Benefits of an Audience Response System based on Polls with Mobile Phones in Engineering Education

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Abstract: Traditional teaching techniques based on either chalk and board or PowerPoint are usual in civil engineering schools, fostering a passive behaviour in students. Active learning techniques based on audience response systems can overcome such passivity. Currently, most undergraduates and postgraduates own a smartphone. Therefore, lectures based on polls with smartphones can help to improve student learning. This study presents the benefits of a lecture based on an audience response system compared with a traditional teaching technique. A poll related to smartphone-use was applied to a lecture in hydraulics delivered in a civil engineering school to solve a complex open-channel flow problem. The results showed that student learning and understanding about the procedure to perform the exercise correctly improved highly by means of active learning activity. The number of students that failed a similar exercise after the class halved because of the mobile-based poll. In addition, the student satisfaction survey highlighted that the activity led to a more active class. The survey also found that most of the students felt that the activity is interesting and useful to understand how to address such exercises.

1 INTRODUCTION

In engineering schools, traditional teaching methods based on one-way techniques to communicate with students are usual, through either standard lectures or PowerPoint presentations (Lim, 2017). By using such techniques, students obtain information from the instructor inactively, as the instructor talks and the students listen to her or him passively. Traditional teaching does not allow the instructor to know if the students have understood the lecture content, mainly in large groups in which students are not motivated to participate in class.

In contrast, active learning methods that engage students in the learning process have been proven to be more effective (Prince, 2004; Barros et al., 2016; Lima et al., 2017; Christie and Graaf, 2017). Active learning techniques include activities developed in the classroom that engage students in the learning process actively. Furthermore, active learning promotes the capacity for lifelong learning in students, required to succeed in contemporary society, as lifelong learners are curious, motivated, reflective, analytical, persistent, flexible, and independent (Lord et al., 2012).

An active learning technique entails classroom response systems (CRS) that are a set of combinations of hardware and software to support an active communication in classes (Beatty, 2004; Fang, 2009). CRSs can be classified into audience response systems (ARSs), voting machines, wireless keypad response systems, classroom communication systems and electronic response systems (Fies and Marshall, 2006). In the past, ARSs were based on clickers or small wireless hand held devices. Several studies found that clickers improve student attendance and increase their active participation in classroom (Kenwright, 2009; Yourstone et al., 2008). Such clickers allow instructors to engage students in class and class surveys have shown that students enjoy

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clickers (Martyn, 2007). In addition, ARSs are suitable in implementing active learning activities in large groups, in which students are not motivated to answer questions in class and lecturers cannot obtain any feedback (Caldwell, 2007; Ayu et al., 2009). ARSs have been implemented previously in several engineering courses (Silliman and McWilliams, 2004; Petr, 2005). ARSs are generally well-perceived by teachers and students in all the disciplines (Herrada et al., 2020).

Recently, clicker costs have been reduced by following the bring-your-own-device (BYOD) system that promotes the use of devices that students own (Sundgren, 2017; Hung, 2016). Nowadays, most higher education students own a smartphone that can be used for educational purposes (Florenthal, 2019). In addition, most classrooms at higher education schools have a personal computer and a projector. Consequently, the application of ARSs to higher education has become a cost-free activity, as no devices or clickers have to be acquired to implement such methods, the responses can be sent through a web browser in a smartphone and the results can be displayed in classrooms.

Universities have shown great expectation about rethinking educational strategies with mobile phones (Kadry and Roufayel, 2017; Barreiro-Gen, 2020). An effective ARS can be developed by combining student smartphones and a polling website (Wong, 2016). Mobile-based polling (MBP) techniques increase student engagement in class in three levels: behaviourally, emotionally, and cognitively (Noel et al., 2015). MBP helps students to identify their weaknesses and strengths, as well as increase class attendance (Voelkel and Bennet, 2014). In addition, brainwave data have shown that attention increases in polling activities compared with traditional teaching techniques (Sun, 2014). The main strengths of MBP systems involve anonymity, knowledge acquisition, interactivity, immediate feedback, usefulness, ease of use and motivation to participate (Florenthal, 2018). Furthermore, results can be displayed in real time in the classroom, if a computer and a projector are available, thus promoting discussion with students. The instructor can detect questions that have not been understood by students, improving the feedback obtained by traditional teaching techniques.

Polling techniques have been applied previously in higher education engineering schools (Sánchez-Carracedo et al., 2018; Villanueva et al., 2017). Several applications are available to implement MBP systems in class, such as Poll Everywhere, Kahoot, Socrative and Mentimeter, among others. In this study, Poll Everywhere is used. This paper presents an ARS with a MBP technique by using Poll Everywhere, in order to implement an active learning activity on the Hydraulic and Hydrology module taught at the Civil Engineering School of the Universidad Politécnica de Madrid. A complex open-channel flow problem was summarised through a set of questions in Poll Everywhere to avoid the long numerical calculations required to perform the exercise, focusing on the theoretical aspects that students have to understand to solve correctly such kinds of problems. A gamification-based approach was used to solve the exercise step by step.

This paper is organised as follows. Section 2 presents the methodology, including a summary of the subject, students and groups selected to assess the proposed activity, the description of the Poll Everywhere software and the specific activities proposed to assess the benefits of the MBP. In Section 3, the results of the activities are shown and discussed. Section 4 discusses the results. Lastly, Section 5 summarises the main conclusions.

2 METHODOLOGY

In this section, first, the subject, groups and problem selected to assess the active learning activity are presented. Second, the Poll Everywhere software is described. Third, a short exercise similar to the problem explained to students in class used to assess student learning is presented. Lastly, the satisfaction survey is shown in detail.

2.1 Subject, Groups and Problem

The MBP system was implemented in an undergraduate module taught in the third year of the civil engineering degree at the Universidad Politécnica de Madrid, in hydraulic and hydrology. More specifically, it is taught in the first semester of the third year. The syllabus of the subject in hydraulics includes hydrostatics, flow in close conduits, hydraulic pumps and open-channel flow. In hydrology, it includes statistical hydrology, the rational method, the curve number method, unit hydrographs and stream channel routing.

The subject had 136 students enrolled in the academic year 2019-2020. The students are split into two groups with around 60 students in each one at the beginning of the academic year. Consequently, they can be considered large groups collected randomly.

In order to assess the benefits of the proposed MBP system, different teaching techniques were applied to each group. In Group A, the MBP method based on Poll Everywhere was applied (Figure 1). In addition, the chalk-and-board methodology was used for clarifying learning flaws detected in questions answered incorrectly. In Group B, a traditional teaching method based on board and chalk was used.

Figure 1: Lecture with an MBP method by using Poll Everywhere.

A problem similar to those included in the problem-solving exam that is set at the end of the course to evaluate student learning in the subject was selected. The selected exercise belonged to the open-channel flow part of the subject syllabus. It consisted of a 10-m width channel with a descending step of 50 cm in subcritical flow. Students usually encounter difficulties in understanding how to solve this type of problem, as they have to combine the theoretical hydraulic concepts taught previously regarding steady and gradually varied flow, specific-energy curves and hydraulic jumps. In addition, long calculations based on iterative methods are required. An MBP system is proposed to improve student learning about the theoretical reasoning required to solve the problem. The MBP system avoids the long calculations required, focusing on understanding the theoretical concepts needed to solve it.

The same exercise was taught in both groups, Group A with the MBP system and Group B with a traditional chalk-and-board class. At the end of both MBP and traditional chalk-and-board classes, a short exercise analogous to that explained in class was set to evaluate if students understood the lecture.

2.2 Poll Everywhere

Poll Everywhere is online MBP software that can collect student answers either named or anonymous by using an electronic device such as a smartphone. Poll Everywhere is suitable software to apply the BYOD system to a higher education class. The instructor previously shapes the poll by using a sequence of questions. The questions can be true/false, multiple choice, open-ended and numeric (Shon and Smith, 2011). In class, the students can access the poll questions through the website pollev.com by using the poll name given by the instructors. Students do not need to install any application on their smartphones. The responses can be collected anonymously.

Students have a given time to answer each question. If a computer and projector are available, the results can be displayed through the Poll Everywhere website in real time, showing the answer histogram. After the given time, the question is closed. Then, a discussion about the results can be opened. Instructors can detect student weaknesses in the response histogram, mainly if an incorrect response shows a high probability of answers. The discussion can be focused on the parts of the problem in which students have had more difficulties.

In this case, the MBP problem was presented as a collaborative game with a series of levels. Each level corresponded to a multiple choice question with only one correct answer. Each question included all the information required to select the correct answer, avoiding any long calculation. For instance, given the critical and uniform flow depth values, the student had to identify the type of slope, either mild or steep. Students were allowed to discuss answers only with his or her neighbour.

The problem solution advances depending on the most voted answer. Consequently, if a wrong answer is the most voted in a given level, it opens a way that leads to the wrong solution. The problem moves until the students realise that it is the incorrect way.

2.3 Short Exercise to Evaluate Student Learning

At the end of both the MBP class in Group A and the traditional board-and-chalk class in Group B, a short exercise similar to the problem explained previously was passed in order to evaluate student learning and the effectiveness of each methodology regarding student understanding about how to solve the problem. In addition, the short exercise aimed to assess if students were able to solve the problem individually by using what they had learned in class.

In this case, the short exercise consisted of a 6-m width channel (instead of 10 m) with a descending step of 40 cm (instead of 50 cm) in subcritical flow. The students had to obtain the profile of the water level, identifying the location of the hydraulic jump. They had around 10 minutes to do the short exercise. All the required values of uniform and critical water depths, specific energy in uniform and critical flows and conjugate water depth of the uniform water depth were supplied. In addition, the specific-energy curve for the given channel width was supplied to obtain additional required water depths qualitatively without calculations. Students had to draw the water profile in the open channel, instead of answering questions similar to the proposed in either the MBP-based or chalk-and-board classes.

2.4 Student Satisfaction Survey

Lastly, at the end of the MBP problem in Group A, a student satisfaction survey was conducted, in order to obtain the feedback of students engaged in the active learning activity. The satisfaction survey included the following questions:

- Q1: Has the voting-based activity been interesting for you?
- Q2: Has the voting-based activity been useful for you?
- Q3: Has the voting-based activity improved your motivation in this part of the subject?
- Q4: Has the voting-based activity improved your active participation in class?
- Q5: Do you consider that the voting-based activity allows a more active class?
- Q6: Has the voting-based activity improved my attention and concentration in class?

Each question had five answers: (i) much; (ii) rather; (iii) indifferent; (iv) little; and (v) nothing.

3 RESULTS

The MBP activity with Poll Everywhere was applied to Group A and 32 students attended the class and participated in the poll. In Group B, 43 students attended the chalk-and-board lecture. Students in Group A did not know that the lecture would involve an active-learning activity based on a polling with smartphones, to avoid some students from Group B moving to Group A to attend such a lecture.

In this section, first the results of the short exercise passed at the end of the class to evaluate student learning are presented and, second, the results of the satisfaction survey are discussed.

3.1 A Short Exercise to Evaluate Student Learning

A short exercise was set at the end of the class in both groups, to assess the improvement of the MBP lecture compared with the traditional chalk-and-board lecture, in terms of student learning after the lecture and skill to solve the problem. Figure 2 shows the histogram of marks in the short exercise for each group. Marks can range from zero to 10. In Group A, 65.6 % of students obtained a mark of 10. However, in Group B, a smaller proportion of students did so perfectly (48.8 %). In Group A, two out of three students obtained the highest mark.

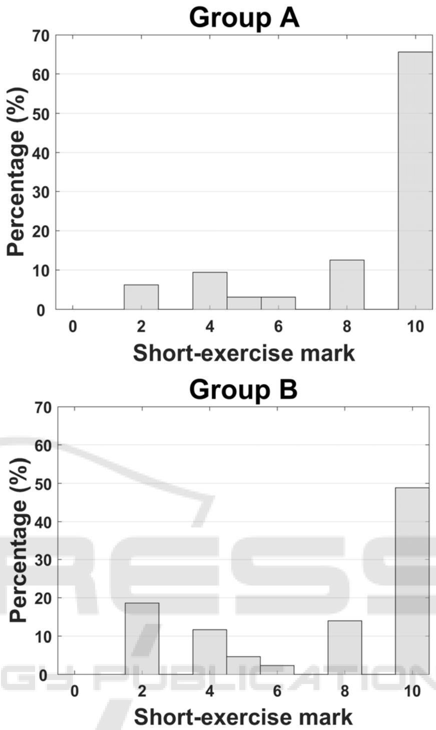

Figure 2: Marks in the short exercise passed at the end of the class: a) Group A; b) Group B.

In Group A, 15.6 % of students had a mark below five and failed the short exercise. In Group B, a larger number of students failed the exercise, doubling the figure obtained in Group A to 30.2 %.

Consequently, the active learning activity with an MBP improved student learning in the lecture, as well as understanding of the problem. A lecture based on polls with smartphones led to a higher probability of students with the highest mark, solving the problem perfectly, as well as a lower probability of students that had a mark below five. Students in Group A understood better how to solve the problem, applying the theoretical reasoning correctly.

Table 1 shows the main statistics of the marks in the short exercise passed at the end of the class. It can be seen that Group A has both mean and median values greater than in Group B. The median value in Group A is 10. This means that more than half of the students obtained a mark of 10. The median value in

Group B is eight, two points smaller than in Group A. In addition, Group A had a mean value 1.20 points larger than Group B. The mean and median values pointed to an improvement in the problem understanding and student learning thanks to MBP methodology proposed.

Table 1: Main statistics of the marks in the short exercise passed at the end of the class.

Statistics	Group A	Group B
Mean	8.41	7.21
Median	10	8
Standard deviation	2.61	3.27
Coefficient of variation	0.31	0.45

Regarding the variability in marks, Group A showed smaller values of both the standard deviation and coefficient of variation statistics than Group B, indicating that the MBP technique homogenises student skills to solve the exercise, compared with a traditional lecture based on chalk and board.

Summarising, the lecture with an active learning activity following an MBP improved student learning and problem understanding, leading to a higher proportion of students with the highest mark and a larger mean value in marks. In addition, the MBP lecture homogenises the student skills to solve the exercise, smoothing the differences among students observed after a traditional chalk-and-board class.

The differences between groups in terms of student learning and problem understanding could be attributed to both students and the instructor. The polls with smartphones fostered student attention in class. Consequently, the students realised their weaknesses through the answer histogram displayed in real time in class. In addition, they realised their mistakes compared with their classmates, motivating them to improve their learning. In a traditional chalk-and-board class, students cannot be aware of their weaknesses. In addition, students cannot compare their learning level with their classmates, as traditional teaching methods promote a passive behaviour in students. In a chalk-and-board class, most of students devote their time to copy what is written in the board.

In addition, in an MBP lecture, the instructor could become aware of the usual student mistakes, as well as the aspects that have not been understood correctly by them. The answer histogram shows such weaknesses in the wrong answers answered with a considerable probability. Consequently, the instructor can use the class time between sequent questions to clarify the theoretical concepts not understood correctly by the students, avoiding wasting time to explain concepts that students know perfectly. In a traditional chalk-and-board class, the instructor hardly obtains feedback from their students and cannot detect their weaknesses. In this case, the lecture is prepared in advance to cover the time of the class with a low flexibility to adapt and spend more time in the parts of the problem in which a given group has more problems, as the instructor cannot know such information. In addition, most of students do not realise their weaknesses until they study their notes at home some time after the end of the class.

3.2 Student Satisfaction Survey

At the end of the Group A class, delivered with the MBP system, a survey was conducted by using Poll Everywhere. The survey consisted of six questions about interest, usefulness, motivation, active participation, active class, and attention and concentration. The full questions are included in Section 2.4. The responses were collected anonymously. Figure 3 shows the answer histogram for each question. 28 students responded the student satisfaction survey out of the 32 students that attended the lecture and participated in the poll.

Most of the students that responded to the survey agreed that the lecture based on polls with smartphones was either very or rather interesting, 85.71 %, for them, 42.86 % answered that it was very interesting and 42.86 % rather interesting. Only 14.29 % of students answered that the lecture was indifferent for them. Therefore, students showed a high interest in the class. Maybe such interest was intensified because civil engineering students are used to classes based on traditional techniques.

The responses about the usefulness of the lecture were similar to the previous question: 85.71 % responded that the lecture was either very or rather useful for them; 10.71 % of students felt indifferent and 3.57 % thought that the usefulness of the active learning activity was low. Apart from the interest of students in the activity, maybe intensified by its novelty, the students felt that the lecture was useful for improving their learning, clarifying the problem understanding. This result is crucial for the activity assessment, as the teaching methodology was changed and aimed to improve the lecture usefulness for students.

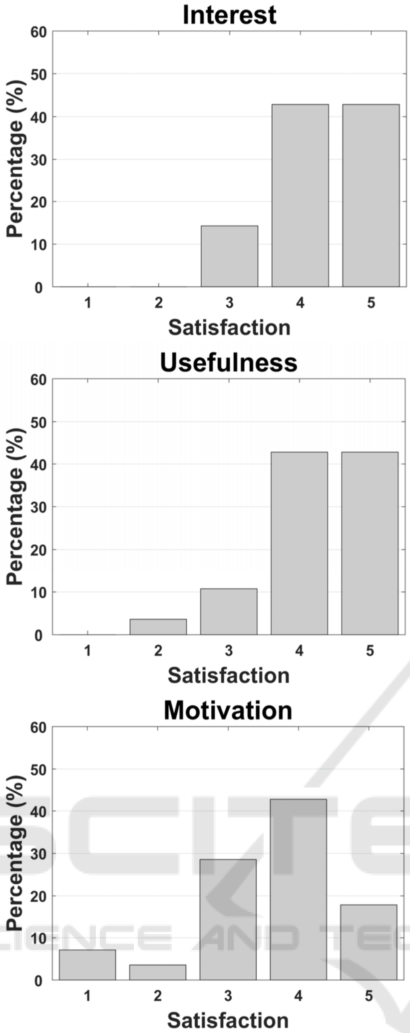

Figure 3: Results of the student satisfaction survey conducted after the MBP lecture in Group A regarding interest, usefulness and motivation. In x axis, the numbers indicate the satisfaction grade: 1 – Nothing; 2 – Little; 3 – Indifferent; 4 – Rather; 5 – Much.

In terms of motivation, the answers were more spread. Of the students, 60.71% felt that the lecture based on an MBP system improved their motivation in the part of the subject devoted to open-channel flow. However, 39.29 % of students thought the contrary. Consequently, the active learning activity did not foster the motivation in the subject in one out of three students. It should be highlighted that 7.14 % of students felt that the activity did not improve their motivation at all.

The MBP activity improved the active participation in 64.29 % of students, though 32.14 % of students felt indifferent about such improvement. However, 96.43 % of students agreed that the active learning activity allows a more active class either much or rather. Only 3.57 % of students felt indifferent compared with a class based on a traditional technique. Consequently, almost all the students agreed that an MBP activity led to a more active class compared to traditional teaching. However, only two out of three felt that the activity has improved their active participation in class. The proposed activity improves the passivity of traditional techniques, though some improvements are required to foster the active participation of students in class.

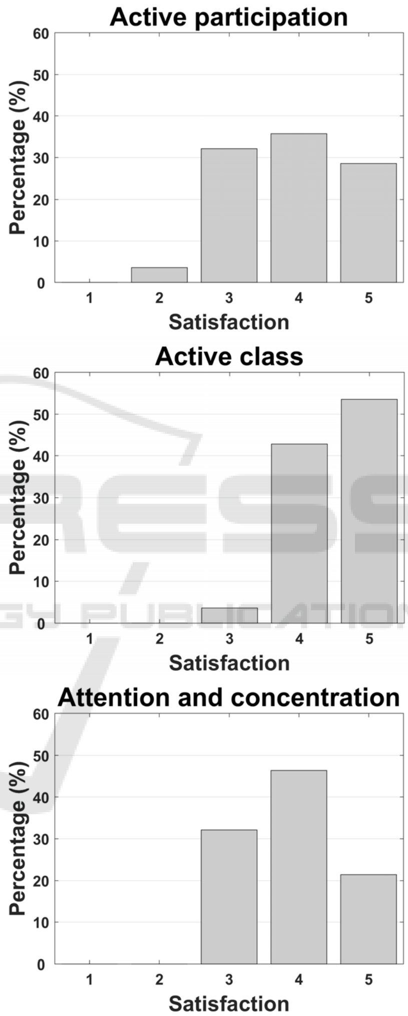

Figure 4: Results of the student satisfaction survey conducted after the MBP lecture in Group A regarding active participation, active class, and attention and concentration. In x axis, the numbers indicate the satisfaction grade: 1 – Nothing; 2 – Little; 3 – Indifferent; 4 – Rather; 5 – Much.

Lastly, 67.86 % of students felt that the MBP lecture improved their attention and concentration. However, 32.14 % of students felt indifferent in this aspect.

Table 2 shows the main statistics that summarise the answers in each question. The highest mean value is obtained in Q5 regarding the lecture improvement in terms of an active class. Consequently, students highlight that the proposed activity leads to a more active class. Q1 and Q2 also obtain mean values greater than four, pointing to the interest and usefulness of the activity. Q3 shows the lowest mean value, indicating that the MBP lecture can be improved to stimulate the student motivation in this part of the subject.

Table 2: Main statistics summarising the student impression about the MBP polling passed at the end of the class in Group A.

	Number of responses	**Mean**	**Standard deviation**
Q1	28	4.29	0.713
Q2	28	4.25	0.799
Q3	28	3.61	1.066
Q4	28	3.89	0.875
Q5	28	4.5	0.577
Q6	28	3.89	0.737

4 DISCUSSION

The student satisfaction survey conducted at the end of the class showed that students highlighted that the activity led to a more active class, compared with either chalk-and-board or PowerPoint-based classes that are usual in civil engineering schools. The survey also found that most of the students felt that the activity was interesting and useful to understand how to solve open-channel flow problems. The novelty of the active learning activity in civil engineering schools could intensify student interest in it. However, the usefulness of the lecture based on polling with smartphones was emphasised by students regardless of its novelty.

The results of the short exercise at the end of the class showed that while two out three students obtained a mark of 10 after the active learning activity, less than a half obtained such mark after the chalk-and-board class. In addition, the number of students that failed the short exercise after the traditional teaching class doubled the number that failed such exercise after the lecture based on polling with smartphones. Consequently, the active learning activity with smartphones improved the student learning in the lecture, as well as the understanding of the theoretical reasoning required to solve the problem.

5 CONCLUSIONS

The results of an active learning activity entailing an audience response system with a smartphone-based poll have been presented. The activity used the software Poll Everywhere. The teaching methodology was applied to a lecture on the Hydraulic and Hydrology module taught at the Civil Engineering School of the Universidad Politécnica de Madrid. An open-channel flow problem similar to those included in the problem-solving exam that is set up to evaluate student learning at the end of the subject was selected to assess the technique.

The passivity of traditional teaching was overcome through a lecture based on electronic voting. Students highlighted that the new activity led to a more active class and was interesting and useful.

Student learning and the skill required to solve the problem were assessed by using a short exercise at the end of the class in which students had to apply the aspects learnt in the lecture in both groups. The results showed that the activity with smartphones improved the student learning. However, the poll was passed in only one class. Therefore, the new technique should be applied in the future to more classes to validate such results.

The differences between the two teaching methodologies were attributed to both students and the instructor. Students can become aware of their weaknesses and compare themselves with their classmates through the answer histograms displayed in real time in class, overcoming the passive behaviour of students in traditional chalk-and-board classes. The instructor can become aware of student mistakes by inspecting incorrect answers, using the class time between polls to clarify the theoretical concepts that have not been understood correctly by students. In a traditional class, the instructor hardly obtains some feedback from their students.

In addition, some improvements in the proposed teaching methodology could be carried out to increase the active participation of students in class, as well as their motivation in this part of the subject.

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