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Impact of Instant Feedback on Student Performance in a 300-level Class

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Impact of instant feedback on student performance in a 300 level class

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Abstract

Using iClickers in lectures allows students to obtain instant feedback on their performance when solving an example problem in a low-stake environment. It also helps instructors to identify common mistakes that need to be corrected before higher-stake assessments. Here, iClickers were used in a junior level introductory power circuits and electromechanics course at the University of Illinois to try to improve overall class performance and aid in material retention for later electrical power courses. The course material and types of graded assessments were not changed from previous semesters when iClickers were not used. Extra credit was offered to students who attended lectures as an incentive to participate in iClicker questions.

iClickers were used in lectures where the theory needed to solve an example problem was first introduced and then the students were asked to solve a problem based on the given material. The time given to solve each problem varied based on the problem difficulty, and the answer choices provided included values obtained from computations that included common mistakes. After the student responses had been recorded, the example problem was solved in full so that students could confirm that they were approaching the problem correctly or could see where they made their mistake.

The impact of using iClickers was measured based on student average performance on quizzes, midterm and final exams, and the final course grade before extra credit assignment. These results were compared to the average performance on the same assessments from all previous semesters that the author taught where iClickers were not used. The assessment averages for the semester that used iClickers were larger than in the semesters where iClickers were not used. The significance for this rise in assessment averages was obtained using a one-tailed t-test with a significance level of 5%. The results from the hypothesis testing suggest that using iClickers in the method given did not significantly improve student performance in the class. This also suggests that changes to using iClickers will need to be made in subsequent semesters to improve student performance.

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1 Introduction

Personal response systems, or "clickers", have been used extensively in the classroom by instructors to gain feedback on student performance and identify misconceptions that the instructor can correct early on [1–7]. Clickers have been used effectively in large lecture style courses, and have yielded improved student performance [2, 8]. One advantage of using clickers in the classroom over other instant feedback methods is the level of anonymity that it provides to the students in answering the questions [1, 6, 7]. This anonymity can be very helpful in lecture/discussion type classes seen in junior level engineering courses that typically have smaller class sizes. Students in these smaller classes are more likely to be influenced by their peers when answering questions through traditional methods, such as polling by hand raising [9, 10], and may not answer truthfully. This can affect the instructors perception on the class's understanding of the material, and could lead to some students internalizing misconceptions that would not be corrected.

Here, iClickers (an instant feedback technology developed by Macmillan Learning that has been adopted for widespread use by the author's institution) were used as a means of instant feedback in two sections of a junior level introductory power circuits course using a combination of conceptual and quantitative questions based on that day's material. This was the first semester that the author attempted using polling technology to assess class understanding of core concepts. The hypothesis was that using polling technology would increase student understanding of core concepts, which would assist them in later power circuit and machine classes.

To encourage attending lectures and participating in the in-class polling, students were awarded extra credit based on submitting a response to the in class polls. The effectiveness of using clickers in this manner was determined through student performance on course assessments; the same assessment types were used as in previous semesters with no polling, and the course used the same grading scale. The assessment averages were higher in the semester where clickers were used for instant feedback; however, analysis showed that this improvement was not statistically significant, consistent with Martyn [7]. This suggests that simply using a polling technology in a lecture course is not enough to improve student performance and more thought is needed to incorporate the technology to make students an active participant in their education.

2 In Class Implementation

The classes were structured as a mix of lecture and discussion. The course material for each day was presented during the lecture portion using slides. The derivations for different equations were given in the slides and were shown to the students via slide animations. The example problems for the discussion portions were mixed in with the lecture material, and were presented to the students after the theory needed to solve the problems had been shown. The students were asked to solve the problem on their own and provide their answer anonymously using their clickers. Students were given class participation points for submitting an answer to at least 1 of the questions asked in class. Their response did not have to be correct to receive participation points, and class participation was given as extra credit towards their final grade. Students had to attend a majority, but not all, class lectures to receive the maximum amount of extra credit points, which was capped at a 3% boost to their final grade. Students who did not attend a majority of lectures received a portion of the extra credit points that correlated to the number of lectures they attend. While this method for awarding

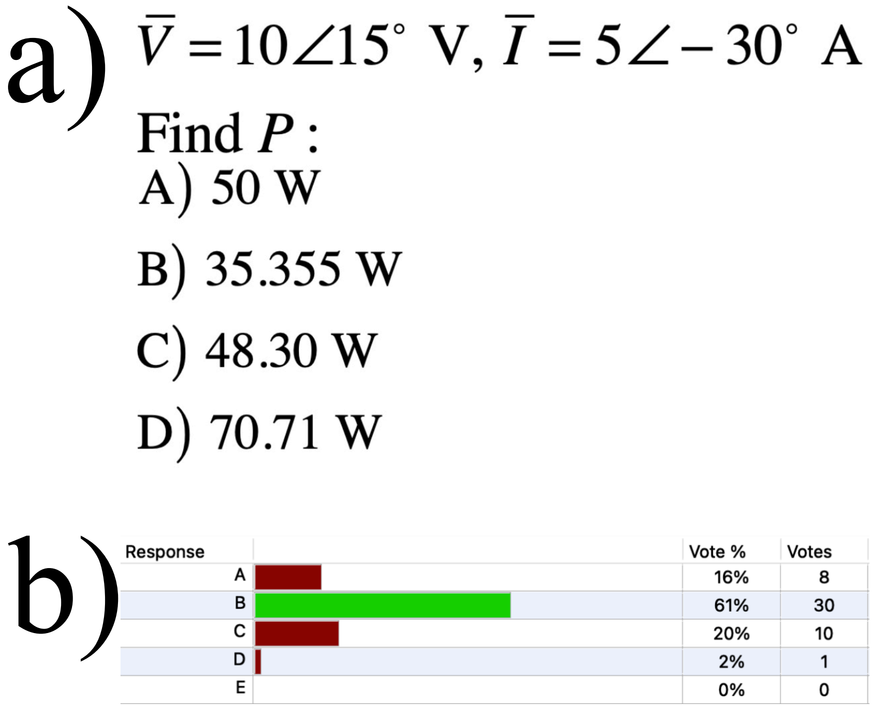


Figure 1: Selected problem from the beginning of the course for calculating the real power dissipated by a single phase system. (a) is the selected problem with the multiple choice answers given. (b) is the student responses, and the correct answer is marked in green.

extra credit gave students an external (extrinsic) motivation to attend class, it relied on their internal (intrinsic) motivation to improve their understanding of the course material to actually attempt the practice problems.

A selected problem statement and the student responses from the beginning of the semester for finding the real power consumed by a single-phase system are given in Figure 1. The students were shown in a previous slide during that lecture that the real power can be calculated as

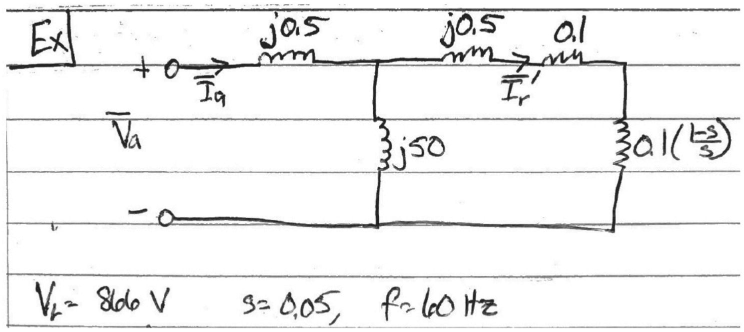
$$P = VI\cos(\theta_v - \theta_i) = \text{Re}\{\bar{V}\bar{I}^*\} \tag{1}$$

where V and I are the magnitudes of the voltage and current, and θ_v and θ_i are the voltage and current phase angles, $\bar{V}$ is the voltage phasor and $\bar{I}^*$ is the complex conjugate of the current phasor. The correct answer for this problem was answer B), which a majority of the students selected. The provided multiple choice answers also contained common mistakes, similar to a ConceptTest proposed by Mazur [11]. For example, answer A) of 50 W is simply the product of the voltage and current magnitude, and neglects the effects of the phase angles. Answer C) uses the incorrect sign for θ_i, which occurs from not taking the complex conjugate of the current phasor, and D) is $50\sqrt{2}$.

This mix of lecture, discussion, and practice problems was used throughout the semester. A selected problem with student responses from the end of the semester is given in Figure 2 for calculating the 3-phase power consumed by an induction machine. The students were shown for many class periods that the 3-phase power $\bar{S}_{3\phi}$ for a system can be calculated using

$$\bar{S}_{3\phi} = \sqrt{3}VI\cos\left(\theta_v - \theta_i\right). \tag{2}$$

a)



What is the 3-phase power supplied to the machine?
a) 336.02∠28.72° kVA c) 194.0∠28.72° kVA
b) 336.02∠ − 28.72° kVA d) 194.0∠ − 28.72° kVA

b)

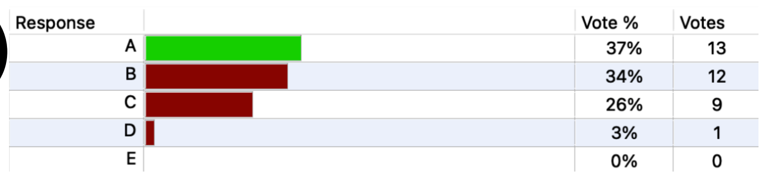


Figure 2: Selected problem from the end of the course for calculating the 3-phase power of an induction machine. (a) is the selected problem with the multiple choice answers given. (b) is the student responses, and the correct answer is marked in green.

(Student class attendance lowered throughout the semester, which caused the number of responses to fall from 49 at the beginning of the semester to 35 at the end). Again, the multiple choice options contain common mistakes [11]; for example, c) and d) do not include the factor of $\sqrt{3}$, and b) and d) do not account for the correct sign in the current phase angle. There was no clear majority for the student responses to this question, suggesting that more time was needed on this material in lecture [6].

After the polling time for each question was closed, the problems were solved in full on the blackboard so students could see the proper way to solve the problem. The common mistakes used in the multiple choice solutions were identified and explained to the students to help them avoid potential pitfalls when solving these types of problems on their own [6].

3 Results and Discussion

Student performance (final grade, for both sections of the course) was evaluated based on 4 types of assessments: weekly quizzes, 2 midterm exams, and 1 final exam. The average and standard deviation for each of the assessments for the semester that used instant feedback in lecture are compared to data from 2 previous semesters that did not use instant feedback in lecture, and are given in Table 1. The final grade was calculated from

$$\text{Final Grade} = 15\% \left(\frac{\text{Quiz}}{10}\right) + 25\% \left(\frac{\text{MT1}}{100}\right) + 25\% \left(\frac{\text{MT2}}{100}\right) + 35\% \left(\frac{\text{FE}}{150}\right) \quad (3)$$

Table 1: Average μ and standard deviation σ in points for the assessments and final score for semesters with and without iClickers. The number of students N for the comparisons are given and the total points for each assessment is also given.

	No Clicker (N=238)		Clicker (N=119)	
	μ	σ	μ	σ
Quizzes (10 points)	7.90	3.08	8.37	2.35
Midterm 1 (100 points)	71.43	15.95	73.65	13.88
Midterm 2 (100 points)	77.30	14.28	82.70	10.54
Final Exam (150 points)	90.16	21.59	92.33	26.33
Final Grade	70.05	12.53	72.27	13.32

where Quiz is the average quiz score, MT1 is midterm 1 performance, MT2 is midterm 2 performance, and FE is final exam performance. The course material and assessment types did not change; the only difference was the implementation of instant feedback for the students when solving example problems during lecture.

The data given in Table 1 suggests that the implementation of instant feedback improved student performance in the class. However, there are other variables (such as student makeup of the class, student experience with the material, etc.) that could also have contributed to the increase in the average for all of the assessments. To determine the statistical significance of the perceived increase in student performance, a 1 sided t-test was performed with the null and alternative hypothesis

$$\mu_I - \mu_{NI} \leq 0 \tag{4}$$

$$\mu_I - \mu_{NI} > 0 \tag{5}$$

where μ_{NI} is the average with no instant feedback and μ_I is the average when instant feedback was used.

The t value for each assessment was obtained using [12]

$$t = \frac{\mu_I - \mu_{NI}}{\sqrt{\left(\frac{\sigma_{NI}}{N_{NI}}\right)^2 + \left(\frac{\sigma_I}{N_I}\right)^2}}. \tag{6}$$

This t value was then used with the Student's t distribution [13] to obtain the probability p of at least the observed t value occurring as

$$p = 1 - \int_{-\infty}^{t} \frac{\Gamma\left(\frac{k+1}{2}\right)}{\sqrt{k\pi}\,\Gamma\left(\frac{k}{2}\right)} \left(1 + \frac{\tau^2}{k}\right)^{-\frac{k+1}{2}} \tag{7}$$

where $\Gamma\left(x\right)$ is the gamma function and k is the degrees of freedom for the system which were calculated using [14, 15]

$$k = \text{int}\left(\frac{\left(\frac{\sigma_{NI}^2}{N_{NI}} + \frac{\sigma_I^2}{N_I}\right)^2}{\frac{\left(\frac{\sigma_{NI}^2}{N_{NI}}\right)^2}{N_{NI}-1} + \frac{\left(\frac{\sigma_I^2}{N_I}\right)^2}{N_I-1}} + 1\right). \tag{8}$$

Table 2: The associated t, k, and p values for each assessment type used to determine the statistical significance of the observed increase in student performance when using instant feedback during lectures.

	t	k	p	$\mu_I - \mu_{NI} \leq 0$
Quizzes	1.625	299	0.0526	Do not reject
Midterm 1	1.352	268	0.0888	Do not reject
Midterm 2	4.034	306	3.47×10^{-5}	Reject
Final Exam	0.776	200	0.219	Do not reject
Final Grade	1.509	224	0.0663	Do not reject

The associated t, k, and p values for each assessment are given in Table 2.

The associated p values were compared to a significance level of 5%. If the p value for each assessment was less than 5%, then the null hypothesis of $\mu_I - \mu_{NI} \leq 0$ should be rejected, suggesting that the increase due to using instant feedback in lectures produced a statistically significant increase in student performance. However, if the p value for each assessment was greater than 5%, then the null hypothesis of $\mu_I - \mu_{NI} \leq 0$ should not be rejected, suggesting that the increase due to using instant feedback in lectures was not a statistically significant increase in student performance. Examining the p values in Table 2 shows that every assessment, except for Midterm 2, had a value that was greater than 5%, suggesting that the use of instant feedback did not significantly increase student performance. A clear example of this is seen in the Final Exam score, which has a p value of 21.9%, which is much larger than the 5% significance level. The outlier with Midterm 2 showing a significant increase could also be due to other factors, such as writing an easier midterm that semester.

This analysis suggests that the method tested here for using instant feedback was not effective for increasing student performance in the class. One reason for this could be the types of questions asked in the polls. For example, the question given in Figure 2 includes a lot of calculations that need to be performed to obtain the final answer. Questions like this may be too involved for students to attempt, which would not help them identify common mistakes. The amount of time needed for the students to attempt the problem might also be too long, which could also have affected the flow of the class. A more effective method might be to break problems up into smaller calculations, which students would be more likely to attempt. Another method could be to have students just perform the calculation where common mistakes are likely to occur. This could reduce the time needed for students to perform the calculations, but would still allow them to identify common mistakes in lecture.

Another reason why the current implementation of instant feedback did not yield a statistically better understanding of the course material could be the method used to motivate students to participate in class polls. Because the clicker responses were used essentially to mark attendance, students may not have attempted to work the problems effectively before seeing the common mistakes. This is consistent with research that shows intrinsic motivation (students wanting to improve) can decrease when extrinsic motivation (extra credit on final grade) is solely tied to participation in an activity [16–18]. This loss in motivation for actually attempting to solve the problems might have also played a role in the more uniform distribution of students answers near the end of the semester, as shown in Figure 2, as students started to randomly guess answers. A more effective method may be to tie student performance on the in class questions to the extra credit, i.e. they have to get a correct answer for a proportion of the questions asked that day to earn the extra credit points. Studies suggest that awarding extra credit in this manner (where students demonstrate competence) can increase student motivation to better understand the course material to improve their course grade [19–21].

4 Conclusion

The use of instant feedback was implemented in two sections of a junior level electrical power course. Example problems were mixed in with the lectures, and were presented after the theory needed to solve them had been introduced. Students were encouraged to participate in obtaining instant feedback in the lectures by offering extra credit based on class attendance, which was registered by a student submitting an answer to one of the example questions. The answer did not have to be correct to receive attendance credit. The effectiveness of the instant feedback on student performance for a variety of assessments was compared to previous semesters that did not use clickers, and analyzed using a one-tailed t test with a significance level of 5%. The data suggests that the use of instant feedback did not result in a statistically significant increase in student performance in the class. This is most likely due to awarding extra credit points for class attendance rather than correct responses to the practice problems, which did not encourage students to actually attempt the practice problems. The next semester that this type of instant feedback is used, smaller and more pointed questions should be used for the polls, and the motivation for using the in-class polling should be changed to include student performance on practice problems as a factor in obtaining extra credit. This would help encourage students to attempt the problems and work to better understand the course material, which in turn would increase their performance in the class.

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