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Dr. Ayala received his BS in Mechanical Engineering with honors (Cum Laude) from Universidad de Oriente (Venezuela) in 1995, MS in Mechanical Engineering in 2001 and PhD in Mechanical Engineering in 2005, both from University of Delaware (USA). Dr. Ayala is currently serving as Assistant Professor of Mechanical Engineering Technology Department, Frank Batten College of Engineering and Technology, Old Dominion University, Norfolk, VA.

Prior to joining ODU in 2013, Dr. Ayala spent three years as a Postdoctoral Researcher at University of Delaware where he expanded his knowledge on simulation of multiphase flows while acquiring skills in high performance parallel computing and scientific computation. Before that, Dr. Ayala hold a faculty position at Universidad de Oriente at Mechanical Engineering Department where he taught and developed graduate and undergraduate courses for a number of subjects such as Fluid Mechanics, Heat Transfer, Thermodynamics, Multiphase Flows, Fluid Mechanics and Hydraulic Machinery, as well as Mechanical Engineering Laboratory courses.

In addition, Dr. Ayala has had the opportunity to work for a number of engineering consulting companies, which have given him an important perspective and exposure to industry. He has been directly involved

in at least 20 different engineering projects related to a wide range of industries from petroleum and natural gas industry to brewing and newspaper industries. Dr. Ayala has provided service to professional organizations such as ASME. Since 2008 he has been a member of the Committee of Spanish Translation of ASME Codes and the ASME Subcommittee on Piping and Pipelines in Spanish. Under both memberships the following Codes have been translated: ASME B31.3, ASME B31.8S, ASME B31Q and ASME BPV Sections I.

While maintaining his industrial work active, his research activities have also been very active; Dr. Ayala has published 23 journal papers and 20 peer-reviewed conferences papers. His work has been presented in several international forums in Austria, USA, Venezuela, Japan, France, Mexico, and Argentina. Dr. Ayala has an average citation per year of all his published work of 23.78.

The Use of Polleverywhere in Engineering Technology Classes

to Stimulate Student Critical Thinking and Motivation

Abstract

Critical thinking is considered one of the most important aspects of the learning process at the college level, especially in the field of engineering technology. However, developing critical thinking can prove to be quite challenging. It takes a lot of instructional effort and support for undergraduate students enrolled in engineering technology programs to develop the ability to analyze, adequately synthesize conceptual knowledge, and then apply that knowledge to practical problem-solving situations. This ability is a critical component of any successful completion of job responsibilities for future engineers. In this study we examine the effectiveness of the web-based polling system *Polleverywhere* in promoting all stages of learning, with the emphasis on acquisition and generalization of new knowledge. The study also evaluates the effectiveness of the above-mentioned web-based system in promoting students' motivation. Besides traditional face-to-face interaction in class (students asking questions and verbally responding to the instructor's questions) students were engaged in class participation through the use of Polleverywhere software. A polling system increases the likelihood that all students in the class answer the questions presented. Furthermore, after polling, students can compare and discuss their answers across the entire group. This is a peer-review process important in the success of their learning. A survey was administrated towards the end of the class and data from this survey was used in the analysis. The evaluation in this study is based on a Circuits course in electrical engineering technology, for a relatively small-lecture classroom.

Introduction

The use of audience response devices, such as clickers, has become a common learning tool in various universities. As a result, a considerable amount of literature has focused on their use in the classrooms, in case studies from different disciplines. Caldwell (2007) makes a detailed review of the literature related to clickers, their use, typical characteristics of questions used, attitude towards clickers and practice tips [(1)]. A detailed report on the use of clickers for example is presented in Gachago (2008) [(2)]. Students' perception on the use of clickers was analyzed in depth in Pelton's study [(3)]. An adapted version of the student survey used by Pelton in [(3)] is used in this paper to analyze students' perception on the web-based polling system Polleverywhere. Currently, people are highly dependent on technology and almost everybody carries a smart phone, a tablet or a laptop. Even in K-12 schools "bring your own device" has become something quite popular lately, and every college student has a personal electronic device. Still, there is very little literature on the use of these devices as response devices in the classroom. Dr. W. Kappers published a paper on the use of Polleverywhere system in a large classroom setting

[4], and analyzes what devices students use most often. The paper also includes a well referenced review of the literature on clickers, which have been used for over a decade now in different disciplines and settings with the principal purpose of increasing students' engagement in the class. It is noted [4] that some studies show no learning differences between students that used clickers and those that did not. The authors of this study experienced teaching with and without an immediate feedback system and our conclusion is that the use of it is very beneficial for the overall class, and even if some students choose not to participate using the response system they still benefit from its use in the class. Instead of waiting for the results of a quiz, homework or even a test to see how well the class assimilated a particular concept and decide at that point if extra work needs to be done, an immediate feedback during the lecture gives the instructor the chance to adapt the presentation immediately and include extra examples, to reinforce some concepts, or to review some basic math concepts for example.

Motivation for the study

In the department of Engineering Technology at Old Dominion University the electronic Personal Response Systems (PRS) or "clickers" have not been used so far. Clickers are used in the university, and our students encounter them especially for the required courses in physics and chemistry. Also, the university offers to the faculty training and access to the Turning Point Software to use with the clickers. Introducing clickers in the engineering technology department classes was a new initiative supported by Center for Learning and Teaching which encourages faculty to explore the use of technology in teaching and learning issues that are targets for improvement and innovation. As not all the students had a clicker from previous courses and this being an exploratory study we did not want to impose the purchase of new clickers, we decided to substitute the clickers with an electronic version of them offered on-line by Polleverywhere. At the end of the course, this choice proved to be an inspired one from both instructor and students point of view.

The idea of using clickers or their web-based version first came from the need to energize the class, facilitating a way for all students in the class to participate in the discussions, and giving a fast feedback to the instructor on students' learning. In the electrical engineering technology circuits classes the same concepts are studied as in a regular electrical engineering circuits course, but the math requirements are significantly reduced. Also, at Old Dominion University, there is a large diversity within the student body, including traditional students, distant learners, students in different age groups, students working full time, active military students, students of under representative groups, and transfer students from community colleges. Along with this diversity come big differences in the math background with which the students start the class. The class often struggles because of this difference in background and a lot of students find the lack of exercise in using mathematical skills as a barrier against assimilating the new concepts taught in the class. If the students are more vocal and express their concerns or point to the math parts that hold them back, it is easy for the instructor to address the problems. But it happens, especially in a small group setting, that the class becomes quiet and the instructor does not have a clear understanding of what causes a problem until eventually a test is administered. In a small group some students feel shyer and choose not to express their misunderstandings or lack of background knowledge. This attitude affects the students' engagement in the class and in the end their motivation and critical thinking. This was the main reason to introduce an immediate feedback system, to get the pulse of the class as the lecture progresses and to correct any problems in a faster manner, before the administration of a test. The study presented here was part of a larger research study funded by the university called "Critical Thinking: Beyond Theoretical Knowledge", with the primary goal of improving critical thinking through the use of technology. To achieve this goal the research proposed to address student motivation through all three stages of learning (acquisition, generalization and maintenance). The research involved students in the department of engineering technology and education, and the results on both study groups were similar. This paper focuses on the group of students from engineering technology, and the emphasis is on the first two stages of learning, acquisition and generalization.

Using Polleverywhere

A mention needs to be made relative to the ease of implementation and use of the Polleverywhere software. No training for the instructors was necessary. The only requirement is creating an account. Once the account is set up the instructor is given an ID number and a web link. These will be the same for all the questions used in the class. To answer, the students can either text the code of their answer to the ID number using their cellphones or go to the given website and select their answer, using any device that they have to access the internet. The free version of the software does not have a way to identify the person that answers, but as the use of the polling system for grading was not intended the free version was just what we needed for this study. While editing the questions text, equations and pictures can be inserted, and the program offers the possibility of two types of questions: questions with multiple choice answers and questions with open answers, for which the students can type their own answer. This later type of questions can bring something new in an engineering class. Rather than simply asking the students to calculate something and pick the right answer, they can also be asked for an opinion or a comment. When critical thinking is what we want to stimulate, open answer questions might be a better choice. Some examples on how an open answer question and a multiple choice question were posted in the class are illustrated in Figures 1 and 2.

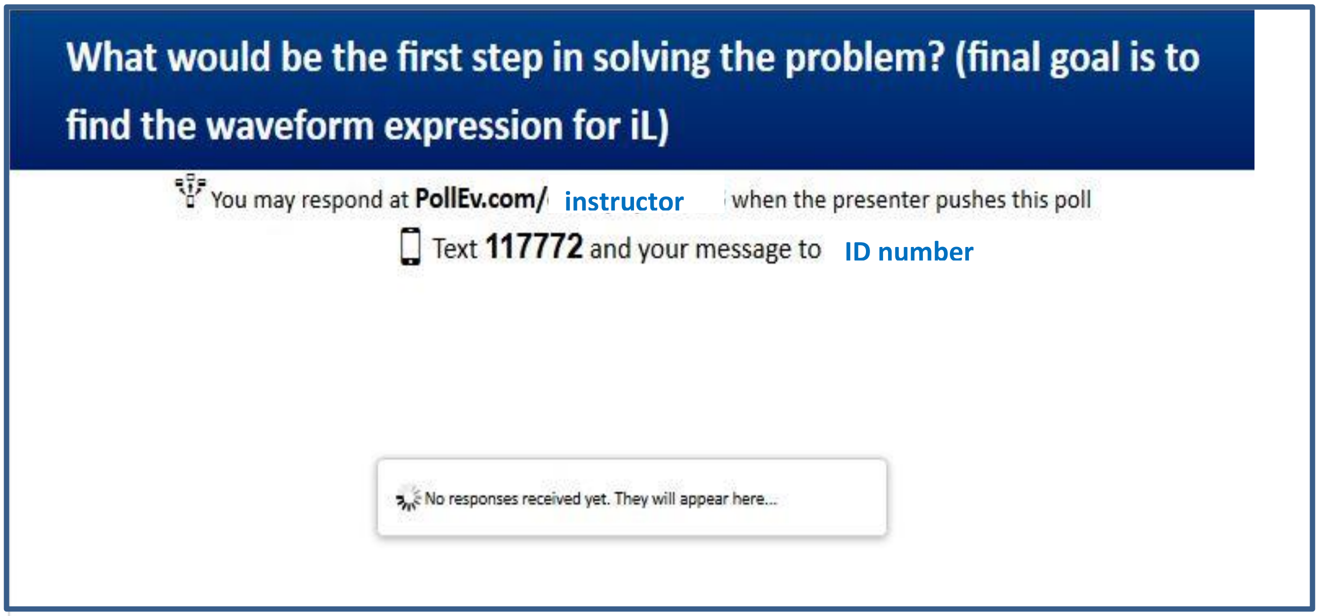

Figure 1. Example of an open answer question

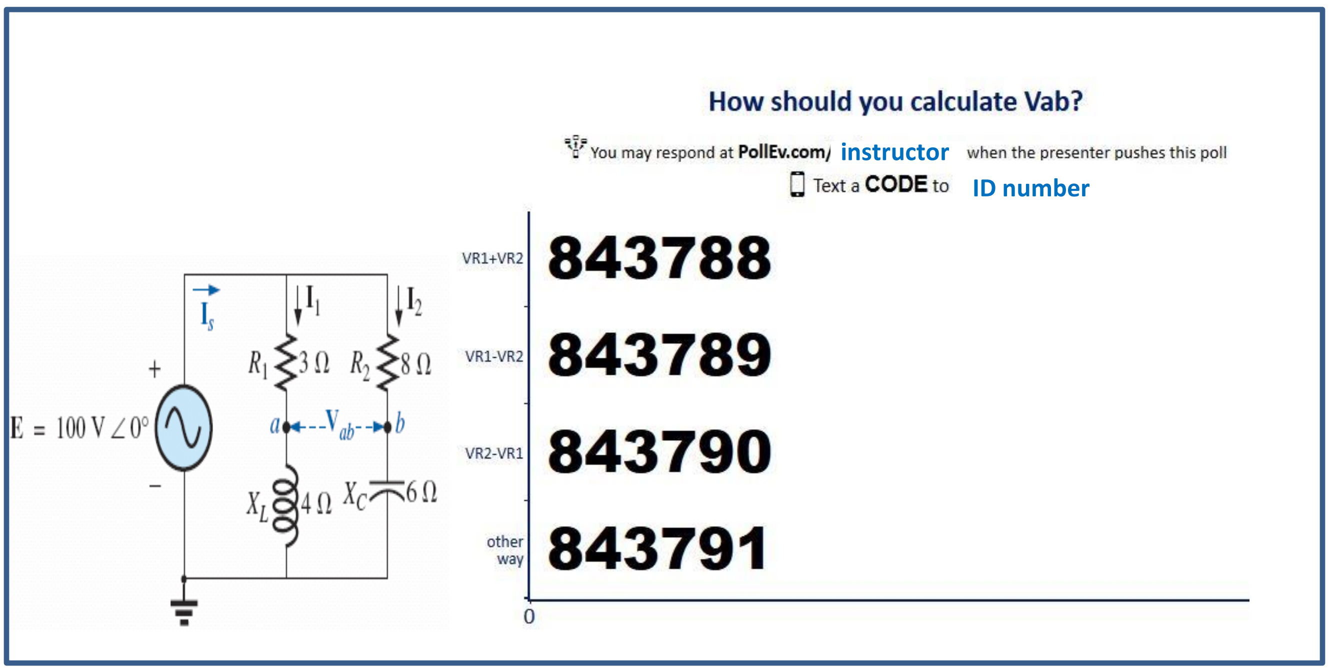

Figure 2. Example of multiple choice question

Class Experience

In the junior level circuits course used for this study there were 26 students registered, but since the attendance was not enforced the actual number of students in the class varied from lecture to lecture, from 75% to 100%. The class was offered in the traditional face-to-face setting. About half of the class had previous experience with clickers. Even those that did not use any type of clicker before became easily accustomed to the software with a short introduction and two test questions, one of each type. Thus, very little time was necessary to get the instructor and the students ready to use the on-line polling software, and this is important to mention because a long training time might discourage an instructor from introducing a new technology in the class. To send their responses most of the students in the study group used their cellphones for texting, only 2 students used their laptops to connect to internet. This aspect is consistent with the study presented by Kappers (2014) [(4)].

When the question is displayed on the screen directly from the Polleverywhere website, or the question is integrated into a PowerPoint presentation, the students can see how the answering progresses in real time. This is a very nice feature that regular clickers of the web-based Polleverywhere system offer, but sometimes this might influence slower students in their reply. For this class a snapshot of the question was taken from the Polleverywhere website and inserted into Power Point slides, so the students could see the question and all the information necessary to send the answer, and the screen was switched to the Polleverywhere website to show the answers only when the polling time had ended.

Instructor perspective on the use of Polleverywhere: The use of this polling system was very beneficial over all. As mentioned, it was easy to introduce in the lecture, with relatively no training time. Compared to classes taught without the use of an immediate feedback system, the class was more dynamic, students were more engaged in the class. This engagement came not only through answering the questions posted, but those questions very often stimulated further discussions and a variety of questions coming from the students. Many times students wanted to discuss how they came to the wrong or the right answer and this was a valuable learning time, from which in this instructor opinion all students benefited. The engagement of the students in debating the answers is the best example of their critical thinking at work. In regards to time, especially when lecture time is limited, waiting for the students' answers to a question posted through Polleverywhere (or any other polling system) might take more time than when the question is directly address to the class. But the direct dialog in the class has the deficiency that most of the time only a few students participate, or they are faster to answer, intimidating this way other students in the class who choose to remain silent. Furthermore, those that answer most of the time are usually among the best students in the class and their answers are very often correct, giving the wrong impression to the instructor that the concept studied was understood and no further discussions are necessary. Several times during this study, even for simple questions to which the instructor expected mostly correct answers, the web-based polling system showed much divided answers and not necessarily a majority of correct answers. The result of the polling system gave the chance for a class discussion in regards of what created the confusion and helped clarify it. A direct dialog might not have identified such cases.

Critical Thinking and Motivation through the use of Polleverywhere

The questions posted to the class during lectures can be viewed from learning perspective as addressing the different stages of the learning process. Most of the questions used during this study can be categorized as addressing either the acquisition or the generalization stages, as they were generally either testing on a newly introduced concept or a new situation involving that concept. The maintenance stage of learning was addressed only during review lectures, when concepts studied earlier in the course were revised, and the instructor's perception is of a moderate to high level of performance for these questions. To address maintenance stage of learning same type of questions were used as for acquisition and generalization, only that the questions were not put right after the concepts were studied but later in the semester.

The experience with the undergraduate students in the engineering technology circuits course suggests that students' level of performance is higher during the acquisition phase of the learning process, when students are required to identify, define, or reproduce a concept taught or discussed during class session. Questions in this category were posted using Polleverywhere during lectures right after new concepts were introduced, as practice exercises. Examples of acquisition type questions include: identify the formula of inductance, evaluate the frequency, peak-to-peak value or other parameters of a sinusoid on a graphic, calculate the Cartesian coordinates of a complex number when the polar coordinates are given and vice versa.

Generalization related questions showed a lower level of performance compared with the acquisition type questions. Generalization requires students to apply the new concepts to practical situations different than those discussed so far in class. Questions in this category usually followed questions used for the acquisition phase, but they referred to more complex examples, or included something different than the cases discussed before. Examples of generalization type questions include: calculate the energy stored in an inductor at steady state, evaluate different characteristics of sinusoids, use phasor analysis to identify elements inside a black box when current and voltage are given, perform conversions between Cartesian and polar coordinates when phase corrections are necessary.

Through the use of the Polleverywhere system in the class, students' motivation can be related to the number of students participating to discussions or asking questions during class sessions. From the instructor's experience with this study, participation can be estimated to around 80% or higher, with the mention that in situations in which time was critical (the classes were only 50 minutes long) once a trend of responses was formed the instructor stopped the polling and started the discussions based on that trend.

Students' Perception on Using Polleverywhere.

This study is part of a pilot study at Old Dominion University to introduce polling systems in the engineering technology classes, and to analyze the impact these systems have on engagement, motivation and critical thinking of the students. The polling system used for this study was the web-based polling system Polleverywhere and the analysis is based on a survey that was distributed to the students towards the end of the semester. The survey was posted in Blackboard and an e-mail was sent to the students asking them to fill out the survey and leave it in the instructor's mailbox. A hard copy of the survey was also distributed to the students during the last class. Data was collected and introduced by hand into the computer. Out of 26 students 20 students filled out the survey. The survey administrated was a modified version of the survey used for clickers by T. Pelton and all in [3]. There were few demographic questions that were not used in this study as the participating group was small. The survey included 21 questions with 5 possible answers rated with 1 to 5 points from strongly disagree to strongly agree. In the analysis that follows the percentages represent a cumulative number between agree and strongly agree, and between disagree and strongly disagree.

A group of questions in the survey referred to the actual use of Polleverywhere in the class: I feel uncomfortable sharing my response via Polleverywhere (Q4 – 84% disagree); using Polleverywhere during the class is distracting (Q3 – 95% disagree); using Polleverywhere in the class is too time consuming (Q13 – 84.2% disagree); I had difficulties using Polleverywhere in class (Q15 – 95% disagree); class time passes more quickly when Polleverywhere is used (Q1 – 68.4% agree); the response graphs provided by Polleverywhere are useful (Q11 – 84.2% agree), I benefit from seeing other students' response to a question (Q12 – 68.5% agree). The responses for these questions show that the students do not have problems using the polling system in the class and they do not find it disturbing. The last question in the survey, Q21, compared the use of clickers to Polleverywhere: 42% agreed that Polleverywhere is easier to use than clickers and 37% were not decided. These answers were in the context that about half class mentioned at the beginning of the semester that they were never exposed to clickers, so they were not in the actual position to compare the two systems. A better interpretation of these answers would be that the students do not find difficulty in using any of the polling system.

The survey was developed with the idea of analyzing the impact of Polleverywhere on student motivation, engagement and critical thinking. Few questions addressed the motivation: when we use Polleverywhere my participation increases in other ways too (Q2 – 84.2% agree); at first learning with Polleverywhere was enjoyable but later was boring (Q17 – 79% disagree). Several questions are relative to students' engagement: using Polleverywhere encourages me to spend more time preparing for the class (Q6 – 37% agree, 37% undecided); learning with Polleverywhere gives me confidence to ask more questions (Q7 – 42% agree, 32% undecided); using Polleverywhere encourages me to attend more classes (Q8 – 44% agree, 39% undecided). Even though there is not a large majority of students who considered that their engagement increased due to Polleverywhere, the survey shows much higher numbers when they were asked if the polling system helped them with the academic content: learning with Polleverywhere improves my understanding of course content (Q5 – 79% agree, 16% undecided); using Polleverywhere helped me better prepare for quizzes and tests (Q16 – 52.6% agree, 26.3% undecided), using Polleverywhere helped me understand the concepts (Q19 – 84.2% agree, 10.5% undecided), using Polleverywhere helped me learn how to apply the concepts to practice (Q20 – 73.7% agree, 15.8% undecided), I would do better in my class without Polleverywhere (Q14 – 76.5% disagree, 23.5% undecided). These results show that most of the students find the use of the polling system beneficial in their academic learning. The fact that they would like to see more of it used in the class also demonstrates that the students find the use of Polleverywhere useful: I would like to use Polleverywhere more often in the class (Q15 – 68.4% agree, 15.8% undecided), I would like to use Polleverywhere in other courses (Q10 – 84.2% agree).

A more detailed analysis on how Polleverywhere helped the learning process can be done by relating the questions to the stages of learning: 1. *Acquisition* – learning with Polleverywhere improves my understanding of course content (Q5 – 79% agree, 16% undecided), using Polleverywhere helped me understand the concepts (Q19 – 84.2% agree, 10.5% undecided); 2. *Generalization* - using Polleverywhere helped me learn how to apply the concepts to practice (Q20 – 73.7% agree, 15.8% undecided); 3. *Maintenance* – using Polleverywhere helped me better prepare for quizzes and tests (Q18 – 52.6% agree, 26.3% undecided). The results show that in students' perception the polling system helped more in the acquisition and generalization stages of learning, and not as much in the maintenance stage. Still, no student said he or she would do better in class without Polleverywhere: I would do better in my class without Polleverywhere (Q14 – 76.5% disagree, 23.5% undecided).

Some questions in the survey have directly addressed students' critical thinking: using Polleverywhere promotes more focused discussions during the class (Q9 – 84.2% agree), using Polleverywhere helped me learn how to apply the concepts to practice (Q20 – 73.7% agree, 15.8% undecided), when we use Polleverywhere my participation increases in other ways too (Q2 – 84.2% agree, 10.5% undecided). These results show that student perception is that the use of the polling system contributed to their critical thinking. It is interesting to note that the results on engagement are much lower than those related to critical thinking and motivation and based on these results we can conclude that there is a better correlation between motivation and critical thinking than between engagement and critical thinking. This conclusion might also be due to the formulation of the questions in the survey, as the students did not come more to the class or study more for the class because the polling system was used (Q6 and Q8). Also, only 42% agreed and 32% were undecided that learning with Polleverywhere encouraged them to ask more questions. These might seem as low numbers compared with those related to critical thinking and motivation, but in a class where a polling system is not used class participation in a comparable class size is usually much smaller.

Impact on Academic Community

We believe that the results of our study may have a significant impact on our colleagues, department, college, and university for several reasons. First of all, the tools and strategies implemented in this study have applicability across disciplines, courses, and students (in face-to-face or distance learning setting, undergraduate and graduate levels). Secondly, the student survey can be used in its current format or adapted by different instructors across disciplines to collect opinions regarding students' perception of the web-based polling system. This data would allow instructors to adjust and revise the use of a polling system if necessary. Finally, the strategies and the polling system implemented in the study are not associated with costs for instructors or students, and therefore are feasible to implement.

One practical implication relates to addressing all stages of learning that are prerequisites for critical thinking. Instructors should allocate more time and develop tasks that address not only the acquisition of new concepts but also their application to practical situations related to students' future career. This is extremely important because the acquisition of theoretical knowledge does not necessarily guarantees the likelihood of success in applied settings. Instructors should also implement continuous assessment throughout the semester to monitor students' retention or maintenance of new concepts. The ultimate goal of teaching is to prepare our students to be successful professionals capable of using the acquired knowledge in their career.

A second practical implication refers to the use of a web-based polling system during instruction. Our data indicates that students perceived the use of a polling system as motivating, facilitating acquisition and generalization of newly taught concepts, promoting discussions, and easy to use. In addition to the above-mentioned benefits, an instructor using a polling system has the opportunity to collect continuous data on student progress and make informed data-based decisions regarding modifications and revisions of course content and instructional strategies to increase the likelihood that the course goals and objectives will be met.

Conclusions

This paper presents a study on the perception of both the instructor and students on the effectiveness of using the web-based polling system Polleverywhere on students' motivation and critical thinking for a small class setting in an engineering technology course. The instrument used for analysis was a survey administered to the students at the end of the course. The study shows that both the instructor and students found the use of the Polleverywhere very effective through all stages of learning, especially during the acquisition phase. Survey results suggest a better correlation between motivation and critical thinking rather than engagement and critical thinking. However, from the instructor's perspective, the main benefit of using Polleverywhere was in stimulating students' participation, observed through their direct answering of the poll questions and engagement in the follow up discussions.

The results of this study encourage us to introduce the use of Polleverywhere in other engineering technology classes too. Different settings should be considered, including distance learning classes and larger classes. A study that would definitely show the benefits of using the polling system would be to compare the learning outcomes of two similar classes side by side, with one class using the polling system vs. the other class using traditional teaching but with the same set of questions.

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