

Assessing the Impact of Weekly In-class Pop Quizzes on Student Performance in a Fundamental ECE Course

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Abstract

This work evaluates the effect of weekly in-class pop quizzes on the learning outcomes of ECE sophomore-level undergraduate students in a signals & systems course at the University of Illinois Urbana-Champaign. The quizzes pursued two goals: to increase class attendance and to motivate students to keep up with the material in a timely manner. While the quizzes may help achieve both goals, in-class pop quizzes may also result in the elevation of students' stress as well as they may negatively impact the students' attitude toward the instructor.

We analyze the overall impact of the quizzes on the students' final grades from multiple perspectives. In addition, we examine the students' opinion about the quizzes and the instructor. Finally, we evaluate if the quizzes encouraged students to attend lectures and stay on top of the material.

Our findings show that final grades are marginally negatively affected by the quizzes. However, the main reason for that is not the quizzes themselves but the large number of students (~27%) who missed multiple quizzes. In fact, the quizzes resulted in improving the final grades for those students who attended most of them.

In addition, our results indicate that the students agree that quizzes helped them from multiple perspectives: encouraging attendance, promoting frequent review of course material, and preparing them for exams. Despite that, attendance decreased significantly toward the end of the semester.

Our findings also demonstrate that students experienced a high level of stress due to quizzes. However, no evidence was found that the quizzes had a significant negative effect on the students' attitude toward the instructors.

Introduction

For Electrical and Computer Engineering (ECE) undergraduate students, developing a solid understanding of fundamental concepts is essential for performing successfully in advanced courses. Although there are various reasons affecting the student's ability to master the concepts well, two factors are considered often. One factor is class attendance.

Regular lecture attendance is typically expected from college students. Indeed, as the findings presented in [1], [2], and [3] demonstrate, there is a positive correlation between regular

attendance and the student's grades.

The other factor is the ability of students to keep up with the material promptly. As study [4] emphasize, some students may wait until the last moment to study the material, which negatively impacts their deep understanding of the material.

Many studies summarized in [5] believe that in-class quizzes are a valuable tool to encourage students to attend classes and review the material often. One way to conduct in-class quizzes is to announce them to students in advance. However, the concern is that announced in-class quizzes will only increase attendance on a particular day: examination day.

One possible solution is to incorporate daily quizzes as described in reference [6]. The drawback, however, is the significant daily effort required on the part of the course staff. Different versions of the quiz must be created and graded every day to ensure the students' individual efforts. The daily quizzes would also take time away from the lecture, forcing the instructor to rush through the material toward the end of the semester. Thus, such quizzes appear as not a viable option for courses with an intense pace due to the limited class time.

The other solution is less frequent but unannounced pop quizzes. The quizzes should motivate students to attend every lecture without as much time commitment from the instructors. However, it has been observed that in-class pop quizzes can increase students' anxiety and deteriorate the mutual relationship between students and the instructor [7].

This work will evaluate the effect of weekly in-class pop quizzes on the learning outcomes of ECE sophomore-level undergraduate students in a signals & systems course at the University of Illinois Urbana-Champaign during the Spring 2022 semester.

The course covers a combination of circuit analysis and analog signal processing, setting the foundation for the majority of higher-level courses. Due to the wide range of the material covered, the course pace is intense as the class meets four times a week for fifty minutes.

In the Spring 2022 semester, quizzes were introduced for the first time in response to a significant decrease in attendance ($> 50\%$ drop) after the first few weeks during previous semesters. Historically, the authors supported the vision highlighted in [8] as optional attendance should help students to grow. However, it became apparent, that students misinterpreted the freedom skipping too many lectures. In addition, the instructors observed that it was difficult for students to stay on top of the material if it is not somehow enforced.

The quizzes were offered along with homework assignments, laboratory assignments, midterm exams, and the final exam. The quizzes also contributed to the final grade to motivate students to approach quizzes more seriously [9].

The quizzes were given in class once a week at a random time on a random lecture day to avoid students simply showing up for the quizzes on fixed days and not attending lectures the rest of the week. However, students were notified in advance about having only one quiz per week. Students were also told that the quizzes covered the previous week's material. To ensure that students had enough time to arrive at class and not miss the quizzes, it was guaranteed that quizzes would not occur during the first ten minutes of the lecture. It is important to note, that students with disabilities were permitted to schedule their quizzes with appropriate accommodations, if

deemed necessary. Consequently, it would no longer be considered a surprise quiz for students with disabilities since they were informed of the scheduled time of occurrence.

Due to the extensive course enrollment (over 300 students), the course is typically divided into four synchronized sections where students were taught by different instructors on the same material. Previously, students were not obligated to attend only the section they signed up for. However, in the Spring 2022 semester, the students were forced to attend only their registered section to ensure that they could not take the same quiz multiple times in different sections.

The quizzes were eight minutes long and contained either one longer or two shorter open-answer problems. To minimize the possibility of copying, quiz problems were printed on paper of two different colors, indicating two different sets of problems of similar difficulty, and students sitting next to each other were given different versions.

Quiz problems and solutions were created by the course instructors. The solutions were released to students immediately after all students took the quiz of the corresponding week. The quizzes were graded on a 0-10 scale by graduate teaching assistants, following a rubric created by the instructors, and returned to students within a week after the quiz date.

Methodology

First, this course improvement work examines the overall impact of the quizzes on students' final grades. We compare the calculated final grades against re-scaled grades in which the quizzes are excluded from the calculation. The final grades are calculated based on eleven quizzes (15% of the total grade), fourteen homework assignments (15%), six laboratory assignments (10%), three midterm exams (36%) and one final exam (24%). The two lowest-scored quizzes and the two lowest-scored homework assignments were dropped from the final grade calculation.

In order to remove the contribution from the quizzes, the grades for comparison are calculated by re-scaling the initial percentages by 85 points, resulting in 17.65%, 11.76%, 42.35%, and 28.24% respectively. The two lowest-scored homework assignments were still excluded from the final grade calculation.

In order to further evaluate the impact of quizzes on grades, we compare grades based on solely individual efforts such as exams and quizzes, while excluding homework and laboratory assignments from the calculations. By the authors' observations, homework assignments may not always provide an accurate reflection of a student's knowledge or performance, as students often seek assistance from others or even may copy answers from peers or online sources. Although labs are relatively more representative of a student's individual effort, students still receive significant help with them.

For this comparison, we calculate the grade with quizzes by re-scaling both quizzes and exams, so that the total adds up to 100%. We consider eleven quizzes contributing 20%, three midterm exams of 48%, and one final exam of 32%. The grade without quizzes is calculated by re-scaling the exams only, so that the total adds up to 100%. Here we consider three midterm exams contributing 60%, and one final exam of 40%.

Next, we evaluate the impact of particular factors on the final grades such as the number of

missed quizzes, the difficulty of the quizzes compared to the exams, and the pop nature of the quizzes.

In order to assess the impact of the number of quizzes missed on the final grade, we divide the students into two groups based on the frequency of missed quizzes. We refer to the students who missed less than three quizzes as group 1, and the remaining students as group 2. The number of quizzes for the group separation is based on the policy of dropping the two lowest scored quizzes. Then, we compare the average grades between these two groups. In addition, we repeat the analysis with homework and lab assignments excluded.

After our discussion on grades, we examine the results of two surveys conducted during the semester. These surveys aimed to determine whether the quizzes motivated students to attend lectures and review the material frequently, as well as to evaluate students' attitude toward the quizzes.

The first survey was conducted after the first three weeks of classes. The survey consisted of questions that asked students to reflect on specific topics using a five-point Likert scale. These topics included the extent to which quizzes motivated students to review the material frequently, the extent to which quizzes helped them to prepare for exams, whether the quizzes were of appropriate length for the given time, and whether the quizzes encouraged students to attend lectures.

The Likert scale ranged from 1, indicating agreement, to 5, indicating disagreement, and the questions were as follows:

- Quizzes motivate you to review course material often.
- Quiz length is appropriate for the time allocated.
- Quizzes help you to prepare for the exam.
- Quizzes encourage you to attend lectures.

Another survey was conducted before the final exam. The initial part of this survey asked students to answer the same questions as in the first survey. Subsequently, students were presented with the statement "*We have determined by analyzing the grades that the quizzes did not affect the overall grades. Please answer the questions again.*".

In addition to the same questions from the initial part, the second part of the survey also included an inquiry into the level of stress that pop quizzes induced in students. Responses were recorded on a 5-point scale, ranging from Very high (1) to Very low (5)."

Finally, in order to evaluate the impact of the quizzes on the students' attitude toward the instructor, we discuss the results of an optional end-of-semester Instructor & Course Evaluation System (ICES) survey. We compare the "Rate the instructor" scores in Spring 2022 with the scores from Fall 2021 when the same instructor taught the course without pop quizzes. It is important to note, that only three instructors participated in this work since the fourth instructor was different in both semesters.

We considered the three main items of the end-of-year feedback form, which are as follows:

- Rate the instructor’s overall teaching effectiveness.
- Rate the overall quality of this course.
- How much have you learned in this course?

All of these items were rated on a 1 to 5 integer scale, with the first two having 1-Exceptionally Low and 5-Exceptionally High, while the last question had 1-Very Little and 5-A Great Deal.

Findings on effect of quizzes on grades

First, a comparison of the average of the calculated final grades against re-scaled grades without the quizzes is presented in Figure 1 (a), which depicts a slightly negative impact of the quizzes on the final grades, with an average reduction of merely 1.1 points out of 100, with a standard deviation of 2.27.

Figure 1 (b) shows a distribution of difference (grade with quizzes minus grade without quizzes) in final grade comparison among individual students. The figure clearly demonstrates that a slightly negative impact was a result of a combination of some students experiencing lower scores with quizzes factored in while others achieved higher scores. Specifically, approximately 62% of students experienced a decrease in their grades, with an average decline of 2.34 points out of 100. Conversely, the remaining 38% of students saw an improvement in their grades, with an average increase of 0.91 points out of 100.

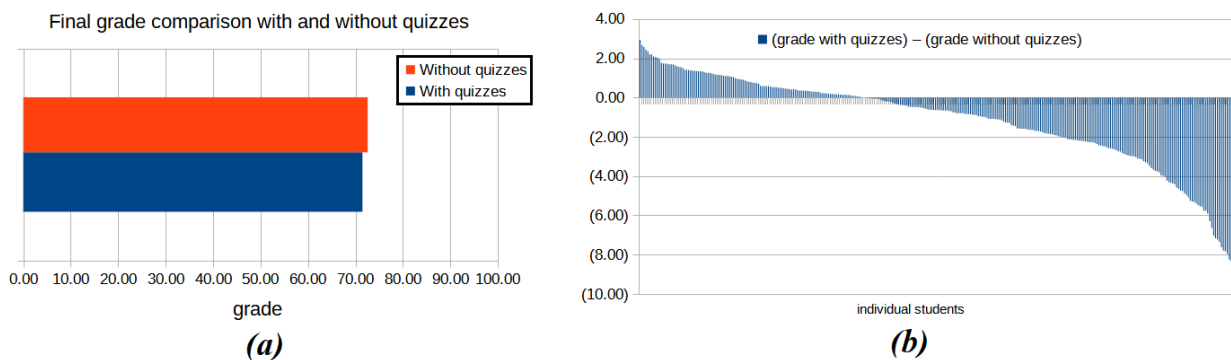


Figure 1: a) Final grade comparison. b) Distribution of difference in final grade comparison among individual students, where each vertical bar represents the grade difference for one student.

During the semester, students raised concerns about their grades being significantly impacted by their unsatisfactory performance on the quizzes. However, the reality is that the majority of students typically performed similarly in quizzes and exams. A 1-2% difference is well within the expected range.

Next, we present the results of the grades comparison when the homework and lab components were removed from the calculation. Figure 2 (a) shows a comparison of the average of the calculated final grades against re-scaled grades without the quizzes. Here we observe an even

smaller negative impact of the quizzes on the final grades than before, when the homework and labs were included. Indeed, the average decreased by only 0.39 points of 100, with a standard deviation of 3.19.

Figure 2 (b) shows a distribution of difference (grade with quizzes minus grade without quizzes) in final grade comparison among individual students. The range in the grade difference falls between -11.42 and 6.14. Out of all the students, 54.42% had a positive difference in their grades, indicating that their scores were improved with the quizzes. Conversely, 45.57% of the students had a negative difference, which implies that their scores were lower with the quizzes. Furthermore, the data indicates that only 5% of the students have a larger negative difference than the largest positive difference. This indicates that only a small percentage of students are responsible for the average difference being negative.

Overall, it seems that the inclusion of quizzes in the final grade does not significantly affect the final grades. This observation is in line with the typical behavior of students roughly scoring similarly in each exam, with significant deviations being uncommon.

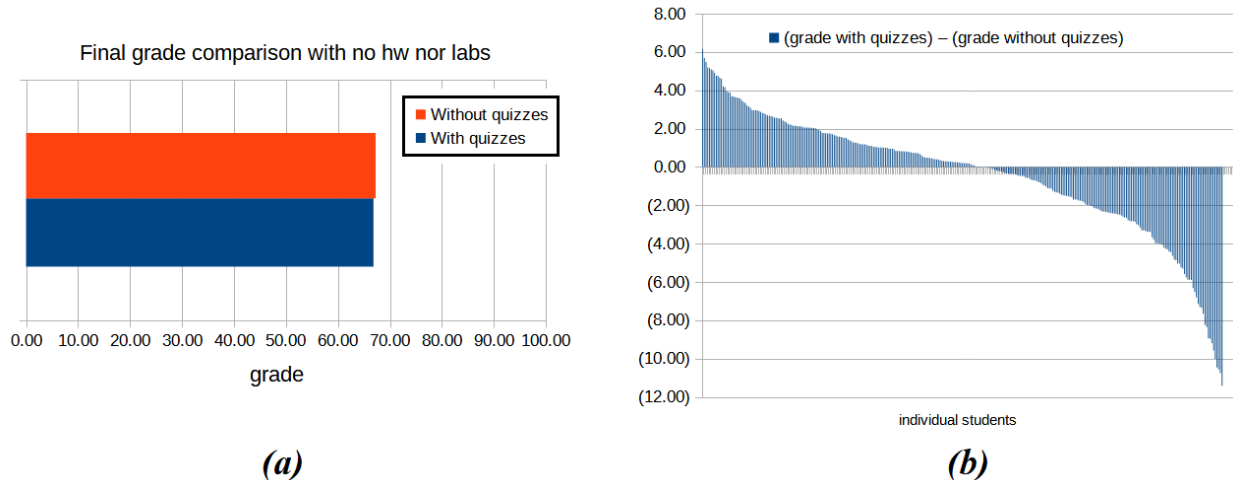


Figure 2: (a) Final grade comparison with homework and lab assignments excluded. (b) Distribution of difference in final grade comparison among individual students, where each vertical bar represents the grade difference for one student.

Next, we present the results showing the impact of the number of quizzes missed on the final grade. A comparison of the average of the grades between the group 1 and the group 2 (see Methodology) is presented in Figure 3.

Final grade comparison based on number of quizzes missed

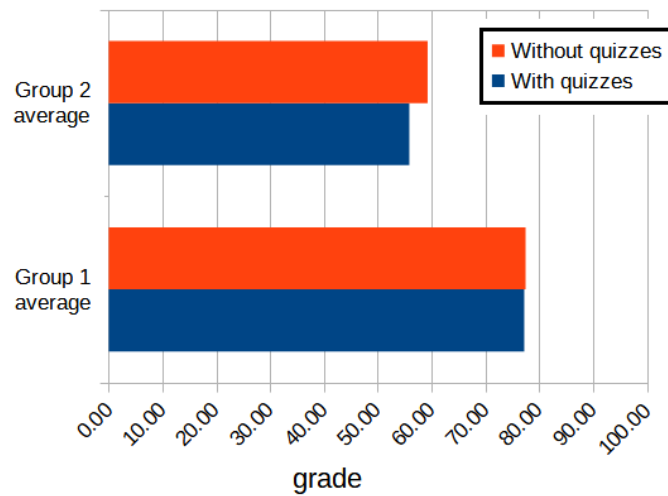


Figure 3: Final grade comparison based on number of quizzes missed. Group 1: students who missed less than three quizzes. Group 2: students who missed three or more quizzes.

It depicts an almost negligible impact of the quizzes on the final grade of group 1 and a more pronounced impact on group 2. For group 1, the average final grade decreased merely by 0.26 points out of 100, while for group 2, the average final grade decreased by 3.39 points out of 100. There is a significant difference between the impact of quizzes on the final grades between these two groups, which can be corroborated by a t-test with p -value of $5.04E - 18$. This indicates that the overall negative impact of the quizzes is due to the number of quizzes students missed and got zeros on, not on the difficulty of the quizzes.

Figure 4 depicts the distribution of the difference in grades (grade with quizzes minus grade without quizzes) for each student in group 1 and group 2. The figure clearly shows that group 2 was more negatively impacted by the quizzes than group 1.

The range in grade differences within group 1 was found to be between -6.63 and 2.94, with a mean of -0.26 and a standard deviation of 1.50. Additionally, 49% of students had a positive difference, while 51% had a negative difference. In contrast, the range in grade differences within group 2 was between -8.35 and 2.05, with a mean of -3.54 and a standard deviation of 2.35. The results indicated that only 5% of students had a positive difference, while a vast majority of 95% had a negative difference.

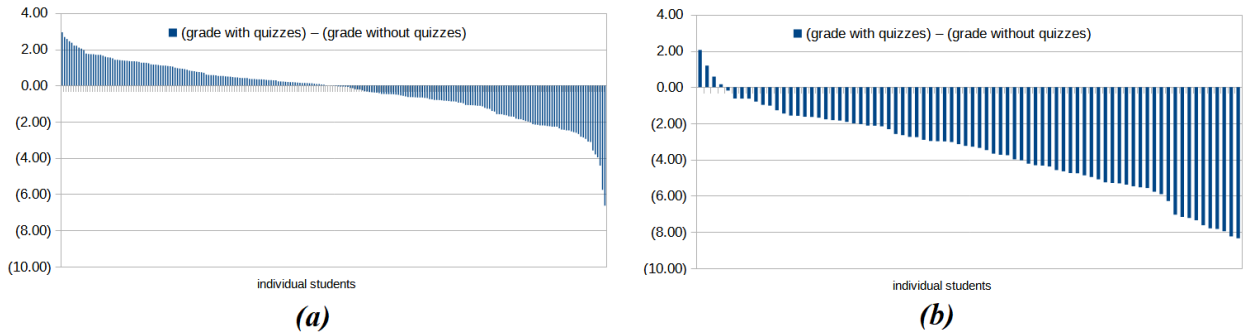


Figure 4: Distribution of difference in final grade comparison with and without quizzes. (a) group 1: students who missed less than three quizzes. (b) group 2: students who missed three or more quizzes. Each vertical bar represents the grade difference for one student.

Figure 5 depicts the distribution of missed quizzes. It is very surprising that such a large percentage of students, 27%, missed more than two quizzes, directly impacting 15% of their grades. Some students missed all eleven quizzes, effectively giving up 15% of the grade. This large number of missed quizzes among such a large percentage of students definitely plays a significant impact on the final grade.

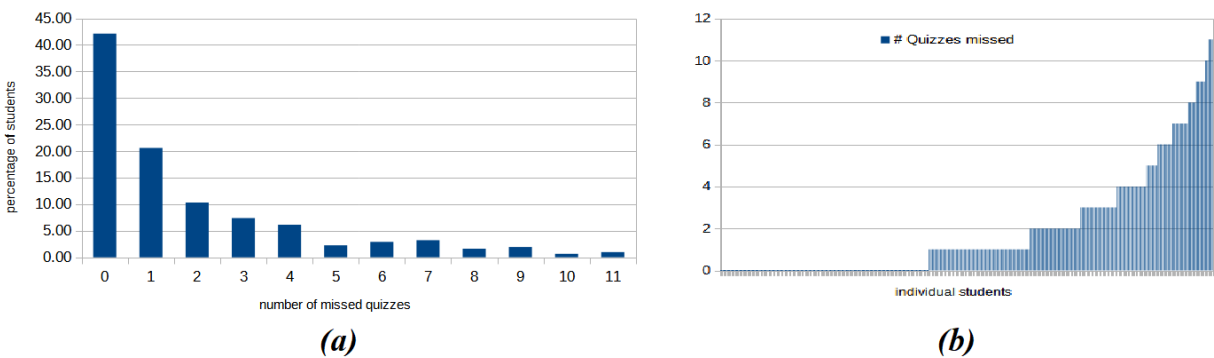


Figure 5: Distribution of missed quizzes. (a) histogram of number of missed quizzes. (b) distribution of number of missed quizzes among individual students.

Figure 6 compares the grades stripped of the homework and lab components again to compare the effect of the quizzes on the re-scaled grade but within the two previous groups: group 1 being the one that missed less than three quizzes and group 2 being the one that missed at least three quizzes.

Final grade comparison based on number of quizzes missed, without HW nor labs.

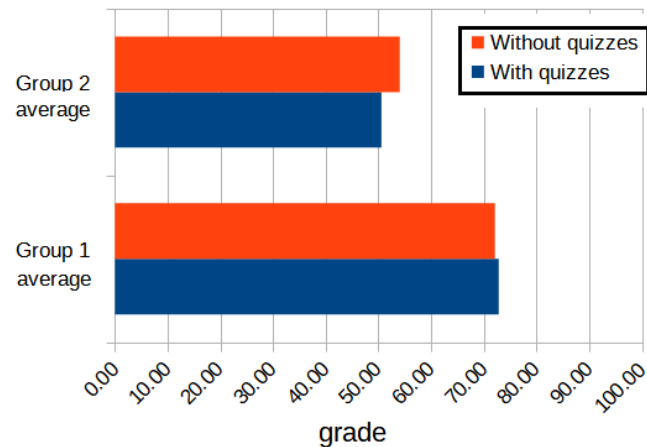


Figure 6: Final grade comparison between groups 1 and 2 with homework and lab assignments excluded. Group 1: students who missed less than three quizzes. Group 2: students who missed three or more quizzes.

Figure 6 now depicts a marginal positive impact of the quizzes on the final grade of group 1 but still a negative impact on group 2. For group 1, the average increased by 0.73 points out of 100, while for group 2, the average decreased by 3.64 points out of 100. There is a significant difference between the impact of quizzes between these two groups, which can be corroborated by a t-test with unequal variance with p -value of $2.4E - 17$.

Figure 7 depicts the distribution of the grade differences for each student in the two groups. The data clearly demonstrates that the students in group 2 experienced a significant negative impact.

For group 1, the range in grade differences was found to be between -7.16 and 6.14, with a mean of 0.73 and a standard deviation of 2.15. Notably, 68% of the students had a positive difference, while 32% had a negative difference. In contrast, for group 2, the range in grade differences falls between -11.32 and 4.21, with a mean of -3.64 and a standard deviation of 3.48. Remarkably, only 15% of the students had a positive difference, while a substantial 85% had a negative difference.

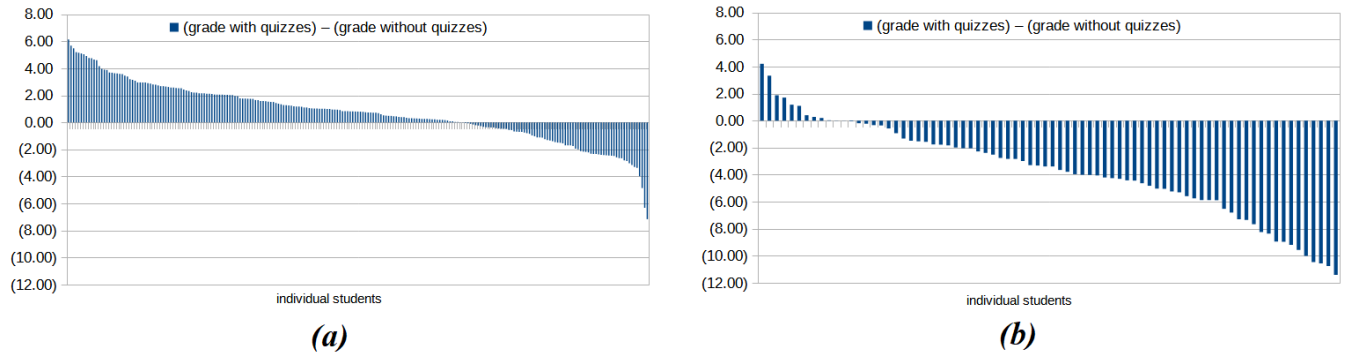
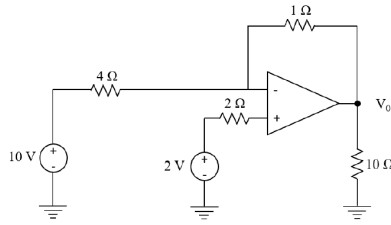


Figure 7: Distribution of difference in final grade comparison with and without quizzes and with homework and lab assignments excluded. (a) group 1: students who missed less than three quizzes. (b) group 2: students who missed more three or more quizzes. Each vertical bar represents the grade difference for one student.

This reinforces the fact that the reason why quizzes had a marginally negative impact on final grades was missing quizzes, not the quiz difficulty. We can see that among students that actually took most quizzes, the quizzes actually improved their grades on the components of the course that required purely individual work: exams.

For completeness, we address the potential effect of quiz length and difficulty on final grades. The difficulty of the quizzes was immensely lower than that of the exams because students only had eight minutes to work on the quizzes, compared to 75 minutes for the exams. A typical exam consists of four questions with multiple parts, totaling around 12 parts. The typical quiz had only one question, sometimes split into two parts. The questions themselves were much different in level of difficulty, level of understanding needed, and amount of computation required. Figure 8 presents a comparison between op-amp questions in a quiz vs. an exam. The quiz question simply requires a basic KCL at the inverting terminal, a technique that was used multiple times during lectures in the week prior to the quiz, and in the homework due the week of the quiz. On the other hand, the exam question requires multiple and more complex KCLs, as well as a deeper understanding of op-amps, in terms of cascading them and their buffering effect.

(5 pts) Use the ideal op-amp approximation to determine V_o in the following circuit:



[15 pts] Consider the circuit below. Determine V_1 , V_o , and i using ideal op-amp approximations.

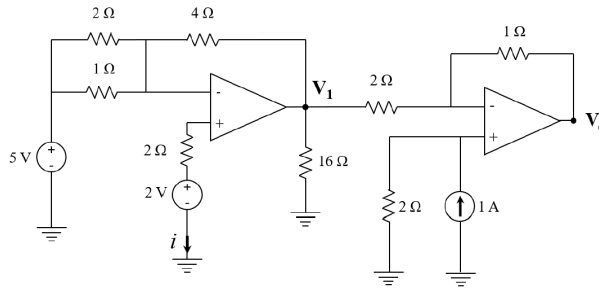


Figure 8: Question comparison between quiz (top) and exam (bottom).

Findings on students' perspective of quizzes

In this section, we present the results of the two anonymous surveys administered at the end of lectures, which asked students to reflect on certain aspects of the quizzes.

A total of 202 students responded to the first survey, which was conducted after the first three weeks of classes. Figure 9 presents the distribution of student responses and the average results, providing compelling evidence that the objectives of the quiz implementation were largely achieved, as the majority of students agreed with the statements.

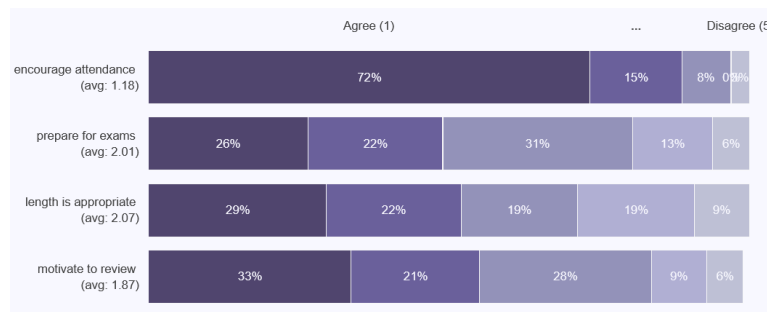


Figure 9: Student responses to the first survey on a five-point Likert scale, with 1 corresponding to Agree and 5 to Disagree.

The second survey, conducted before the final exam, had similar results to those of the first survey. It shows that the objectives of the quiz implementation were still largely accomplished by the end of the course since students still agreed more than disagreed with the statements, although

to a lesser degree. Despite this, it should be noted that the number of students attending lectures had decreased considerably by the time of the second survey, with only 129 students attending compared to the original 202. This decrease suggests that the goal of promoting attendance through the quizzes was not fully realized in practice even though quizzes constituted 15% of the final grade.

Figure 10 depicts the change from the first survey to the second survey, which indicates a decline in agreement across all questions as the semester progressed.

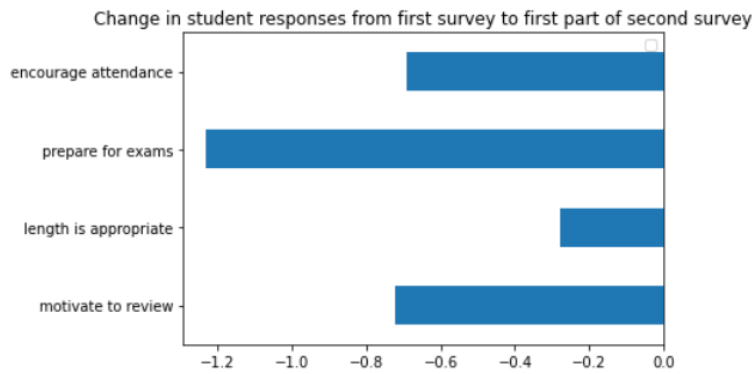


Figure 10: Difference in student responses from first survey to the first part of the second survey.

Figure 11 presents the distribution of student responses and the average results, revealing that the objectives of the quiz implementation were largely achieved, with students expressing agreement with the statements in general. However, the category of "prepare for exams" deviates from this trend, indicating a potential area where the objectives may not have been fully met.

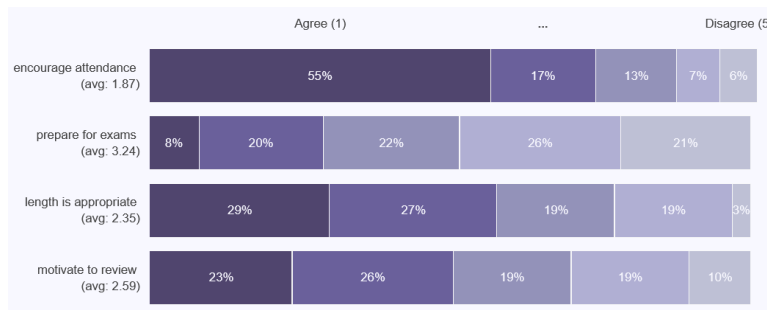


Figure 11: Student responses to first part of second survey on a five-point Likert scale, with 1 corresponding to Agree and 5 to Disagree.

The second survey had a follow-up segment, which asked the same questions after students were informed that the quizzes did not have a substantial impact on their overall grades. The survey results indicate that there was a notable shift in students' level of agreement after they became aware that grades were not significantly impacting their grades as they believed.

Figure 12 depicts the change between the initial and follow-up segments of the second survey. The observed increase in the category "prepare for exams" is expected since knowing that quizzes

had no significant bearing on their grades might lead students to think that quizzes might serve as a useful study tool. However, the corresponding changes in other categories are somewhat unexpected. For instance, how does that newly acquired knowledge change how much the quizzes encouraged attendance.

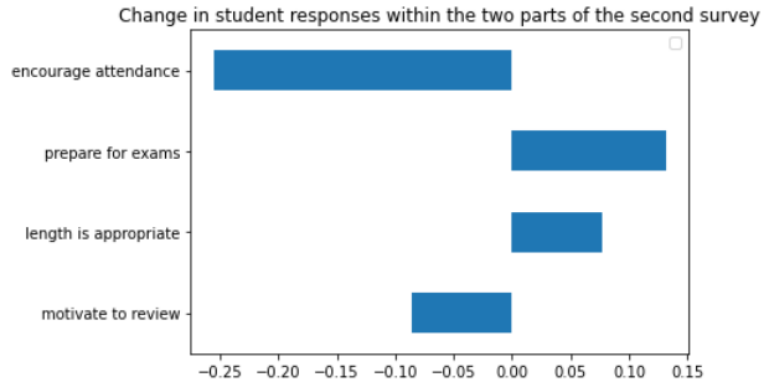


Figure 12: Difference in student responses from first survey to the first part of the second survey.

Figure 13 presents the distribution of student responses and the average results, further corroborating that the objectives of the quiz implementation were largely met, as evidenced by the students’ overall agreement with the statements. However, it is notable that the ”prepare for exams” category continued to exhibit lower levels of agreement, despite a slight increase after students were informed that their grades were not significantly impacted by the quizzes.

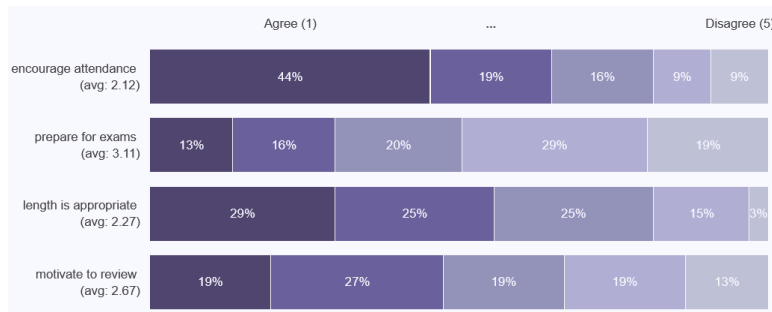


Figure 13: Student responses to second part of second survey on a five-point Likert scale, with 1 corresponding to Agree and 5 to Disagree.

The second survey also asked students to ”Evaluate your level of stress due to quizzes”. Students responded on a 5-point scale of Very high (1) to Very low (5). Figure 14 presents the distribution of student responses and the average results. Notably, the average value was 2.67, indicating that stress was high. It is crucial to address this, if a similar implementation is to be considered. It is possible that stress is the reason why students missed quizzes, despite the positive impact of quizzes on students’ overall performance in the course.

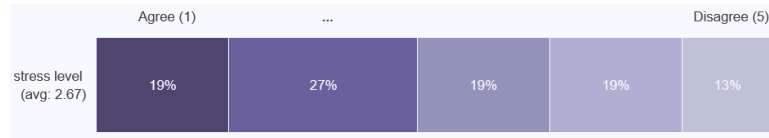


Figure 14: Student responses to stress level part of second survey on a five-point Likert scale, with 1 corresponding to Agree and 5 to Disagree.

Findings on effect of quizzes on students' attitude towards the course and the instructors

We present the results for the three instructors in Tables 1, 2 and 3.

Table 1: Summary of end of year student feedback form results for instructor 1.

	# responses	effectiveness	quality	learned
Fall 2021	9/58 (15.5%)	4.0	3.33	4.22
Spring 2022	21/101 (20.8%)	4.57	4.05	4.71

Table 2: Summary of end of year student feedback form results for instructor 2.

	# responses	effectiveness	quality	learned
Fall 2021	12/79 (15.2%)	3.75	3.50	4
Spring 2022	14/54 (25.9%)	3.43	3.29	4.64

Table 3: Summary of end of year student feedback form results for instructor 3.

	# responses	effectiveness	quality	learned
Fall 2021	12/58 (20.7%)	4.33	4.08	4.75
Spring 2022	14/73 (19.2%)	3.43	2.71	3.93

It should be noted that in one section, scores increased across all categories despite the quizzes were instituted, whereas in the other sections scores mostly decreased. However, the one item that consistently increased was the the amount of learning, which ultimately the primary goal of the quizzes.

It is important to remember, that aforementioned data is based on self-reporting, and as such, it would be necessary to compare data across multiple semesters under the same conditions, which is virtually impossible due to various factors such as changes in course staff, and availability of past exams for students to review.

Conclusions

In this work, we evaluate the effect of weekly in-class pop quizzes on the learning outcomes of an ECE sophomore-level undergraduate signals & systems course. The quizzes pursued two main goals towards improving performance: to increase class attendance and to motivate students to keep up with the material promptly.

It was determined that quizzes improved the performance of students who completed the majority of the quizzes. However, it is possible that the observed correlation may be confounded by a

selection bias as well-performing students are the ones that attend lectures regularly, and therefore, take the quizzes consistently.

In addition, our results show that the grades of students who missed many quizzes were negatively affected. Furthermore, our findings show that the impact of missed quizzes on students' grades was twofold. Firstly, the grades were directly affected by the zeros received from the missed quizzes. Secondly, the students who missed many quizzes also did not study regularly, which indirectly contributed to a reduction in their exam grades.

Our analysis also shows that students believe that the quizzes were motivating them to review the course material frequently, helping them to prepare for exams and encouraging attendance. Unfortunately, despite the self-reported survey data indicated that the pop-quizzes were effective in promoting attendance, the results demonstrated a different outcome. It was observed, that attendance still declined, which is evident from the decrease in responses to the in-class surveys. Initially, 202 responses were received at the beginning of the semester, but only 129 responses were collected near the end. As previously mentioned, the large number of students who missed multiple quizzes, was unexpected since quizzes accounted for 15% of the final grade and had a direct impact on the students' final grades.

A drawback of the use of pop-quizzes was the increase in students' stress level, which may have prevented some students from taking the quizzes altogether. Thus, we need to devise a way to obtain performance benefits without causing added stress. This is a challenge in this course due to the high volume of content and fast-paced nature of the course.

It is important to note, that despite the negative side-effect of increased stress, students' self-reported score in the end-of-year feedback form about how much they learned has improved compared to the previous semester without quizzes. This improvement is a crucial objective of the quizzes and provides evidence of their effectiveness.

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