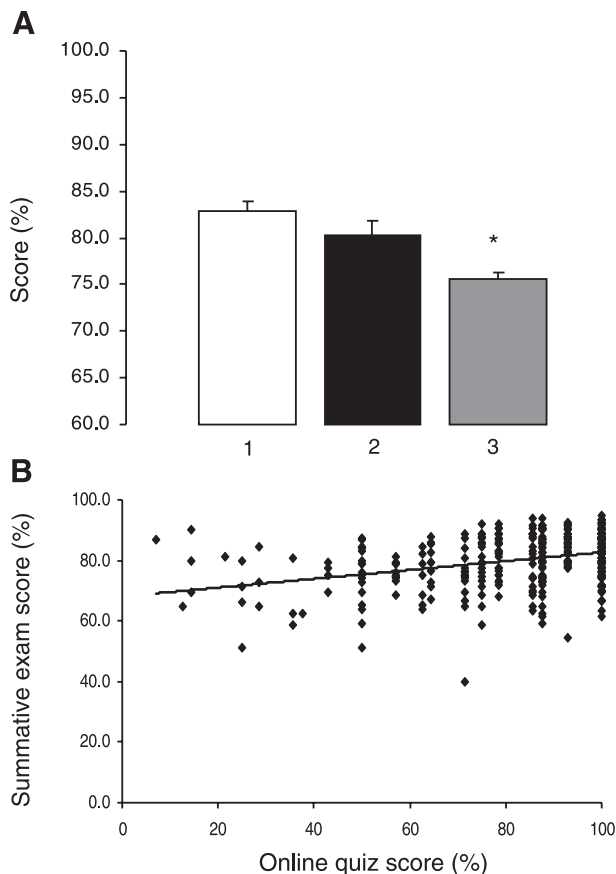
**A**



**B**

Fig. 1. *A*: comparison of online quiz scores with summative examination scores for *model 1* (no credit given for quiz; scores recorded after the first attempt). *Group 1*, mean online quiz score ($n = 339$ quiz scores); *group 2*, mean summative exam score for students taking an online quiz ($n = 179$ students); *group 3*, mean summative exam score for students not taking an online quiz ($n = 167$ students). *Significantly different scores in *group 3* compared with *group 2* (ANOVA plus Bonferroni-corrected *t*-test, $P < 0.05$). *B*: significant correlation between summative examination scores and online quiz scores for individual students ($r = 0.34$, $n = 339$ quiz scores, $P < 0.05$).

Despite higher quiz scores, summative examination scores for students that used a quiz only once were significantly lower ($80.3 \pm 0.4\%$, $n = 516$ scores) than students who repeated an online quiz ($83.9 \pm 0.9\%$, $n = 108$ scores). Individual scores from the first of several quiz attempts showed a significant positive correlation with corresponding summative examination scores. Twenty-nine students did not post any online quiz scores. Their mean summative examination score was significantly lower ($77.4 \pm 0.4\%$, $n = 29$ students) than the mean of students taking at least one online quiz ($80.9 \pm 0.5\%$, $n = 329$ students).

*Model 4.* The mean quiz score for students taking a quiz only once ($96.0 \pm 1.0\%$, $n = 147$ quiz scores) was significantly greater than the first effort of students who subsequently repeated a quiz ($72.6 \pm 0.8\%$, $n = 500$ quiz scores; Fig. 4). There were no significant differences in summative examination scores for students who took a quiz only once ($79.4 \pm 0.9\%$, $n = 147$ scores) compared with students who repeated an online quiz ($80.5 \pm 0.4\%$, $n = 500$ scores). Individual scores from the first of the two quiz attempts showed a significant positive correlation with corresponding summative examination scores. Ten students did not post any online quiz

scores. Their mean summative examination score was not significantly different ($78.9 \pm 1.8\%$, $n = 10$ students) than the mean of students taking at least one online quiz ($80.3 \pm 0.5\%$, $n = 335$ students).

*Model 5.* The mean quiz score for students taking a quiz only once ($99.3 \pm 0.3\%$, $n = 307$ quiz scores) was significantly greater than the first effort of students who subsequently repeated a quiz ($76.6 \pm 0.9\%$, $n = 337$ quiz scores; Fig. 5). Despite higher quiz scores, summative examination scores for students who used a quiz only once were significantly lower ($74.5 \pm 0.7\%$, $n = 307$ scores) than students who repeated an online quiz ($77.6 \pm 0.6\%$, $n = 337$ scores). Individual scores from the first of the two quiz attempts showed no significant correlation with corresponding summative examination scores. Seven students did not post any online quiz scores. Their mean summative examination score was not significantly different ($77.1 \pm 2.4\%$, $n = 7$ students) than the mean of students taking at least one online quiz ($76.1 \pm 0.6\%$, $n = 336$ students).
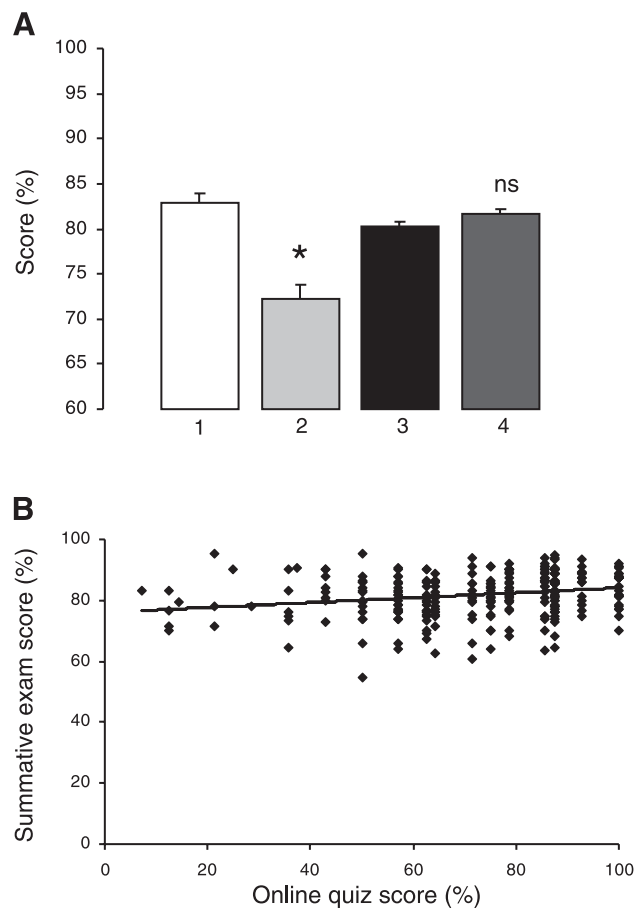
**A**



**B**

Fig. 2. *A*: comparison of online quiz scores and summative examination scores for *model 2* (0.5% of course credit per quiz; credit awarded for any posted score). *Group 1*, online quiz score for students taking a quiz only once ($n = 356$ quiz scores); *group 2*, first online quiz score for students taking a quiz more than once ($n = 284$ quiz scores); *group 3*, corresponding summative exam score for students taking an online quiz only once ($n = 356$ quiz scores); *group 4*, corresponding summative exam score for students taking an online quiz more than once ($n = 284$ quiz scores). *Significantly different scores in *group 2* compared with *group 1* (ANOVA plus Bonferroni-corrected *t*-test, $P < 0.05$). ns, Not significant. *B*: significant correlation between summative examination scores and first online quiz scores for students taking a quiz more than once ($r = 0.22$, $n = 284$ quiz scores, $P < 0.05$).
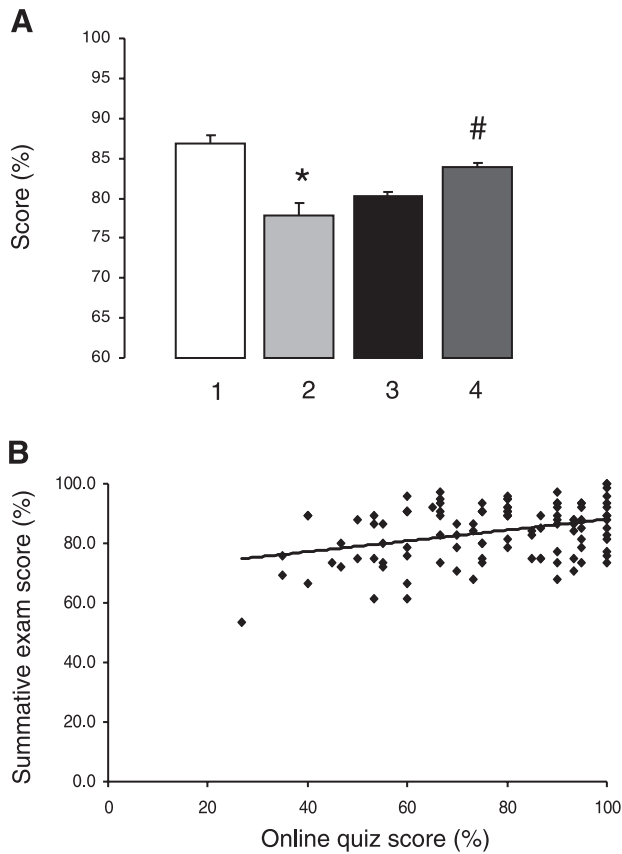
**A**



**B**



Fig. 3. *A*: comparison of online quiz scores and summative examination scores for *model 3* (1% of course credit per quiz; credit given if first quiz score was >30%). *Group 1*, online quiz score for students taking a quiz only once (*n* = 516 quiz scores); *group 2*, first online quiz score for students taking a quiz more than once (*n* = 108 quiz scores); *group 3*, summative exam score for students taking an online quiz only once (*n* = 516 quiz scores); *group 4*, summative exam score for students taking an online quiz more than once (*n* = 108 quiz scores). *Significantly different quiz scores in *group 2* compared with *group 1*; #significantly different summative exam scores in *group 4* compared with *group 3* (ANOVA plus Bonferroni-corrected *t*-test, $P < 0.05$). *B*: significant correlation between summative examination scores and first online quiz scores for students taking a quiz more than once ($r = 0.35$, $n = 108$ quiz scores, $P < 0.05$).

## Surveys

*Student survey.* Students from cohorts using *models 4* and *5* responded to an anonymous online survey about their online quiz experience. Responses from each semester were similar and were thus pooled; 55% of students responded. *Questions 1–5* inquired about the formative value of online quizzes. At least 80% of respondents agreed or strongly agreed that they used quizzes to provide feedback on their learning; that quizzes were helpful in identifying weak areas, reviewing for summative examinations, and motivating study; and that they provided a valuable learning activity overall. More than 90% of respondents agreed that they completed quizzes because course credit was associated with them, consistent with the near 100% observed student participation rates in *models 4* and *5*. Over 90% of respondents also agreed that online quizzes could adequately replace supervised offline quizzes. Survey respondents indicated that use of lecture notes and peer discussion were commonly used to assist in taking quizzes.

*Faculty member survey.* Toward the end of this study, a number of other disciplines within the basic medical sciences curriculum were starting to use online quizzes. Forty-four full-time faculty members responded. More than 90% of respondents agreed that online quizzes would be useful in helping students keep up with studies. Ninety percent of respondents agreed that online quizzes help students learn and that they provide useful feedback about student mastery of learning objectives. More than 90% also recognized the likelihood that awarding course credit would increase student participation. The faculty member response was divided as to whether unsupervised online quizzes could adequately replace supervised offline quizzes. Two-thirds of faculty respondents felt that online quizzes should be compulsory for students.

## DISCUSSION

### Summary of Main Findings and Limitations of the Data

The main outcomes of this study were as follows: *1*) students who used formative assessment generally performed better on
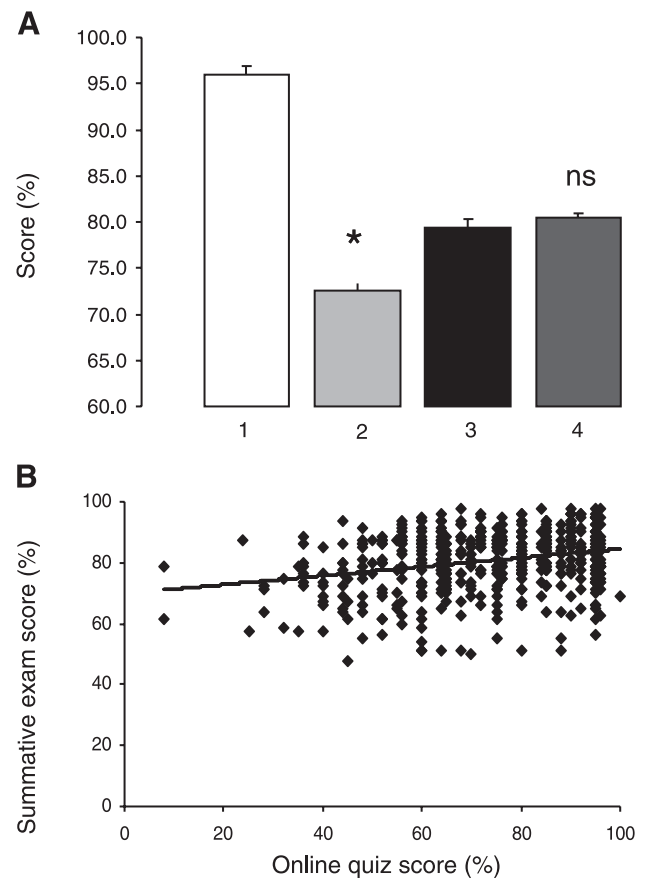
**A**



**B**



Fig. 4. *A*: comparison of online quiz scores and summative examination scores for *model 4* (1% of course credit per quiz; credit based on best quiz score from two attempts). *Group 1*, online quiz score for students taking a quiz only once (*n* = 147 quiz scores); *group 2*, first online quiz score for students taking a quiz more than once (*n* = 500 quiz scores); *group 3*, summative exam score for students taking an online quiz only once (*n* = 147 quiz scores); *group 4*, summative exam score for students taking an online quiz more than once (*n* = 500 quiz scores). *Significantly different quiz scores in *group 2* compared with *group 1* (ANOVA plus Bonferroni-corrected *t*-test, $P < 0.05$). *B*: significant correlation between summative examination scores and first online quiz scores for students taking a quiz more than once ($r = 0.26$, $n = 500$ quiz scores, $P < 0.05$).
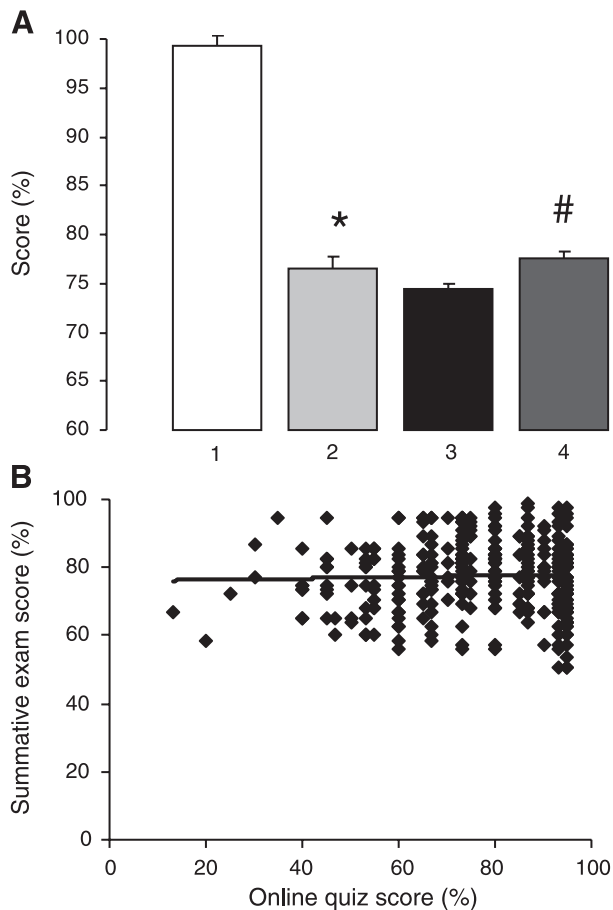
Fig. 5. *A*: comparison of online quiz scores and summative examination scores for *model 5* (2% of course credit per quiz; credit based on a better quiz score from two attempts). *Group 1*, online quiz score for students taking a quiz only once ($n = 307$ quiz scores); *group 2*, first online quiz score for students taking a quiz more than once ($n = 337$ quiz scores); *group 3*, summative exam score for students taking an online quiz only once ($n = 307$ quiz scores); *group 4*, summative exam score for students taking an online quiz more than once ($n = 337$ quiz scores). *Significantly different quiz scores in *group 2* compared with *group 1*; #significantly different summative exam scores in *group 4* compared with *group 3* (ANOVA plus Bonferroni-corrected *t*-test, $P < 0.05$). *B*: lack of correlation between summative examination scores and first online quiz scores for students taking a quiz more than once ($r = 0.04$, $n = 337$ quiz scores).

summative examinations, *2*) providing incentives for online quizzes increased student participation, and *3*) predictive validity of online quizzes was demonstrated. An unexpected but important finding was evidence for inappropriate use of online quizzes when incentives were applied. I use the term "inappropriate use" to refer to the significant number students who scored 100% on quizzes in a single attempt but who did not subsequently perform well on summative examinations. Their strategy in using quizzes appeared to defeat the formative purpose for which quizzes were intended. This pattern of behavior was not defined as cheating because no rules were defined in terms of strategies that students were allowed to use when taking unsupervised online quizzes. Data were analyzed anonymously, presenting limitations in terms of studying effects of gender or other cohort characteristics. Faculty member and student survey response rates were lower than desired, at 37% and 55%, respectively, presenting limitations in terms of true representation of the populations sampled.

*Aim 1: use of formative quizzes is associated with better outcomes.* The first study hypothesis considered whether use of formative online quizzes was associated with better outcomes on summative assessment. Data from quizzes in *model 1* showed a significant difference between students who participated in quizzes and those who did not. These data were striking because the class distributed itself evenly between participators and nonparticipators. The same effect was repeated for *models 2* and *3*, where 49 of 382 students and 29 of 358 students, respectively, elected not to participate. No differences were noted in *models 4* and *5* with regard to the effect of participation on summative examination outcomes. However, *models 4* and *5* had 97% and 98% participation, respectively, so the remaining group of students who elected not to participate was very small for comparison.

There are several examples in educational research literature showing that students who make use of all learning activities have a higher likelihood of successful outcomes (4, 6). In the present study, it should be noted that "nonparticipation" was defined as not recording responses when quiz windows were open. Students were able to access quiz materials again and may have used them at some later time. Lack of compliance may therefore be a more important issue. Understanding why some students behave in this way is important because this group performed worse on summative examinations. Others have noted a relationship between lack of compliance and poor examination outcomes in medical students (18), but this seems too simplistic a view. In our Medical Physiology course, all assessments are computer-graded, multiple-choice questions designed to reflect the United States Medical Licensing Examination Step-1. It is been reported that students with a learning style that shows a strong preference for abstract conceptualization perform better on this kind of assessment (8). Our uniform offering of such assessment may discourage use among students with different learning styles. Similarly, students who adopt a surface learning approach are less conscious of monitoring and managing studying and generally have lower examination performance in medical school (9). Peat and Franklin (12) studied the effectiveness of formative assessment in a group of first-year biology students during their first semester and found no demonstrable benefit. However, a second study, performed with a different cohort, reported that use of self-assessment modules had a significant positive impact on performance for students by the end of their second semester (13). This suggests that benefits of self-assessment become apparent as students learn how to work more independently. In the present study, it seems likely that the nonparticipating groups reflect a population who have not yet optimized their approaches to studying.

*Aim 2: student participation is increased by offering incentives.* The second hypothesis addressed in the present study examined whether student participation increases when reward in the form of course credit is available. The study was able to partially address this question because a range of quiz models were presented with different credit values, ranging from 0% to 2% of final course grade per quiz. Quizzes in *model 1*, for which no credit was available, had a disappointing participation of only 52%, although it should be acknowledged that student motivation to participate at the requested time may be reduced by allowing access to quizzes again later. Student participation rates rose dramatically to 87% in *model 2* and to 98% in *model 5*. These data

confirm student survey responses in which >90% of respondents indicated that they completed quizzes to earn available credit. The trend of increasing participation may have been reinforced by criteria that made it progressively more difficult to earn full credit for quizzes. In *model 2* simply taking a quiz was sufficient, whereas in *models 4* and *5* students needed to score 100% on a quiz within two attempts to earn all available credit. It may be that students viewed earning these course points as an insurance policy in case they were close to a grade borderline.

Offering course credits for online quizzes has the apparent advantage of increasing participation. Given the observation that nonparticipation is associated with lower summative examination scores, increasing participation with a reward might be expected to produce generalized improvements in student outcomes. However, widespread inappropriate use of online quizzes was an unexpected side effect of offering rewards. This was most apparent in *models 4* and *5*, where students were expected to take a quiz once for formative assessment and then use the feedback given to review weak areas and correct their mistakes in a second attempt. Contrary to faculty expectations, large numbers of students took quizzes only once and were able to score close to 100%. These students did not sustain a high level of performance on summative examinations and even had worse performance than their classmates in the cases of *models 3* and *5*. For this group of students, any formative value of the quizzes was likely to be lost, defeating the faculty's purpose in providing them. It was of particular concern that students scoring significantly lower in summative examinations appeared more likely to be in the group using quizzes inappropriately (*models 3* and *5*). Their lower summative scores may reflect a missed learning opportunity from not using quizzes as intended by the faculty, or, perhaps more likely, it reflected students who perceived the need to insure points were scored above other considerations.

Outcome data in the present study suggest that strategies used by students to insure quiz points are scored, but which circumvent learning, are unwise. Are such strategies unethical? A great deal has been written recently, both in the popular press (1) and educational literature (5, 10, 15), about the rising severity of unethical approaches by university students to completing their homework and examinations. Student perceptions of what constitutes "cheating" probably vary significantly from those of faculty members. In a study of engineering undergraduates across 11 institutions (11), it was reported that 41% of students regarded working in groups on web-based quizzes as cheating, 28% considered it unethical but not cheating, and 30% thought it was neither unethical nor cheating. Similarly, only 27% of students regarded asking another student about questions on an exam not yet taken as cheating, 45% felt it was unethical but not cheating, and 27% regarded it as neither unethical nor cheating. In the present study, students were encouraged to take quizzes without assistance and then to review their results using course materials or a discussion with peers and faculty members. The survey given to cohorts in *models 4* and *5*, where there was evidence of inappropriate quiz use from outcomes data, indicated that use of lecture notes and discussion with peers were widely used to assist in taking quizzes. My intention in utilizing quizzes was to provide students with an indicator of their current mastery and then use such tools to further enhance their performance. I did not give students explicit rules about how the unsupervised quizzes were to be used and what was acceptable or otherwise. I do not, therefore, regard the patterns of quiz use described as unethical or cheating.

However, in retrospect, it does seem important to agree with students what is acceptable and to document this before assigning course credit to any form of unsupervised homework.

*Aim 3: online quizzes show predictive validity for summative examinations.* Outcome data from a first quiz attempt for students who made a repeat effort was used to address this hypothesis. It was assumed that these students were likely to have used the quizzes as intended and that their first attempt represented the current state of their knowledge. In *models 1–4*, a consistent pattern was observed in which formative assessment scores were weakly but significantly correlated with summative examination scores. This suggested that the quizzes themselves were constructed from items that tested the same knowledge and understanding as summative examinations.

In summary, students who chose to use formative online quizzes generally had better outcomes on summative examinations. In the absence of course credit, the quiz participation rate was low. Offering course credit and introducing performance criteria to earn credit increased student participation. However, with rising quiz value and performance requirements to earn credit, the incidence of inappropriate quiz use increased. Formative online quizzes had predictive validity for subsequent summative examinations, indicating that quizzes have the potential to be useful learning aids to help students perform better on course assessments. Future work will focus on how to encourage student participation, on understanding reasons for nonparticipation, and on the effect of agreeing ethical standards for quiz use with students.

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