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Work-in-Progress: Enhancing Conceptual Understanding by Using a Real-time Online Class Response System in Engineering Courses

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Abstract: To engage students, and assess students' understanding in real-time, Classroom Response Systems (CRS), have been increasingly used in many engineering classrooms. Previous research has shown that CRS can enhance students' participation, promote active learning, and develop their critical thinking skills. It can also generate either neutral or positive learning outcomes depending on whether it is combined with other cooperative learning strategies. This paper presents a collaborative study on how to combine the implementation of a web-based CRS with class discussion to clarify student misconceptions in a freshman-level engineering graphics course, a sophomore-level dynamics course, and a senior-level control systems course at a small private institution in the Southeast.

The purpose of the study is to evaluate how web-based CRS combined with class discussion can be used to engage students in class, catch their misconceptions, promote their critical thinking skills, and improve their academic performance in different engineering courses. Anonymous surveys were implemented to collect student's feedback on their attitude towards the use of web-based CRS. The test results from three courses were collected to assess the effectiveness of web-based CRS and class discussion on improving students' academic performance.

Introduction

For many years, lectures in engineering fields have been delivered in a traditional mode. The instructor talks, and students take notes. Periodically the instructor will either call on a number of students to answer questions or use volunteers¹. Although these strategies may promote an interactive learning environment in class, the small sample size or volunteers are normally dominated by the better and candid students. This may mislead the instructor into believing that the majority either understands, or misunderstands, the concept being questioned¹. It is not until the periodic quizzes or the examination time that, the instructor can assess the proficiency of the entire class. Previous research also has found that students attention spans during lectures is typically fifteen minutes long and after this time their attention begins to drop dramatically. Therefore, Prince² pointed out that breaking up the lecture into discrete sections can refresh the students' mind and help to keep them engaged. To engage students, and have a real time assessment of students' understanding, a Classroom Response Systems (CRS) has been increasingly used in many engineering classroom³⁻⁶. A CRS (sometimes called a personal response system, student response system, or audience response system) is a set of hardware (clickers) and software that facilitates face-to-face teaching activities.

Previous research has shown that CRS can enhance student participation, promote active learning, and develop their critical thinking skills^{7, 8}. It can also improve student outcomes such as improved exam scores depending on whether it is combined with other cooperative learning strategies^{1, 9, 10}. The disadvantages of using CRS are the cost of clickers for the students, malfunction of the clickers, inability or difficulty in allowing students to provide text responses, and the management and high life cycle cost of clickers^{11, 12}. To take advantage of a CRS, and

avoid its disadvantages, the authors used a web-based CRS that doesn't involve clickers, PollEverywhere.com¹³, in three courses to improve teaching activities. Instructors can create either multiple choice questions, true/false questions, or open-ended questions before class. The questions can be embedded into PowerPoint slides and activated during class. Students can use either their personal cell phones (text messages, Twitter, or the PollEverywhere app), tablets (Twitter, app or web browser), or computers (Twitter or web browser) to respond. Bar charts of the results can be generated after the question has been completed. Web-based CRS such as PollEverywhere, Socrative, Top Hat Monocle, SMSPoll.net, ClickerSchool, Text The Mob, or Shakespeak, works on any Internet capable computer or device, eliminates the cost of clickers added to students, and allows for questions that require richer feedback¹². This paper does not compare different web-based response systems, but a side-by-side comparison about their services can be found on the PollEverywhere webpage, <http://www.polleverywhere.com/vs>. The authors have not used any web-based response systems other than PollEverywhere, and have no comments on the above comparison.

The purpose of the study is to evaluate if web-based CRS and class discussion can be used to engage students, catch their misconceptions, promote their critical thinking skills, and improve their academic performance in a freshman-level course, Graphical Communications, a sophomore-level course, Dynamics, and a senior-level course, Model Based Control System Design course (Control Systems) at a small private institution in the Southeast in Fall 2014. Graphical Communications, and Dynamics are required courses in aerospace, civil, and mechanical engineering. Model Based Control System Design is a required course for students in mechanical, electrical and computer engineering. The test results from all courses were collected and compared with the corresponding poll question answers to assess the effectiveness of Poll Everywhere on improving students' academic performance. Anonymous surveys were implemented to collect student's feedback on their attitude towards the use of Poll Everywhere at the end of fall 2014.

Course Context

Graphical Communications is a freshman-level course that is designed to familiarize students with the basic principles of drafting and engineering drawing, improve their three dimensional (3D) visualization skills, and to teach the fundamentals of a computer aided design. The students meet with the instructor twice a week in the laboratory during this three-credit-hour semester-long course with each class lasting two hours long. Each class is scheduled to deliver the lecture first after which the students are allowed to complete their assigned homework and ask questions as needed. The students learn the principles of orthographic projections and apply the principles to multiple view drawings by hand during the first four weeks of a fourteen-week semester. A 3D computer aided parametric modeling tool, CATIA, is then introduced after hand drawing, followed by auxiliary and section views, dimensioning, and tolerances. If a student had a misconception of a new concept, it may not be revealed until the teaching assistant has the homework graded after a week. It may take the instructor two to four weeks until the quiz or exam time to discover student's misunderstanding.

Dynamics, the sophomore-level Newtonian mechanics course following Statics, deals with the analysis of objects in motion. This course is often viewed by students as a gauntlet course because it is difficult to understand and learn. If students do not have good study skills

and lack of foundational knowledge from prior courses, they may feel overwhelmed and do not understand the connections between the topics. The pre-test results of the Dynamics Conceptual Inventory, a nationally adopted assessment for dynamics, showed that students had several deficiencies in conceptual understanding^{14, 15}. It is important to capture students' misconceptions during the learning process so the instructor will be able to address the misunderstandings in a timely manner.

Model-Based Control System Design is an introduction to control system analysis and design and general model-based design processes. Students learn to define control systems and components, formulate mathematical models of dynamic systems, solve for dynamic response, and design control systems. Because of the inherently mathematical contents, students often find it difficult to learn due to deficiencies in mathematical knowledge and skills. A real-time classroom response system will be helpful to check students' learning and clarify muddy points in their understanding.

Concept Test Design in Poll Everywhere

Students are required to register a PollEverywhere account and log into their account to answer the questions and view all of the questions as well as their answers. The instructor can track students' responses and generate reports to do post hoc data analysis. In this study, every 20 minutes of the lecture, the instructor paused to ask students to log into their account to respond to the question polled on the screen within 10 minutes either using the classroom computers or their smart devices.

Figure 1 and Figure 2 show snapshots of the concept test question and student responses on PollEverywhere.com from Graphical Communications, and Dynamics courses respectively. Figure 3 shows a snapshot of the open-ended question and student responses from Control Systems. The lectures were punctuated by multiple-choice conceptual questions or open-ended questions to test students' understanding of the material. In the multiple-choice conceptual questions, often the distracters (incorrect responses) reflect typical student misconceptions. These questions are good indicators of students' conceptual understanding, especially in fundamental courses. The open-ended questions provide the senior-level students an opportunity to improve their critical thinking skills through writing and open-ended questions can closely approximate the type of problems they will face on the job¹⁶. Based on the student responses, the instructor can choose to either continue with further instruction or pause to clarify any misconception and promote class discussion.

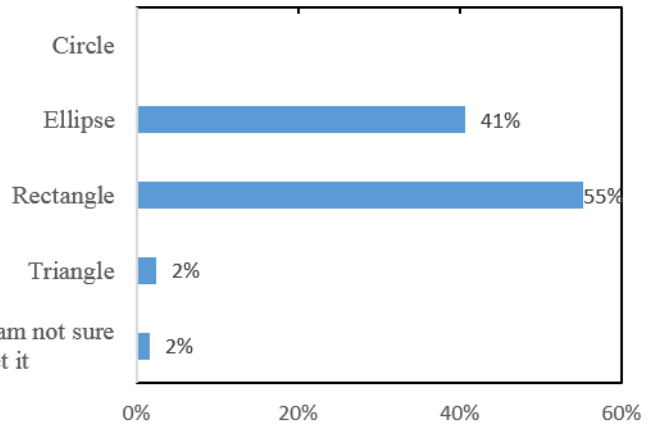
At the end of the semester, students were asked to complete an anonymous survey on the Blackboard learning management system to gauge their attitude and experiences with this polling system.

If a cylinder is cut as illustrated below, the **RIGHT SIDE** view will contain a/an:

- A Circle.
- B Ellipse.
- C Rectangle.
- D Triangle.



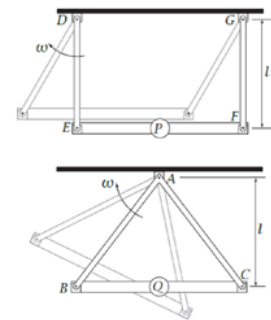
If a cylinder is cut as illustrated, the **RIGHT SIDE VIEW** will contain a/an



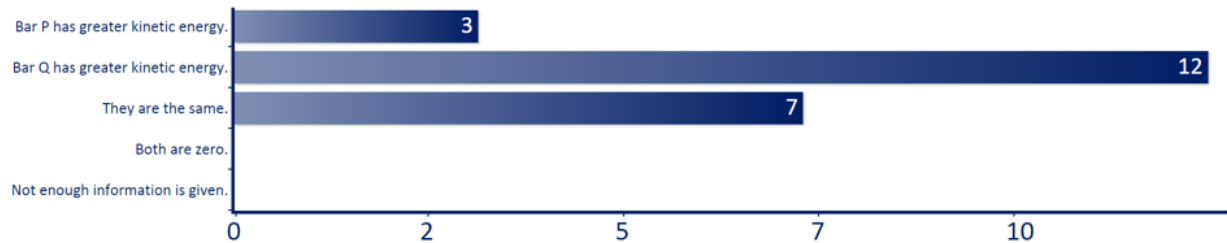
I chose an answer but I am not sure about how to get it

Figure 1. A snapshot of a multiple choice question in a PowerPoint slide, and student responses on PollEverywhere.com from Graphical Communications.

8. Both of the frames are supported by a pair of arms and rotate at the same angular velocity. Compare the kinetic energies of the two identical bars P and Q.



i Start this poll to accept responses



Total Results: 22

Figure 2. A snapshot of a multiple choice question with an embedded image from Dynamics.

What does finding the time response of a system mean?

“to see how a system reacts to an input over a period of time”

“it means finding the behavior of the system based on time”

“it is how the system reacts over time. ie time takes to reach Steady state”

“what the system is doing at a point in time”

“The input to the system is time”

“The time it takes for a system to react to an input.”

Figure 3. A snapshot of an open-ended question and student responses from Control Systems.

Assessment

Table 1 summarizes the participation rates for the three courses, Graphical Communications, Dynamics, and Control Systems used in this study. There were 133 students enrolled in the three courses. The rate of student participation with the CRS polling questions and the end of semester survey is quite high. Over 90% of students participated in the poll questions during the class time. 83% of students (n=67) from Graphical Communications, 100% of students (n=26) from Dynamics, and 92% of students (n=26) from Control Systems completed the surveys.

Poll questions implemented during class from Graphical Communications, and Dynamics were collected. Some questions were duplicated in the exams to check student's understanding, which was counted as 10% of the exam grade. If any student did not attend a class, the student would not be able to see the missed poll questions in his/her PollEverywhere account. Even though the registered students who responded the poll questions during class can review the questions and their answers on PollEverywhere.com website anytime, they do not know the correct answers unless they fully understand the concept.

Table 2 compares the percentage of students answering questions correctly in the poll during class and on the exams in the two courses. Students' conceptual understanding was improved from the poll questions during class to the exam questions. The exams were given at least two weeks after the poll questions were given and discussed in class. We can see clear improvements in scores on all problems given in the two courses. Since most poll questions in Control Systems were open-ended questions, there was no comparison performed within this course.

Table 1. Participation rates in three courses.

Course	Total students in class	Poll participation rate	Exam participation rate	End of semester survey participation rate
Graphical Communications	67	93%	100%	83%
Dynamics	26	88%	100%	100%
Controls Systems	26	92%	100%	92%

Table 2. Comparison of the poll question and exam question performance.

Problem	Graphical Communication		Dynamics	
	Poll question	Exam	Poll question	Exam
1	41%	82%	61%	92%
2	53%	78%	19%	52%
3	75%	94%	77%	92%
4	59%	78%	52%	68%
5	60%	65%	14%	48%

Anonymous surveys were conducted at the end of the fall semester of 2014 to gain feedback on student attitudes on the use of the web-based CRS, Poll Everywhere. Figure 4 shows student survey responses on Likert-scale questions about the web-based CRS. The majority liked the web-based CRS experience and their open-ended comments supported the results as well. In particular they stated that:

“It showed us as we went along how much we knew.”

“It gives us a chance to give live feedback to the lesson and for you to correct us if we have errors.”

“It was a very intriguing approach to class participation and attendance and I feel it worked very well.”

“They let you try out the question yourself, then you go over the answer. That really helps understanding.”

“I found it helpful, because discussion usually followed, and the discussions were helpful.”

“It gives the teacher a chance to see if there is one thing that all of the students are not understanding, and also lets the students see if they know the content.”

“Poll everywhere was good-kept me engaged. the tidbits about how people learn best helped me to digest the knowledge better. I wish I would have learned how to learn a long time ago.”

The Poll Everywhere was a great tool to use for the class. It gave me a better view of what I knew and didn't know but didn't have to raise my hand and hold the class up.”

There were some negative opinions too:

“I felt polleverywhere to be least useful because of the time it took up, and it didn't help with understanding content as much as practicing the material for that day did.”

“The PollEv took a while to log into but it was good change of pace in a 2 hour long class and helped answer small concept questions”

“Poll Everywhere is sometimes not user-friendly.”

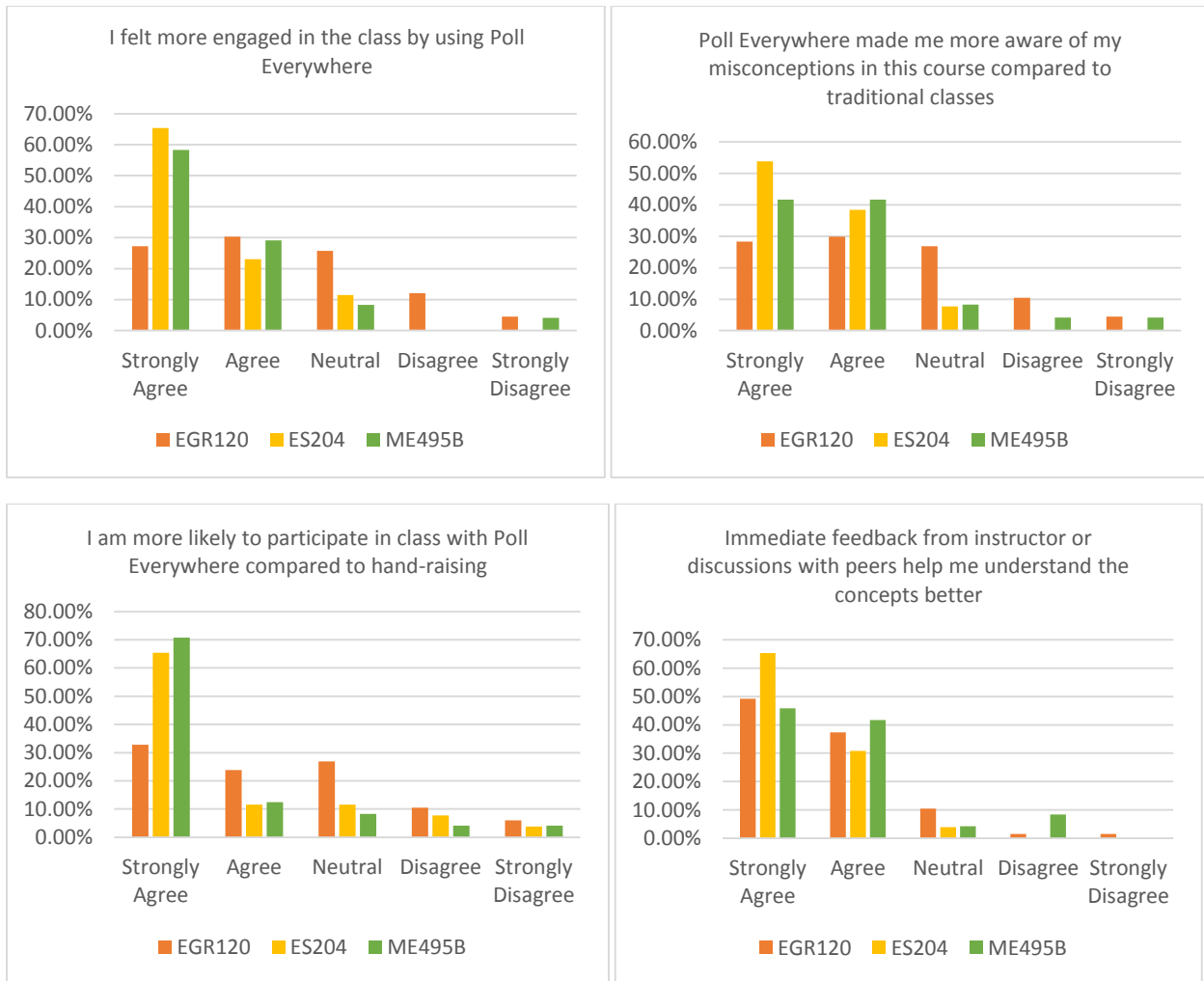


Figure 4. Student survey responses on Likert-scale questions about the web-based CRS.

The authors found that a web-based CRS offered a much more cost-effective, convenient, and flexible approach to the instructor and students than a CRS that uses hardware, clickers. For example, the students do not need to pay over \$20 for using a clicker during the semester, as a web-based CRS do need to involve a cost on the part of students. An instructor can either use a web-based CRS for free with small classes, or a university or department can buy a license for the instructor to use it with more students and access premium features of the CRS. The authors also learned that it took time to develop good conceptual questions and multiple choice questions for use in class. The questions need to catch the key concept covered in the class and need to be

designed cautiously to prevent misleading students. It also extended the regular class time because of the whole class responses, further discussion and misconception clarification.

Conclusions and Future Work

A web-based CRS, Poll Everywhere, was implemented in three engineering courses to query student population's grasp of concepts, engage them in class participation, clarify any misconceptions, and improve their academic performance. The application received positive feedback from students. Because the misconceptions were captured in class right after reviewing question results, the class discussion helped clarify the misconceptions. As a result, students' conceptual understanding was enhanced, and their exam grades were improved accordingly. Using smart devices in the class could be distracting, but can be alleviated by asking students to use the smart devices only during the poll question time, and put the smart devices away after finishing the poll responses.

Overall it is beneficial to integrate the system into engineering classes to enhance class interaction and participation. However, good implementation can be time consuming, as students and instructors need time to adjust to the new technology, there are the technological glitches with the system and network access, the login system may be inconvenient, and questions need to be designed cautiously to prevent misleading students. To clarify the advantages of the web-based CRS, the authors will continue to compare conceptual understanding in sections of the courses using web-based CRS and sections not using web-based CRS. A concept question pool will be established with similar difficulty so that concept questions in each exam will be selected randomly. The data will be collected continuously to support findings in the future.

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