

Article

Increasing Student Success Using Online Quizzing in Introductory (Majors) Biology

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Students often complain about their perceived disconnect between the time and effort spent studying and their subsequent performance on exams. Robert Bjork's research asserts that retrieval of stored information acts as a memory modifier, and that using tests as learning events creates "desirable difficulties that enhance learning." To determine the effect of utilizing testing as a learning event in the introductory (majors) biology classroom, we used an online homework platform to give required quizzes throughout the course. Analysis of exam grades earned by those taking 100% of pre-exam quizzes indicates that not only does this group have a significantly higher exam average than the group of students who took 0% of the pre-exam quizzes, but they also have a significantly higher exam average than the class average. Through detailed, statistical analysis, the benefit of quizzing is demonstrated to be significant for students of diverse academic abilities. Pre-exam quizzing using an online homework platform is an effective way to increase student performance on exams and allows class time to be utilized for teaching activities.

INTRODUCTION

In introductory biology courses, many students find that the adjustment to college expectations can be difficult. This can lead to lower success rates on exams, which can be immensely frustrating to both students and their professors. Low performance on an exam can be the result of a number of issues. Students may not realize how much they need to prepare due to a false level of confidence in their understanding. They may have underdeveloped study habits, which result in insufficient storage of information. Alternatively, a substantial percentage of students are frustrated with the perception that they study and prepare sufficiently to be successful on exams but still experience a lack of successful outcome. This can be due to students becoming familiar with material by reviewing notes or rereading text without actually developing reliable

recall of the information, or it can be due to a study environment that, unlike a testing environment, provides cues that aid in information recall. Evidence indicates conditions that create difficulty in retrieving information actually optimize long-term storage and recall (Bjork and Bjork, 2011).

Bjork's studies point to two distinct events that must occur for students to experience success on classroom exams. Students must first successfully store presented information through lecture, integration of material using familiar associations, and subsequent study of the material. Instructors can aid students in their endeavors to learn and store presented information by sharing real-life analogies as a framework into which students can integrate the presented material. Equally important to success on these exams is the practice of retrieval of the stored information. Bjork asserts that frequent, low-stakes testing opportunities enable students to practice retrieval as a learning event and will strengthen retrieval efforts as students prepare for their exams (Bjork and Bjork, 2011).

This investigation seeks to utilize Bjork's findings to increase success of community college students in the introductory (majors) biology classroom through the implementation of required quizzes using an online homework platform. Although the effectiveness of online quizzing on increasing exam performance has been studied in courses such as undergraduate social psychology (Johnson, 2009) and exercise physiology (Dobson, 2008), the effectiveness of this approach

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when utilized in an introductory (majors) biology course has not been well documented. We evaluate the efficacy of quizzing in increasing student success on exams in the context of the significant challenge inherent to the mastery of the content and vocabulary and rigor of the material in the majors biology classroom. Additionally, optional online quizzing has been associated with increased achievement on tests in a college educational psychology classroom, but student participation was low, resulting in data gathered specifically from the self-selected population of those students choosing to take these optional quizzes (Johnson, 2006). We introduce quiz taking as a required component of the lecture grade to decrease this self-selection factor. Specifically, we have studied the efficacy of using frequent pre-exam quizzing to increase information retrieval by creating required pre-exam quizzes for those chapter topics that are known to present students with difficulty in learning and understanding. Quiz questions were created that assessed understanding of the subject content to be covered on exams. Questions were unique to the quizzes so as to not be a preview of upcoming exam questions. Exam questions were in multiple-choice format, as were quiz questions. Quiz questions were designed to match or exceed the level of difficulty of exam questions. Quizzes were timed to simulate a testing environment. Quiz questions were created to introduce “desirable difficulties,” as our intent was to challenge the students’ level of recall (Bjork and Bjork, 2011). Data were gathered during two semesters—Fall 2011 and Spring 2012—to assess the reliability of our results.

METHODS

Ten quizzes were given throughout the semester, targeting the chapter material that seems most difficult for students. The textbook utilized was *Campbell Biology* (Reece *et al.*, 2011). Three versions of each chapter quiz were created to reduce the potential for cheating. Quiz questions were matched for question content and difficulty. Quizzes were uploaded to the online homework platform MasteringBiology (MB).

Quizzes were established as required in the course syllabus, worth 10% of the total lecture grade. Three groups were created within the MB course, and students were randomly assigned to these groups. Each group received a different version of each quiz throughout the semester. Randomization was accomplished by assigning students to groups A, B, or C as they registered for MB (across all sections). MB settings for pre-exam quizzes were selected to randomize the item sequence so students within a given group would not see quiz questions presented in the same order. Quizzes were generally limited to a 15-min time limit (10 questions) to reduce the chance that Internet searches would be used to determine the correct answer. To reduce the chance that students would help each other, students were able to see whether an answer was correct only after the assignment was due, and if students answered incorrectly, the correct answer was shown only after the assignment due date. Additionally, no hints were shown, no printing was allowed, item titles were hidden, and student access was limited (no access between completion and due date). These quizzes were given during each of the Fall 2011 and Spring 2012 semesters. Pre-exam quiz averages, exam scores, and percent of pre-exam quizzes taken were recorded for analysis.

Table 1. Comparison of percent pre-exam quizzes taken prior to each exam for Fall 2011 and Spring 2012

% Quizzes completed	% Students completing quizzes prior to exam for Fall 2011 and Spring 2012			
	Exam 1 (<i>n</i> = 362)	Exam 2 (<i>n</i> = 339)	Exam 3 (<i>n</i> = 321)	Exam 4 (<i>n</i> = 305)
100	78.5	59.9	62.9	59.3
67	16.3	22.4	—	—
50	—	—	26.5	25.9
33	3.0	11.5	—	—
0	2.2	7.4	10.3	14.8

RESULTS

Student Compliance with the Quiz Requirement Decreased over the Course of Each Semester That Quizzes Were Given

Table 1 provides a comparison of the percentage of students completing required pre-exam quizzes prior to each of the exams given over the course of the Fall 2011 and Spring 2012 semesters. Students who became inactive in the class during the course of the semester, either by formally withdrawing or by ceasing to take exams, were not included in this analysis. Student compliance with the pre-exam quiz requirement was similar for the Fall 2011 and Spring 2012 semesters. Compliance with the pre-exam quizzing requirement was high at the beginning of each semester, as evidenced by close to 80% of the students taking all quizzes prior to exam 1. The percentage of students taking all pre-exam quizzes dropped as each semester progressed, with only 59% taking these quizzes prior to exam 4. Likewise, the percentage of students taking no pre-exam quizzes was low at the beginning of the semester (just above 2%) but increased throughout the semester, with close to 15% of the students taking 0% of quizzes prior to exam 4.

Students Who Take Pre-Exam Quizzes Tend to be More Successful on Exams

Average exam scores of students grouped by the percentage of pre-exam quizzes completed prior to each of the four exams were compared for the Fall 2011 and Spring 2012 semesters (Figures 1 and 2, respectively). Higher exam averages are observed in the 100% pre-exam quiz completion groups. Scores for exams 2, 3, and 4 are significantly lower for the 0% pre-exam quiz group compared with the 100% pre-exam quiz group. The group of students completing 100% of the quizzes, as well as the group completing 0% of the quizzes, maintained a consistent course average (no significant difference) throughout each semester analyzed.

Exam data were analyzed for both the Fall 2011 and Spring 2012 (Figures 1 and 2, respectively) semesters to determine whether exam averages of those taking 0% of the quizzes were significantly below the class average. The sample size for exam 1 (Fall: *n* = 5; Spring: *n* = 4) for 0% quiz completers does not allow any significant analysis. However, for both semesters, the mean of the 0% pre-exam quiz completion group was significantly below the class average and the average for the 100% pre-exam quiz completion group for

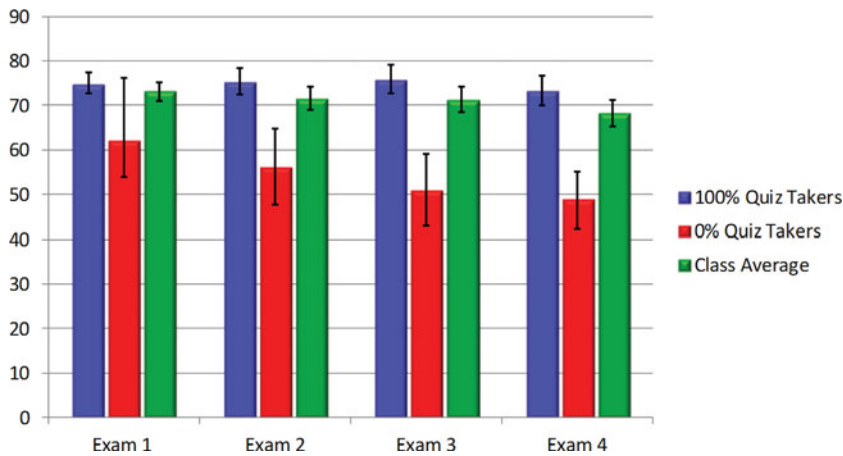


Figure 1. Comparison of exam averages for quiz takers and non-quiz takers for Fall 2011.

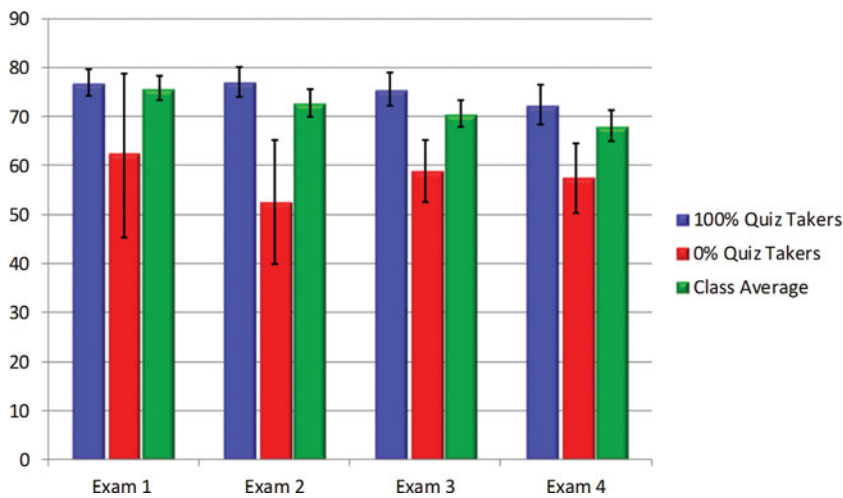


Figure 2. Comparison of exam averages for quiz takers and non-quiz takers for Spring 2012.

exams 2, 3, and 4. Class exam average remained fairly constant for each given exam in both semesters.

Students of All Abilities Benefit from Participating in Pre-Exam Quizzing

To determine whether students of all abilities benefit from participation in quizzing, we grouped students by their averages on exams 1 and 2. Exams 1 and 2 were chosen because they cover roughly eight chapters of material. Performance on these two exams allows us to identify the scholastic ability of students taking this course. These groups are shown in Table 2.

Figure 3 shows that students taking 100% of pre-exam quizzes in the Pass group had a significantly higher exam

3 average than those students in the Pass group who took 0% of pre-exam quizzes. This was true for both the Fall 2011 and Spring 2012 semesters. Significance is defined by nonoverlapping 95% confidence intervals. The groups (sample sizes) shown in Figure 3 are: 100% Pass (Fall 2011: $n = 71$; Spring 2012: $n = 64$), 0% Pass (Fall 2011: $n = 5$; Spring 2012: $n = 9$), 100% Fail (Fall 2011: $n = 41$; Spring 2012: $n = 27$), and 0% Fail (Fall 2011: $n = 7$; Spring 2012: $n = 11$).

Analysis of the Fail group of students (Figure 3) shows that students taking 100% of the pre-exam quizzes in Fall 2011 also had significantly higher exam 3 averages than students in the Fail group taking 0% of the pre-exam quizzes. In Spring 2012, the 95% confidence intervals for the students in the Fail group taking 100% of the pre-exam quizzes versus 0% pre-exam quiz takers overlapped. A higher exam 3 average for the group taking all pre-exam quizzes was still observed, however.

Figure 4 shows that students taking 100% of pre-exam quizzes in the Pass group had a significantly higher exam 4 average than those students in the Pass group who took 0% of pre-exam quizzes. This was true for both the Fall 2011 and Spring 2012 semesters. Significance is defined by nonoverlapping 95% confidence intervals. The groups (sample sizes) shown in Figure 4 are: 100% Pass (Fall 2011: $n = 68$; Spring 2012: $n = 56$), 0% Pass (Fall 2011: $n = 8$; Spring 2012: $n = 15$),

Table 2. Student groups defined by the average of exams 1 and 2

Student group	Exam 1 + 2 average
Pass	70% and above
Fail	Below 70%
Low (weak)	Below 60%
Middle (average)	60–80%
High (strong)	Above 80%

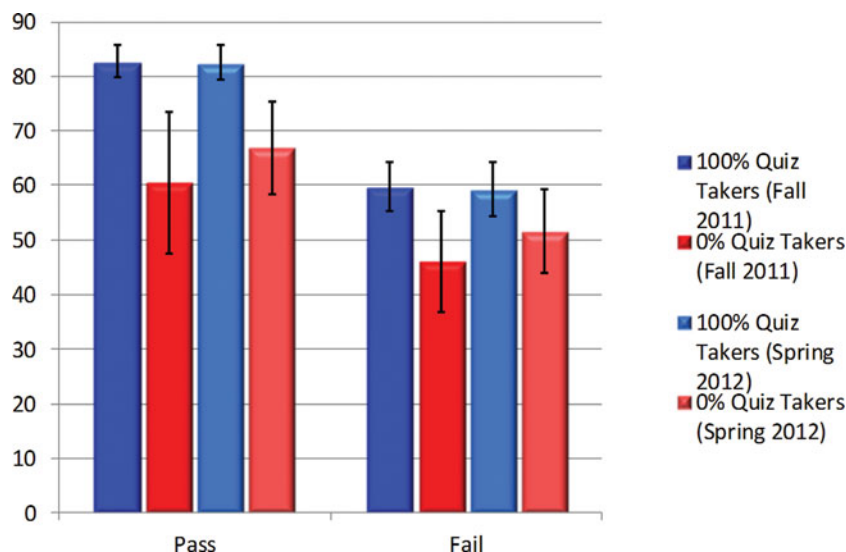


Figure 3. Comparison of exam 3 averages for Pass and Fail groups between 100% quiz takers and 0% quiz takers.

100% Fail (Fall 2011: $n = 34$; Spring 2012: $n = 22$), and 0% Fail (Fall 2011: $n = 8$; Spring 2012: $n = 14$).

The group of students who took 100% of the pre-exam quizzes in the Fail group in Fall 2011 also had significantly higher exam 4 averages than those students in the Fail group who took 0% of the pre-exam quizzes (Figure 4). In the Spring 2012 semester, the 95% confidence intervals for students in the Fail group taking 100% of the pre-exam quizzes versus 0% pre-exam quiz takers overlapped, but a higher exam 4 average for the group taking all pre-exam quizzes was still observed.

In an effort to do an even more granular analysis of the benefit of quizzing using demonstrated performance on exams, we sorted students into three groups representing a more narrow distribution of exam score averages (Table 2). These groups are composed of both Fall 2011 and Spring 2012 students, such that sample sizes might be large enough that statistically significant differences could be observed. (Students took the same exams and the same quizzes each semester.)

The groups (sample sizes) shown in Figure 5 are: 100% Low ($n = 26$), 0% Low ($n = 7$), 100% Middle ($n = 92$), 0% Middle ($n = 21$), 100% High ($n = 85$), and 0% High ($n = 4$). The groups (sample sizes) shown in Figure 6 are: 100% Low ($n = 19$), 0% Low ($n = 9$), 100% Middle ($n = 82$), 0% Middle ($n = 26$), 100% High ($n = 79$), and 0% High ($n = 10$).

Figure 5 shows that students taking 100% of pre-exam quizzes in the High group of students had a significantly higher exam 3 average than those students in the same group who took 0% of pre-exam quizzes. Additionally, students in the Middle group of students also had a significantly higher exam 3 average than those students in the same group who took 0% of pre-exam quizzes. Low-performing students taking 100% of pre-exam quizzes also had higher averages for exam 3 than those taking 0% of pre-exam quizzes, but due to the small sample size of this group, this difference is not significant using 95% confidence intervals.

Figure 6 shows that students taking 100% of pre-exam quizzes in the High group of students had a significantly

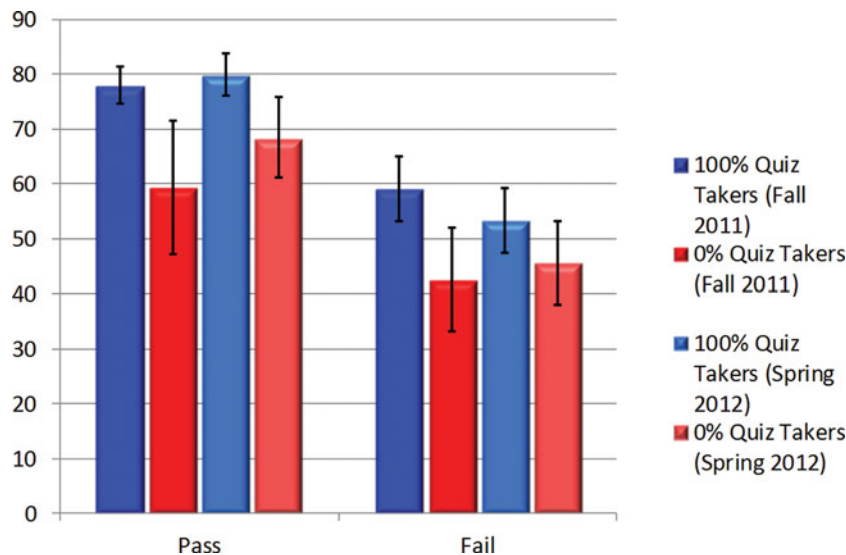


Figure 4. Comparison of exam 4 averages for Pass and Fail groups between 100% quiz takers and 0% quiz takers.

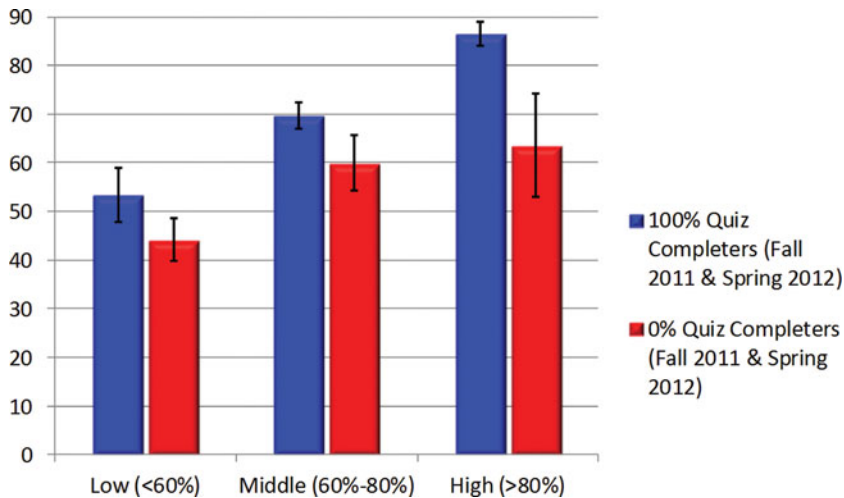


Figure 5. Comparison of exam 3 averages for Low, Middle, and High groups between 100% quiz takers and 0% quiz takers for Fall 2011 and Spring 2012 combined.

higher exam 4 average than those students in the same group who took 0% of pre-exam quizzes. Additionally, students in the Middle group of students also had a significantly higher exam 4 average than those students in the same group who took 0% of pre-exam quizzes. As was seen for exam 3, students with a Low performance taking 100% of pre-exam quizzes also have higher averages for exam 4 than those taking 0% of pre-exam quizzes, but due to the small sample size of this group, this difference is not significant using 95% confidence intervals.

DISCUSSION

The implication of this study is that frequent online quizzing is an effective approach in increasing students' ability to retrieve information and subsequent performance in the introductory (majors) biology classroom. Students who take pre-exam quizzes do significantly better than those who do not take pre-exam quizzes. The exam average gap between quiz takers and non-quiz takers observed as the semester progressed is notable, as the exam average of the group of students not taking any of the required pre-exam quizzes

falls significantly below the class average as the semester progresses. While we do observe that increased quiz scores are significantly correlated with increased exam scores (unpublished data), what is particularly notable about our findings is that simply *participating* in pre-exam quizzing (100% quiz takers vs. 0% quiz takers) is associated with increased exam scores. This supports Bjork's assertions that testing serves as a learning event and should not be utilized only as an assessment tool.

Most intriguing is the evidence that students of all abilities benefit from participation in pre-exam quizzing. That students who take quizzes have higher exam averages than those who did not take quizzes is not surprising (Figures 1 and 2). Many would point to the fact that merely taking quizzes is an indicator of the level of scholastic strength and motivation in a given student. To determine whether this was the case, we grouped these students by ability (as assessed by exam 1 and 2 average) and then compared 100% quiz takers with 0% quiz takers within each group. This effort was made to mitigate the innate ability of the student as a confounding factor and to focus on the potential benefit participation in quizzing might give a student. In both Fall 2011 and Spring 2012, students with a passing

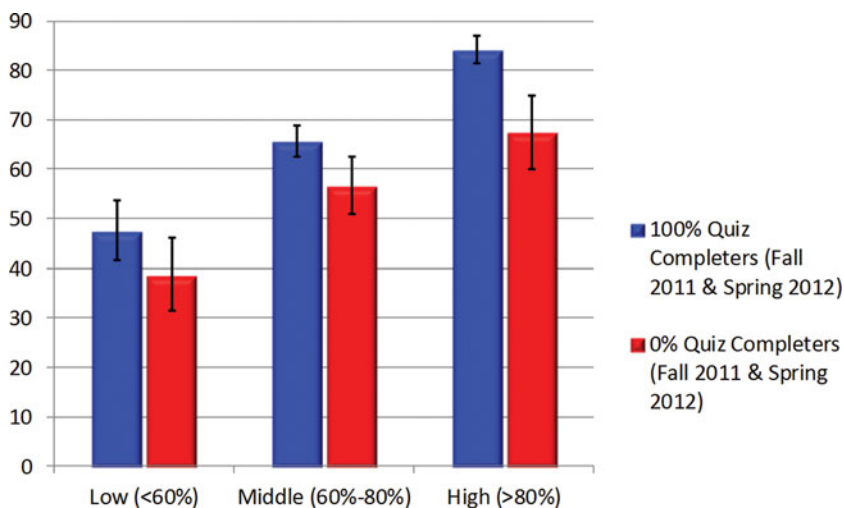


Figure 6. Comparison of exam 4 averages for Low, Middle, and High groups between 100% quiz takers and 0% quiz takers for Fall 2011 and Spring 2012 combined.

average on exams 1 and 2 were observed to significantly benefit from taking 100% of pre-exam quizzes as compared with those not taking these quizzes. Additionally, we were quite encouraged to find that those students with a failing average taking 100% pre-exam quizzes showed significantly higher exam 3 and exam 4 averages than those taking no pre-exam quizzes in the Fall 2011 semester. A similar trend of higher exam scores for students taking 100% of pre-exam quizzes was observed in Spring 2012, although significance was not established for that group (Figures 3 and 4). This resulted in our redefining the Pass/Fail student groups into groups that were more narrowly defined (High, Middle, and Low). Analysis of these groups demonstrates not only that students with a High performance benefit from pre-exam quizzing, but also that those Middle students also see significant benefit from taking pre-exam quizzes (Figures 5 and 6). Those students averaging below 60% on exams 1 and 2 also seemed to experience some benefit from the quiz-taking activity, although significance was not established, due to low sample size.

The advantage to participating in pre-exam quizzing seems to give even the weakest students a letter grade advantage over those not taking pre-exam quizzes. The benefit seen by High or strong students taking 100% versus 0% of pre-exam quizzes seems particularly strong when compared with the benefit seen by middle/average students taking 100% versus 0% of pre-exam quizzes (Figures 5 and 6). However, specific analysis of the gains in exam average with increased quiz-taking activity indicates that the benefit yielded to each of these two groups is not significantly different. In summary, in every group analyzed, students who took all of the offered pre-exam quizzes had higher exam scores than those taking none of the offered pre-exam quizzes.

Of particular interest is the fact that compliance in taking the required pre-exam quizzes declined throughout the semester, in spite of the required nature of these quizzes. One of Bjork's assertions stressed the benefits of introducing "desirable difficulties" to students in the college classroom (Bjork and Bjork, 2011). The introduction of required pre-exam quizzes seems to create a significant enough difficulty for some students such that they reject the effort entirely. It should be noted that the difficulty of the quizzes was significant but not extreme (on a scale of 1–5, in which 1 is easy and 5 is most difficult, quizzes were assessed by MB to average around 2.8). This may be due to the nature of the student population, as this study was done in a community college classroom, in which no selection criteria for admission are in place. This yields a notable variation in the student population from a motivation and preparation standpoint. Current efforts focus on increasing student compliance by emphasizing the potential benefit of quizzing on exam scores to the students prior to each quiz period.

Surveying students regarding their experience with pre-exam quizzing indicates that most students found this strategy valuable, as 87.32% of students surveyed indicated that they plan to continue quizzing as part of their preparation for future classes ($n = 142$). Particularly interesting is that 73.42% reported that taking the required quizzes caused them to go back and do additional studying of the material/additional

preparation prior to the exam. Pre-exam quizzing may act as an early warning system for students, showing them that they have the illusion of knowing the material but have not learned the material sufficiently for accurate recollection in a testing environment (Koriat and Bjork, 2005). In fact, surveyed students reported that pre-exam quizzing increased their understanding of the material (26.28%), but more commonly helped them to pinpoint how to study for exams (57.69%). While pre-exam quizzing is only one of many strategies that a student may utilize in preparing for exams, Koriat and Bjork's research indicates that having all of the information present, such as in the conditions in which most students study (reading the textbook and reviewing notes), is less effective in yielding maximum recall of the information and more likely to produce an "illusion of competence." This leads us to discard the idea that students not participating in pre-exam quizzing could simply increase the time committed to reviewing their notes and the text and see the same results as those taking 100% of the pre-exam quizzes.

Overall, the benefit of pre-exam quizzing seems to be driven by the decision of the individual student to commit to taking all of the required quizzes. Our analysis indicates that this benefit is not limited to only strong students who are typically successful on exams, but that students of all abilities see a benefit from taking online, pre-exam quizzes. Pre-exam quizzing utilizing an online platform seems to be an effective way to increase student performance on introductory biology exams, and quiz averages serve to give students feedback as to potential exam performance.

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