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Electronic Classroom Response System for an Engineering Dynamics Course: Student Satisfaction and Learning Outcomes*

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The Classroom Response System (colloquially called "clickers") is an innovative instructional technology that provides the instructor with immediate feedback and real-time assessment on student learning in the classroom. This paper reports recent efforts of adopting clicker technology in Engineering Dynamics, a high-enrollment, high-impact, core engineering course. Both qualitative (questionnaire surveys and focus group interviews) and quantitative (descriptive statistics, correlation analysis, regression analysis, and ANOVA) research methods are employed. The results show that students are satisfied with clickers in their learning of Engineering Dynamics and that there exists a statistically significant correlation between student clicker performance and exam performance.

Keywords: classroom response system; engineering dynamics; student satisfaction; learning outcomes

INTRODUCTION

Instructional challenges of active learning in large-class settings

As engineering practices become highly complex in the changing world, an increasingly high requirement is set for students to master fundamental knowledge and skills in their disciplinary area of study. The importance of effective instructional strategies can never be overemphasized due to the significant role they play in improving student learning. Take active learning as an example. Active learning is generally defined as any instructional strategy that actively engages students in the learning process [1]. It is built upon an experimentally-proven cognitive learning theory that states that if students become active participants, instead of passive listeners, during the course of knowledge acquisition, they can recall information and learn course materials better [2]. Two core elements of active learning [3] are: (1) introducing student activities into traditional lectures, and (2) promoting student engagement.

In engineering education practices, active learning takes a wide variety of forms, such as one-minute reflection papers [4], peer instruction and reading quizzes [5], small-group interaction [6], multimedia virtual reality and computer simulation [7], and real-world physical experiments and demonstrations [8]. However, in spite of numerous advantages reported in the literature [9], active learning presents a great challenge when class enrollment is high and class lecture time is limited. A typical concern of engineering educators is that active learning takes additional class time, so course materials cannot be sufficiently covered, leading to a negative impact on student learning.

For instance, Engineering Dynamics is usually a high-enrollment, high-impact, core pre-professional course that covers a broad spectrum of foundational engineering concepts and principles, such as motion, force and acceleration, work and energy, impulse and momentum, and vibrations for both a particle and a rigid body [10, 11]. Almost every student in mechanical or civil engineering majors is required to take this foundational course. At Utah State University, each year more than 150 students from three engineering departments take this required course before they can be accepted to enter a professional engineering program. However, Dynamics is also one of the most difficult courses that many students fail. The teaching and learning quality of Dynamics not only affects the retention rate of engineering students, but also greatly impacts student learning in many subsequent courses, such as machine design and manufacturing processes dynamics.

Electronic Classroom Response System and its applications

The Classroom Response System is a radio-frequency, two-way communication system that comprises a set of hardware and computer software [12, 13]. The hardware consists of: (1) the base that is connected to an instructor's computer in a classroom, and (2) hand-held, portable, and wireless transmitters (colloquially called clickers),

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typically 6-inches long by 2-inches wide by half an inch thick (see Fig. 1). Each clicker has a unique serial number that can be set up in advance to associate with the identification number of its owner (i.e., a student). When triggered, the base receives the real-time signal that each student submits from their remote transmitter.

During a lecture, the instructor poses a multiple-choice or true/false question and then asks each student to push one of the five lettered buttons (A, B, C, D, and E) on the student's wireless clicker to anonymously respond to the question. The collective response from all students to the question, that is, the number or the percentage of the students who choose A, B, C, D, or E, can be immediately displayed on a big screen (via a computer projector) in front of the class, so both the instructor and students can see the collective response. In other words, clickers provide both the instructor and students with immediate feedback and real-time assessment on learning, thus teaching can be adjusted in time. After the class, the instructor can also use the clicker-collected data to analyze in detail the performance of each student.

Because they enable real-time, in-class assessments and enhance student–instructor as well as student–student interactions, clickers and other similar technologies (such as a class voting system [14]) have been applied in a wide variety of courses; for example, physics [15], chemistry [16], plant science [17], material science [18], and computer science [19].

Objective and research methods of the present study

The objective of the present study is to answer the following two research questions:

1. Are students satisfied with clickers in their learning of Engineering Dynamics? Student satisfaction is assessed through questionnaire surveys (about their attitude towards and experience with clickers) as well as focus group interviews.
2. What is the relationship between student clicker performance and exam performance? Clicker performance is quantified by the score (percentage of correctness) that a student obtained in answering a set of clicker questions in their regular classroom learning. Exam performance is quantified by the score (percentage of correctness) that a student obtained in answering questions in exams and quizzes.

Fig. 1. A hand-held, portable, and wireless clicker.

Both qualitative and quantitative research methods [20] are employed in the present study. Qualitative research, which addresses the first question, involves 107 students from multiple engineering departments in two semesters. Quantitative research, which addresses the second question, includes statistical correlation analysis, regression analysis, and ANOVA (Analysis of Variance) based on a total of 10,488 quantitative data collected. To prevent educational research activities from interfering with normal teaching activities, the quantitative data were collected during lectures and exams from a group of 69 students who received the same treatment; i.e., all of these students used clickers in the learning process. Comparison of student performance in control and experimental groups, or comparison of student performance in pre- and post-tests, is beyond the scope of the present study.

Novelty and significance of the present study

The present study is novel in two aspects. First, an extensive literature review shows that few published papers deal with the application of clicker technology in Engineering Dynamics. A variety of popular literature databases were examined, such as the Education Resources Information Center, Science Citation Index, Social Science Citation Index, Engineering Citation Index, Academic Search Premier, the ASEE annual conference proceedings (1995–2007), and the ASEE/IEEE Frontier in Education conference proceedings (1995–2007). The results show that clicker technology is primarily applied in science courses [14–19]. The literature most closely related to the present study is a recent, preliminary study [21] in which clickers were used to help the instructor understand student misconceptions of Engineering Statics, a prerequisite course of Dynamics; however, no educational research was performed in that study [21] to address either question 1 or 2 stated above.

Second, little research was conducted—in a comprehensive way and supported by extensive quantitative data—to relate student clicker performance to exam performance. Many published papers focus on the description of various methods (best-practice tips) of using clickers in the classroom, such as checking student understanding of course materials, assessing student prior knowledge, recording class attendance and participation, and recording feedback on teaching [22, 23]. A few studies address the effectiveness of clicker technology through pre- and post-tests and/or the comparison of control and experimental groups [24, 25]. However, those studies only include a limited number of disciplinary-related technical problems and lack extensive data support. The present study focuses on a comprehensive statistical analysis of correlation between student clicker and exam performance, covering numerous technical problems in Engineering Dynamics and supported by extensive data. The comprehensive, data-driven analysis made in the present study is important in terms of both theoretical contribution and practical significance, which is described as follows:

1. The present study provides scientific, data-based evidence for engineering education researchers (who may not teach Dynamics) to better understand different student performance in classroom lectures and in exams, especially the poor performance of those at-risk students who may eventually drop out of engineering programs.
2. As will be shown later, there exists a statistically significant correlation between student clicker and exam performance. This research finding will help encourage engineering educators (who teach Dynamics) think about their own way, and potentially develop a more effective way of teaching with clickers to improve student learning and problem solving.

Structure and contents of this paper

Two primary sections are included in this paper: Student Satisfaction and Learning Outcomes. Each section addresses one of the two research questions. In the Student Satisfaction section, student responses to questionnaire surveys and focus group interviews are described. The surveys, which include nine Likert-type questions, assess student attitude towards clickers, student overall experience with clickers, the effectiveness of clickers on active learning, and diversified learning styles of students. The research findings from the surveys are described, followed by the analysis of the reliability and validity of the collected data.

In the Learning Outcomes section, the method of data collection is introduced. A total of 69 students were involved. Each student answered 84 clicker questions and 68 exam questions. Based on their clicker and exam performance, the 69 students were divided in four subgroups. Detailed statistical analysis is made for all 69 students as a whole and for each student subgroup, including descriptive statistics, correlation analysis, regression analysis, and ANOVA. Particular attention is paid to student subgroup IV whose clicker performance and exam performance were both below the class average.

STUDENT SATISFACTION

Questionnaire surveys

Questionnaire surveys were administered in two semesters at the end of each semester to provide a summative assessment of student satisfaction on clickers. Table 1 shows the demographics of the 107 students (93 male and 14 female students) who responded to the surveys.

Table 1. Student demographics

	Male	Female	Total
Semester #1	45	5	50
Semester #2	48	9	57
Two semesters	93	14	107

Table 2 shows student responses to nine Likert-type questions designed for the surveys. These questions are divided into four assessment categories: student attitude towards clickers (questions 1, 2, 3); student overall experience with clickers (questions 4 and 5); the effectiveness of clickers on active learning (questions 6, 7, 8); and diversified learning styles of students (question 9). Questions 2, 3, and 7 were modified from a set of survey questions [26], and questions 1, 4, 5, 6, 8, and 9 were specially designed by the author of this paper.

Summary of the research findings from questionnaire surveys

Based on the percentage data of each semester listed in Table 2, the following conclusions can be made. For the total of 107 students surveyed in *two* semesters:

- Question 1: 89% of students chose their answers to clicker questions carefully.
- Question 2: 88% of students thought that interacting with the class using clickers made the lecture more interesting.
- Question 3: 75% of students agreed or strongly agreed that observing the performance of other students in the class improved their learning experience.
- Question 4: 79% of students stated that the use of clickers enhanced their learning.
- Question 5: 80% of students were in favor of the use of clickers in all of their future classes.
- Question 6: 86% of students agreed or strongly agreed that clickers promoted active learning and helped them better learn course materials.
- Question 7: 85% of students indicated that clickers helped them focus better on the main points of lectures.
- Question 8: 42% of students indicated that clickers actively engaged them in the class. Another 34% of students stated that clickers allowed them to see immediately how well they understood lectures.
- Question 9: 56% of students selected 'using clickers' or 'all the above' as their preferred learning styles.

Reliability and validity of the collected data

The reliability (or stability) of the collected data, which means producing the same results with repeated measurements over time [27], is confirmed by highly consistent student responses

Table 2. Student response (%) to questionnaire surveys

Question	Semester	A. Strongly agree	B. Agree	C. Strongly disagree	D. Disagree	E.
1. I chose my answer to clicker questions carefully.	#1	31	53	12	4	
	#2	42	49	5	4	
2. Interacting with the class using clickers made lectures more interesting.	#1	43	47	8	2	
	#2	28	56	14	2	
3. Observing the performance of other students in the class improved my learning experience.	#1	20	48	24	6	
	#2	12	68	16	4	
4. Overall, I think the use of clickers enhanced my learning.	#1	18	60	16	6	
	#2	16	67	13	4	
5. I am in favor of the use of clickers in all my future engineering classes.	#1	14	63	12	10	
	#2	21	61	16	2	
6. Active learning via clickers took class time, and hence, clickers prevented me from better learning course materials.	#1	6	16	49	29	
	#2	2	7	63	28	
7. Using the clicker helped me focus better on the main points of lectures.	#1	20	64	8	8	
	#2	16	70	12	2	
8.* I got the most benefit from the use of clickers by	#1	0	34	38	20	8
	#2	3.5	33	46	10.5	7
9.** I prefer to participate in class primarily by	#1	16	4	29	22	29
	#2	10.5	5	37	30	17.5

* For question 8: A) Seeing how well I do pre-reading; B) Seeing immediately how well I understand the lectures; C) Actively engaging me in the class; D) Making the lectures more interesting; E) Other aspects not mentioned above.
** For question 9: A) Raising my hand; B) My name being called by the instructor; C) Using clickers; D) Small group discussion; E) All the above.

to each assessment question in each choice of answer (A, B, C, D, or E) in two semesters. Take student responses to Question 8 as an example. That question provided five choices of answer. The percentage of students who chose A, B, C, D, or E were respectively 0%, 34%, 38%, 20%, and 8% in Semester #1, and 3.5%, 33%, 46%, 10.5%, and 7% in Semester #2. The change in the percentage number for each choice of answer was less than 10% and could even be as small as 1%.

Overall, about 75–90% of the surveyed students were in favor of clickers in the majority of assessment questions. The collected statistical data fits with the expectation that clicker technology is effective on active learning of Engineering Dynamics. Therefore, the validity of the collected data, which means the accuracy of inferences based on measurements [26], is also confirmed in the present study.

In applying clickers to teaching science courses, Duncan and Mazur [12] concluded that "clicker technology actively engages students in learning activities, inspires and motivates students' interest in the subject matter, and changes the way that a course is traditionally taught." The survey data collected from the present study proves that the above conclusion also applies to active learning of Engineering Dynamics.

Focus group interviews

Student focus group interviews were conducted during the course of each semester to provide a formative assessment of clicker technology. During interviews, students were asked about their experience, either positive or negative, with clickers and their suggestions to improve teaching and learning. Student comments were overwhelmingly positive, for instance:

- I never had an engineering class that is so interactive.
- I liked to use the clicker since it kept me awake and made the lecture interesting.
- I could see right away if my answer was correct.
- I paid more attention to the lecture when a clicker question was shown on the screen. I particularly enjoyed my discussion of clicker questions with students around me.
- Like many other students, I am reluctant to ask questions in the class. The clicker gives me an alternative way to gauge my understanding of the lecture material.
- This is my third time to take dynamics [no clickers were used in the previous dynamics classes that were taught by other instructors], and I think I learned the best this time.

The complaint that students generally made about clickers was the price. Although the manufacturer provided our university a discounted price, each clicker (transmitter) still costs $35. As known, any additional dollar beyond the minimum amount adds a financial burden to our students who pay their own tuition and fees. Fortunately, our university bookstore recently provided a new

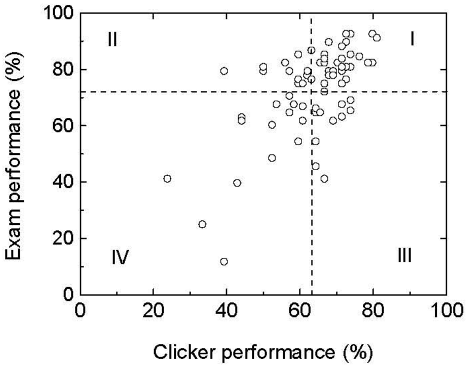


Fig. 2. Student clicker performance vs. exam performance.

option for students to sell back their clickers at half price after use. As more and more engineering classes begin to adopt clickers, students will have additional opportunities to use clickers; therefore, they do not need to buy clickers in the future.

LEARNING OUTCOMES

Data collection

The instructor (i.e., the author of this paper) developed a total of 84 clicker questions and 68 exam questions to assist in teaching Engineering Dynamics throughout the semester. All questions were multiple-choice or true/false questions that addressed key concepts and important applications of dynamics principles. Each lecture (50 minutes) involved three or four clicker questions. The instructor could immediately see collective student responses to clicker questions and thus provided just-in-time instruction. Exam questions were administrated in four exams: mid-term #1 (50 minutes): 15 questions; mid-term #2 (50 minutes): 18 questions; mid-term #3 (50 minutes): 15 questions; and the final exam (2 hours): 20 questions. Exam questions provide a comprehensive assessment on student understanding of key concepts and principles and on student problem-solving skills. A common statistical software package, SPSS (Statistical Package for the Social Sciences), was employed to process all the collected data.

Descriptive statistics

Student clicker performance is quantified by clicker score, and exam performance by exam score. For brevity, this paper analyzed the student performance data collected in Semester #2. In that semester, 69 students answered each of 84 clicker questions and 68 exam questions. In other words, each student was associated with 84 + 68 = 152 data points. The total number of data points used in statistical analysis is 69 × 152 = 10,488.

Figure 2 is the scatterplot of student clicker performance vs. exam performance, where each open and round symbol represents a student. For all 69 students, the average clicker score (C_{avg}) is 63.5%, and the average exam score (E_{avg}) is 72.3%. Using these two averages, 69 students can be divided into the following four subgroups (see Fig. 2):

- Subgroup I: clicker score > Cavg and exam score > Eavg
- Subgroup II: clicker score < Cavg and exam score > Eavg
- Subgroup III: clicker score > Cavg and exam score < Eavg
- Subgroup IV: clicker score < Cavg and exam score < Eavg.

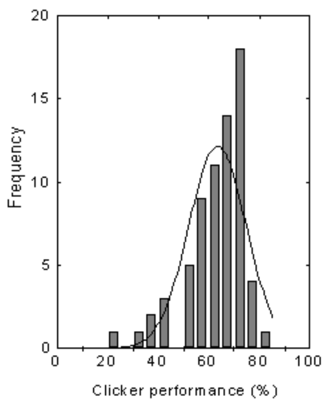
Table 3 lists the mean score and standard deviation of clicker and exam performance for all 69 students as a whole and for each student subgroup. Skewness and kurtosis values are calculated (see Table 3) and a histogram is plotted (see Fig. 3) to study data distribution.

The following observations can be made from Table 3 and Fig. 3:

1. Among the four student subgroups, subgroup IV has the largest standard deviation in terms of both clicker and exam performance. This means the performance of students in subgroup IV varies in a wide range, which is also the primary reason that leads to a large standard deviation of the performance of all 69 students.

Table 3. Descriptive statistics

Student subgroup	Performance	Mean score	Standard deviation	Skewness	Kurtosis
All (n = 69)	Clicker	63.459	11.340	–1.219	1.722
	Exam	72.322	15.777	–1.554	3.029
I (n = 29)	Clicker	71.798	4.246	0.594	–0.242
	Exam	83.291	5.195	0.442	–0.620
II (n = 15)	Clicker	58.181	7.045	–1.567	2.684
	Exam	78.039	5.345	–0.803	1.895
III (n = 10)	Clicker	68.453	3.938	0.253	–1.802
	Exam	59.927	9.651	–1.222	0.203
IV (n = 15)	Clicker	49.286	11.047	–0.933	0.356
	Exam	53.661	17.304	–1.363	1.184



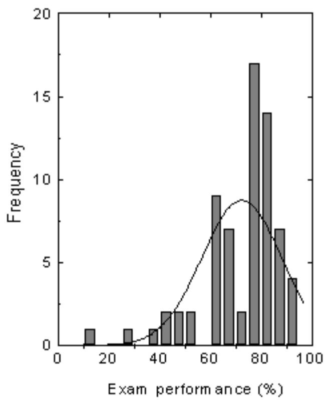


Fig. 3. Histogram of student performance (n = 69).

2. The standard deviation for four subgroups increases in the order of III < I < II < IV (clicker performance) and I < II < III < IV (exam performance). Except subgroup III, the other three subgroups show a common and consistent trend: always I < II < IV. This means that a large standard deviation of clicker performance is generally associated with a large standard deviation of exam performance.
3. The values of skewness and kurtosis (see Table 3) are both positive or both negative in terms of either clicker performance or exam performance for subgroups I, II, IV, as well as for all 69 students as a whole. Figure 3 further illustrates that for all 69 students, both clicker performance and exam performance show negatively and platykurtic distributions.

All the above-made observations imply that a certain amount of correlation may exist between student clicker and exam performance. To mathematically validate this implication, correlation analysis, regression analysis, and ANOVA are made in the following sections.

Correlation analysis

Table 4 shows the Pearson correlation coefficient r for all 69 students and for each student subgroup. Pearson correlation coefficient r is commonly used to measure the strength of correlation. It varies between –1.00 and +1.00. A positive sign means that one variable increases as the other variable increases, and a negative sign means that one variable decreases as the other variable increases. In educational and social science research, a general rule of thumb for determining the strength of correlation between two variables is [2]: weak ($r = \pm 0.10$), moderate ($r = \pm 0.30$), and strong ($r = \pm 0.50$).

Table 4. Correlation analysis

Student subgroup	Pearson correlation coefficient, r	Significance (two-tailed)
All (n = 69)	0.630**	0.000
I (n = 29)	0.386*	0.019
II (n = 15)	–0.318	0.124
III (n = 10)	0.552*	0.049
IV (n = 15)	0.693**	0.002

* Correlation is significant at $p < 0.05$.
** Correlation is significant at $p < 0.01$.

As can be seen clearly from Table 4, there exists a statistically significant correlation between student clicker and exam performance for all 69 students as a whole ($r = 0.630$, $p < 0.01$) and for subgroup IV ($r = 0.693$, $p < 0.01$).

Regression and ANOVA analysis

To cross-validate the findings from correlation analysis, regression analysis and ANOVA were performed, and the major results are summarized in Table 5. The R^2 value in Table 5 reveals that clicker performance accounts for 39.7% of the

Table 5. Regression and ANOVA analysis

		t-test			ANOVA F-test	
Student subgroup	Regression analysis, R^2	Regression coefficient, b_1	t	Sig.	F-ratio	Sig.
All (n = 69)	0.397	0.876	6.638	0.000	44.064	0.000
I (n = 29)	0.149	0.473	2.176	0.039	4.733	0.039
II (n = 15)	0.101	–0.241	–1.210	0.248	1.464	0.248
III (n = 10)	0.304	1.352	1.870	0.098	3.497	0.098
IV (n = 15)	0.481	1.086	3.468	0.004	12.025	0.004

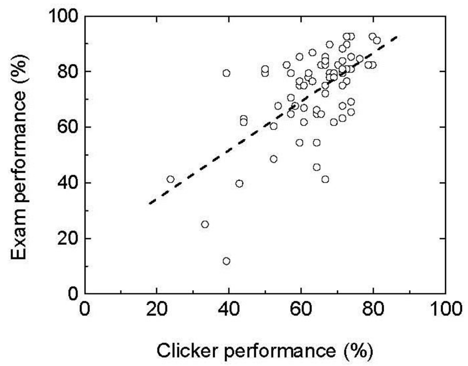


Fig. 4. Regression line for all 69 students.

variability in exam performance for all 69 students as a whole and 48.1% for student subgroup IV.

The effect of clicker performance on exam performance can also been seen from the following two regression models generated from t-statistic tests (see Table 5 for regression coefficient b_1 as well as its associated t-score and significance level):

For all 69 students:
Exam score = 0.876 × Clicker score + 16.713 (1)
For student sub-group IV:
Exam score = 1.806 × Clicker score + 0.146 (2)

The above regression models can also be explained in this way: if clicker score increases by 1%, exam score increases 0.876% for all 69 students as a whole, or increases 1.806% for student subgroup IV. To clearly show the regression line for all 69 students, the data in Fig. 2 was used again, and the result is shown in Fig. 4.

An ANOVA F-test was performed to determine how much the regression models have improved the prediction of student exam performance compared with the level of inaccuracy of the models. The F-ratio values and their significance levels are listed in Table 5. As seen, large F-ratios exit for all 69 students as a whole (F = 44.064, p < 0.001) and for student subgroup IV (F = 12.025, p < 0.005). This means the regression models generated for all 69 students as a whole and for subgroup IV can provide reasonably accurate predictions of student exam performance.

Student subgroup IV

The above analysis shows that student subgroup IV and all 69 students as a whole share many common features: large correlation coefficient r (0.693 and 0.630), large R^2 (0.481 and 0.397), and large F-ratio (12.025 and 44.064). Although the number of students in subgroup IV accounts for only 22% of the total number of students in the class, their performance significantly impacts the performance of the class as a whole. The well-known 80/20 business rule, or 80/20 business principle, seems to be applicable to the field of engineering education.

A deeper investigation, therefore, was conducted to study why clicker performance and exam performance of student subgroup IV are both below the average. Relevant cognitive and non-cognitive data were collected from the 15 students included in subgroup IV. The cognitive data included Graduate Point Average and the grade of a pre-requisite Engineering Statics course. The non-cognitive data includes the semester when a student took Statics, the number of hours a student works on weekdays, and the number of hours a student works on weekends. "Work" is defined as any job that a student takes (such as in a company, library, or restaurant) and gets paid in the same semester when the student takes the Dynamics course. In our university, it is not uncommon for many students to work on or off campus to pay for their tuition and fees and to support their family.

The results are shown in Table 6. Except for Student A whose clicker and exam performance

Table 6. Student subgroup IV

Individual student	Clicker score	Exam score	GPA	Statics course grade	Semester when a student took Statics*	Number of hours a student works on weekdays	Number of hours a student works on weekends
A	53.6	67.6	> 3.50	A–	2	0	0
B	57.1	64.7	2.50–2.75	A–	1	20+	9–12
C	60.7	66.9	3.00–3.25	B+	1	20+	0
D	44.0	63.0	< 2.50	C–	4	20+	0
E	52.4	60.3	3.00–3.25	B+	1	20+	0
F	44.0	61.8	2.50–2.75	C	4	20+	0
G	58.3	67.6	3.00–3.25	C–	1	15–20	3–6
H	60.7	61.8	3.00–3.25	C+	1	10–15	12+
I	57.1	70.6	2.50–2.75	C+	1	20+	12+
J	33.3	25.0	2.50–2.75	C	3	20+	0
K	39.3	11.8	2.75–3.00	C	1	20+	0
L	52.4	48.5	< 2.50	C–	5	20+	12+
M	59.5	54.4	< 2.50	B	1	15–20	6–9
N	23.8	41.2	3.00–3.25	C+	1	20+	0
O	42.9	39.7	2.75–3.00	B	2	20+	3–6

* The numbers 1, 2, 4, and 5 in this column represent, respectively, immediately last semester, two semesters ago, four semesters ago, and five semesters ago.

cannot be explained from this student's high GPA, high Statics course grade, and zero-hour's work load each week, the performance of all other 14 students can be reasonably explained based on either cognitive data or non-cognitive data, or both. To avoid a tedious and boring explanation for each of the 14 students, a general conclusion is drawn from Table 6. This conclusion is that student poor performance is generally associated with low GPA, low Statics course grade, memory deficit due to length of time since Statics instruction, and too many student work hours each week.

CONCLUDING REMARKS

Clicker technology provides the instructor with an immediate diagnosis of student understanding and misunderstanding of course materials and promotes faculty–student interaction as well as student active engagement in learning. In the present study, clicker technology is applied in a high-enrollment, high-impact, core Engineering Dynamics course. The present study not only provides scientific, *data-based evidence* for engineering education researchers to better understand different student performance in classroom lectures and in exams, but it also helps encourage engineering educators to potentially develop a more effective way of teaching with clickers to improve student learning and problem solving.

Based on the results of both qualitative and quantitative research, the answers to the two research questions of this paper and other important findings are summarized as follows.

1. Students are satisfied with clicker technology in their learning of Engineering Dynamics. The data collected from questionnaire surveys are consistent in two semesters and show that students had a positive attitude towards as well as positive experience with clickers. For example, on the two-semester average, 88% of students thought that interacting with the class using clickers made the lecture more interesting, and 86% of students agreed or strongly agreed that clickers promoted active learning and helped them better learn course materials.
2. There exists a statistically significant correlation between student clicker performance and exam performance. This conclusion is cross-validated through correlation analysis, regression regress, and ANOVA based on a total of 10,488 data points collected.
3. Analysis reveals that student subgroup IV (whose clicker performance and exam performance are both below the average) and all 69 students as a whole share many common features: large correlation coefficient r (0.693, $p < 0.01$; and 0.630, $p < 0.01$), large R^2 (0.481 and 0.397), and large F-ratio (12.025, $p < 0.005$; and 44.064, $p < 0.001$). The R^2 value implies that student clicker performance accounts for 48.1% of the variability in exam performance for student subgroup IV and 39.7% of the variability in exam performance for all 69 students as a whole.
4. Although the number of the students in subgroup IV accounts for only 22% of the total number of students in the class, their performance profoundly impacts the performance of the class as a whole. The poor performance of subgroup-IV students is generally associated with low GPA, low Statics course grade, memory deficit due to length of time since Statics instruction, and too many student work hours each week.

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