An Active Learning Technique Enhanced with Electronic Polls

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Abstract: Only very few students answer questions like: "Did you understand this?", "Do you have any question?", etc. In this paper, we present an active learning technique that is based on the think-pair-share technique improved with the introduction of electronic polls to obtain anonymous instant feedback from the students. Electronic polls have been usually performed using Classroom Response Systems in the related literature, but these systems introduce a number of problems related to the excessive cost of the systems and the technical problems that they may cause to the instructors. Thus, we implement our active learning technique in an Interaction System that provides the benefits of supporting electronic polls but avoids the problems of Classroom Response Systems. We also present an example of how we applied our proposal to an Operating System lectures. Finally, we evaluate our proposal and demonstrate that the results we obtain are very similar to the ones obtained in the existing CRS literature without the problems that they introduce.

Key words: Active Learning; Electronic Polls; Feedback; Participation; Think-pair-share

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1. Introduction

During a lecture, only very few students answer questions like: “Did you understand this?”, “Do you have any question?”, etc. Thus, instructors have little feedback from the students. An instructor can ask students to raise their hands in response to a question [1]. However, it can be difficult to count hands in classes with a large number of students.

From the point of view of instructors, having feedback from students can be a very powerful teaching tool, allowing them to assess the evolution of students during the lecture [2]. Classroom response systems (CRS) [9], which are systems made of transmitters to send student responses and a computer that processes all the responses, were one of the first methods used to get quick feedback from students. The benefits of CRS student participation, attendance, and performance have been widely reported [10, 17]. However, it has also been reported that CRS suffer from problems such as the need of a dedicated and costly infrastructure, technical barriers and time requirements. In this paper, we propose an active learning technique that is based on the think-pair-share technique [5] improved with the introduction of electronic polls to obtain anonymous instant feedback. Electronic polls are an interesting approach to apply objective tests for obtaining feedback from the students [2,3]. As we will see later on, this feedback from all the students is a very powerful teaching tool, which allows instructors to assess the evolution of students during the lecture. Therefore, misunderstandings can be early detected and corrected. Specifically, we have assessed the performance of this technique using three different sources of information instructors' impressions, participation reports, class surveys and exam grades. Our results demonstrate that our technique has benefits similar to CRS and overcomes the most reported problems associated with the use of CRS.

The remainder of this paper is organized as follows. Section 2 presents a discussion of works related to our proposal. Section 3 details our proposal to use electronic polls during lectures. Section 4 describes an application to Operating System lectures. Section 5 presents an evaluation of our proposal based on this application. Finally, section 6 presents some concluding remarks.

2. Related Work

2.1. Classroom Setting

Active learning is increasing its importance over the last years as a pedagogical approach intended to boost student interest, motivation and satisfaction [6]. Indeed, there are a great amount of studies in the existing active learning literature. For a thoroughly survey in active learning refer to [7]. There are some studies (e.g. the one performed by Stuart & Rutherford [8]) that prove that students have a decline in concentration after 10-15 minutes when they are merely passive. Active learning partially bases its effectiveness on increasing the student attention span during lecture [7]. This is achieved by using active learning techniques. McConnell [5] presents some active learning techniques for Computer Science teaching. One of these techniques is what McConnell called the modified lecture technique. This technique is based on lecturing for 10 minutes and then taking a break for 5 minutes.

McConnell also proposes two different ways of handling the 5-minute break in [5]. We focus on the think-pair-share technique during the break. In this way, the break is split up in three phases. Firstly, the instructor asks a question to the students who write an individual answer. Secondly, each student discusses his/her answer with one classmate and they reach an agreement to create a common answer. Thirdly, some of the pairs are requested by the instructor to communicate their answers publicly.

In this paper, we propose and evaluate a novel active learning technique that modifies the think-pair-share so that the instructor and the students are able to know all of the answers made by each pair. This feedback can be very useful for the instructor and the students during the lecture, as shown later on in section 3. Moreover, answers are anonymous. We provide participation reports (in Section 5) that show a participation of almost 99% of students during the lecture.

2.2. CRS and Interaction Systems

Classroom response systems (CRS) (most broadly known as simply “clickers”) were the first systems that were used to obtain feedback from students [9,10,11]. CRS are systems composed of transmitters (or clickers) used by students to send responses, receivers that collect these inputs, and a computer that computes the results in real time [12]. CRS have been widely used in K-12 [13,14] and higher education [9,10] for teaching different disciplines such as physics [15], mathematics [13], mechanics [16], etc. In [12] the authors review the most relevant works on the pedagogical theory beyond CRSs and the implementation of CRSs. Moreover, the work contained in [17] proposes a set of best-practice tips for CRSs that have been extracted from the related literature and some guidelines for writing good questions.

It has been extensively proven that the adequate use of CRS during lectures increases student participation, interest in attending classes, early misunderstanding detection, and learning outcomes [10, 17]. However, it has also been reported that CRS implementations usually suffer from some common problems [13, 17]. The first problem is that CRS demand a dedicated infrastructure, i.e., the clickers and the computers that compute the results [17]. This infrastructure can be very expensive and it cannot be reused for other activities rather than that of gathering feedback during lectures. Thus, this usually makes difficult that universities are interested in investing on and implementing this kind of infrastructures. Even in the universities in which clickers have been purchased and implemented, the implementation is usually done in a very reduced number of classes (because of the excessive cost), so that potentially interested instructors may not have access to use them.

The second problem is that instructors are often discouraged to keep on using CRSs because of the barriers that they encounter while using them [13]. These barriers include: problems related to the easy loose and breakage of clickers [17]; inadequate technical support because the IT personal is rarely familiarized with the CSRs technology [17]; insufficient instructors' training and expertise, some teachers encountered difficulties when they want to use the software to make more elaborated questions [13]; time consumption, some teachers complain about the amount of time that is wasted taking out and putting away the clickers [13]. These technical problems are a crucial factor that can play a crucial role to determine the success of the implementation of a CRS.

Recently, Interaction Systems (IS) have been developed for improving the interaction between instructors and students, such as [1,2,4]. These systems are software programs that run in a distributed fashion on a network that can be composed of mobile devices (such as Tablets and Laptops) and PCs indistinctly. These systems provide support for the sharing of electronic slides to make class presentations, the use of digital ink on the slides shared by the instructors as well as the students, and the sending of specific slides to some devices (e.g., to support that students perform an activity in its own device and can send back the solution to the instructor). IS have been proven to be appropriate tools for supporting active learning [19]. Moreover, some of these systems include native support to run electronic polls.

In this paper, we use one of these IS (Classroom Presenter [4]) as the support to implement our active learning technique. We demonstrate that such a system can be used to obtain all of the benefits CRSs or clickers provide for obtaining feedback from the students (increased student participation, interest in attending classes, early misunderstanding detection, and learning outcomes) but avoiding most of the problems that we explained above (excessive cost without reusing possibility, and the barriers that discourage instructors from using CRSs).

From the available IS, we use Classroom Presenter (CP) [4] due to several reasons. The first reason is that we are already using CP to improve student-instructor interactions by using digital ink to aid explanations during lectures, as detailed in the next section. The second reason is that CP is freely available, and thus, it does not introduce any extra cost on its use. Moreover it can run on Tablet-PCs or normal PCs, than can be reused for any other activity or program needed in different subjects. In addition, due to being freely available, other instructors can easily reproduce the experiences described in this paper in their classes. The third and last reason is that CP is able to import power-point slides. This allows instructors to easily migrate their slides used during their lectures to take advantage of CP.

3. Anonymous Instant Feedback during Lectures

In this section, we detail our proposal for an active learning technique based on the think-pair-share technique improved with the introduction of electronic polls to obtain anonymous instant feedback. We provide insights regarding the classroom setting and the classroom activities.

3.1. Classroom Setting

Our setting is a normal class with PCs. We use one PC for each student pair, and one PC for the instructor. PCs run Windows and are connected to each other using a network. The use of PCs could also be seen as costly investment. However, other cheaper devices could be used (such as Tablets, Laptops, or Notebooks). Moreover, the most important point is that any of these devices and PCs can be reused for many other activities (such as hands-on activities) and subjects even from different degrees (many degrees include subjects that train students to use different software that they will need for their future professions).

PCs have the Classroom Presenter (CP) [4, 19] software installed. CP is freely available software that allows electronic slides to be shared between the instructor and the students as well as to be shown in a big screen (or projector) at the same time. Moreover it allows the use of digital ink in the electronic slides. A screenshot of CP can be seen in Fig. 1. As we can see, CP allows the instructor to underline, remark, and stress parts of the slide by means of digital ink that can be of different colors. Students can also use digital ink in their own running instance, so that they can take notes together the notes that the instructor makes. Finally, they can also send the notes they make in a slide back to the instructor. This is very useful for students to perform class activities and send the results back to the instructor, who can then preview the activities and show the ones of she/he chooses in the projector. In this way, CP has already been proven to be an appropriate tool for supporting active learning [19]. What is more, CP allows instructors to launch quick polls that students can answer anonymously. This feature, as explained later on, is essential to the learning technique that we describe in the following section.

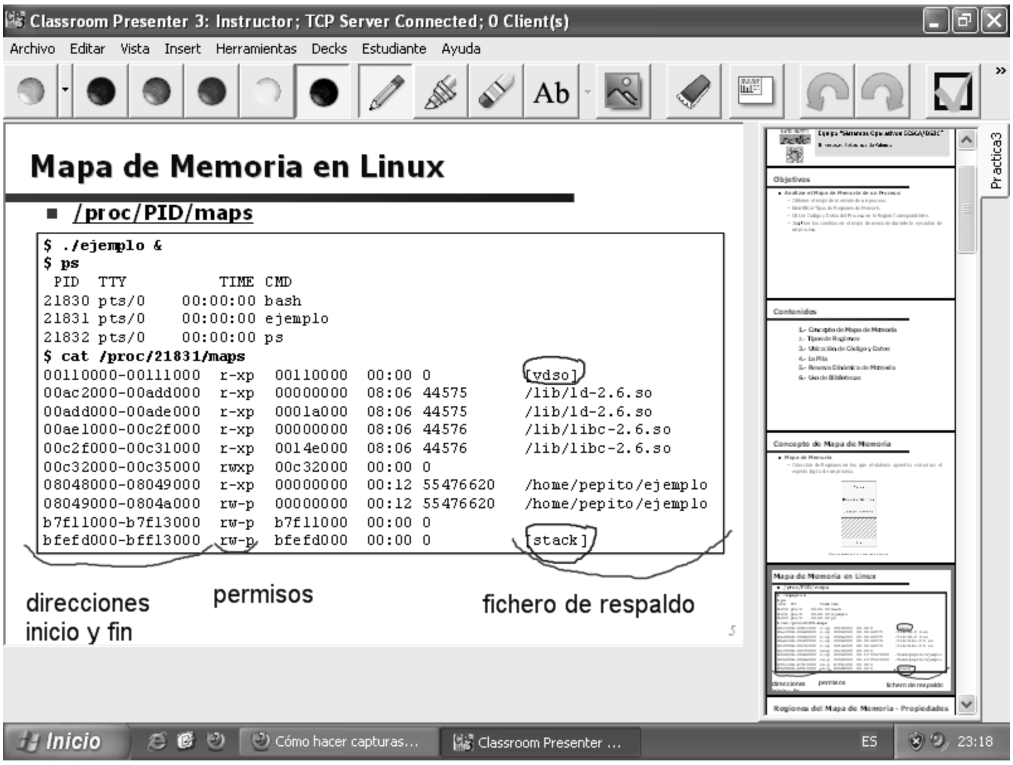

Fig. 1. Classroom Presenter Screenshot

3.2. Classroom Activity

In order to have instant feedback from the entire student pairs, questions are made as objective tests. The instructor shows the question in a slide with the available choices. Then, the instructor launches a quick poll using CP. The students are then presented with the options in their running instance of CP and can choose the option they think is the correct one.

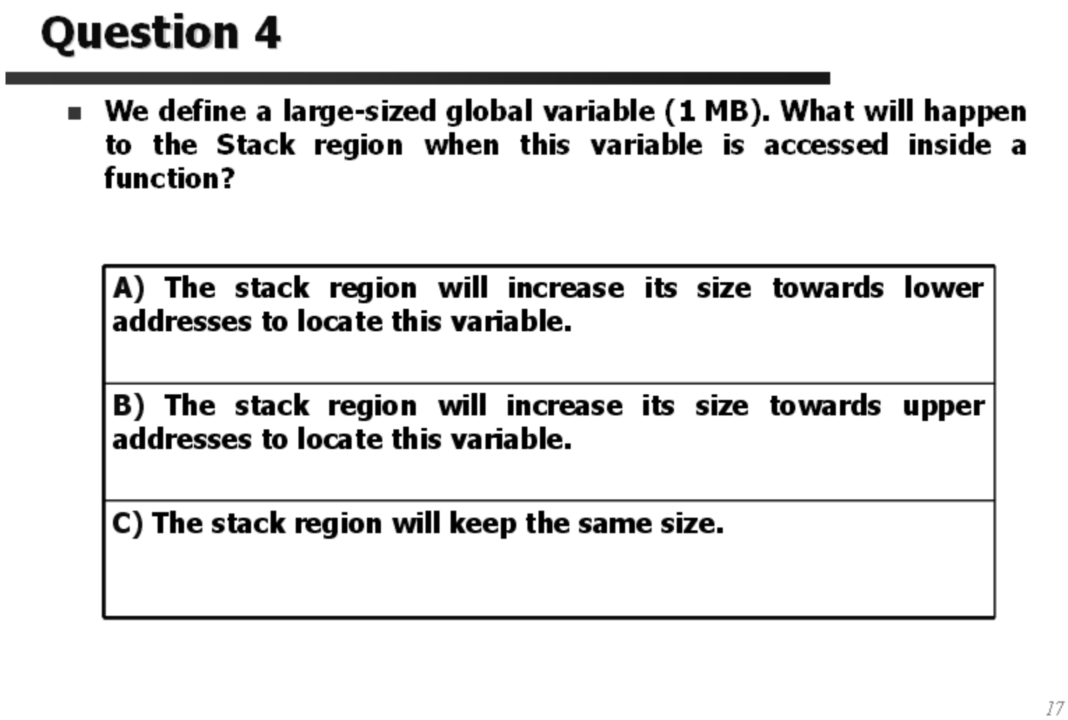

Fig. 2. An example of question for obtaining instant feedback.

As stated in [13], one of the most important factors in order to achieve a large pedagogical value when performing questions to students is the development of appropriate questions. Specifically, we followed the instructions provided in [15] to design our questions taking into account the topic addressed by the question, the cognitive skills that students should develop and the metacognitive goal, which is the perspective about learning to be reinforced. For instance, Figure 2 and Figure 3 show two examples of these questions.

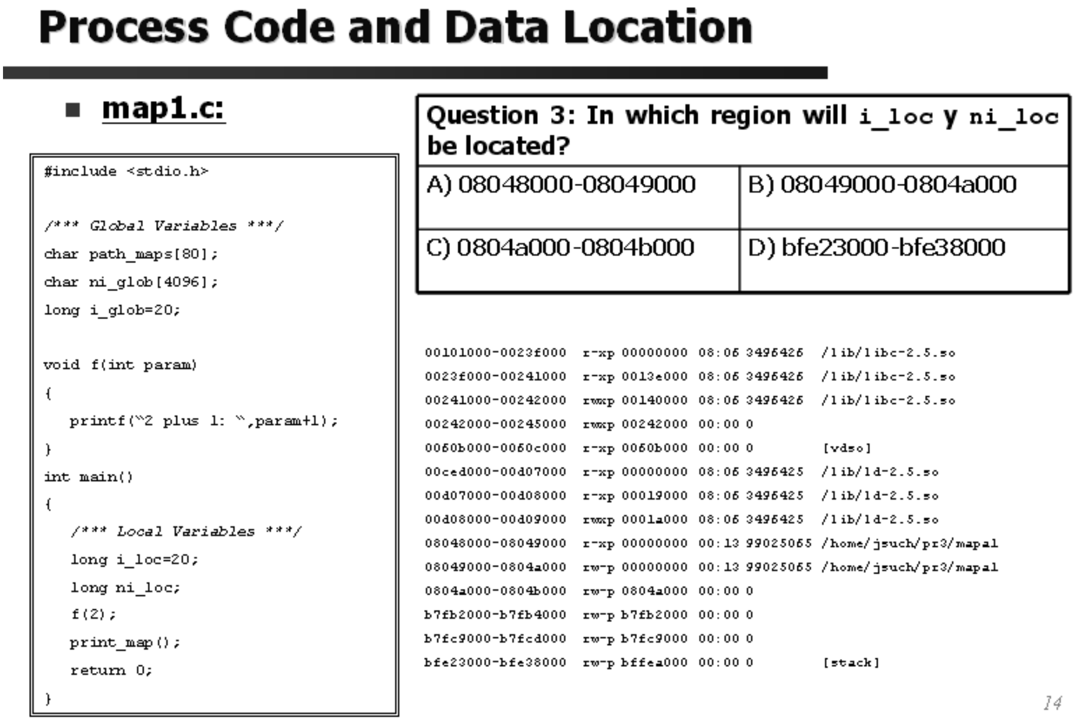

Fig. 3. An example of question including a Memory Map.

When students answer using CP, the instructor has instantly (in his/her running CP instance) a chart with the number and percent of student answers per choice, as shown in Fig. 4. With the results of student's answers, the instructor has instant feedback from the pairs that answered. The instructor can employ this feedback (at least) in five different ways:

1. To assess whether the students are following him/her. In this sense, the instructor can repeat and try to give a thorough explanation of what students do not understand, mainly if a big amount of the students answered wrongly.
2. To reinforce the learning of students by showing wrong answers. Although the answering process is anonymous, each student knows what he/she answered so that he/she is reinforced with the correct answer.
3. To allow students that answered correctly to explain other students why the option they chose is not the right one. The instructor can always clarify the explanation of the student if it is not either well expressed or accurate enough.

4. To slightly modify the question orally so that other option applies. This is very useful to illustrate what conditions must change so that another option is the correct one.
5. To repeat until a desired % of correct answers is achieved. This implies that the instructor prepares a pool of objective tests for the same concept. Thus, the instructor can explain the concept again and evaluate whether or not the desired % of correct answers is achieved in that moment.

As the answer process is totally anonymous, students have no fear to provide they answer. There is no possible embarrassment if they answer wrong; no one knows who answered what [18]. Therefore, as shown later on in the evaluation section, the average participation is nearly 99% of the student pairs.

The instructor decides when to continue lecturing for 10-15 minutes more. The en-tire process is repeated until the end of the lecture. The instructor can also keep an extra amount of lecture time that he/she can distribute among the entire process. Therefore, he/she can manage these minutes at will. For instance, he/she can use this time to explain what students do not understand, to thoroughly explain concepts, to clarify student’s answers, to stress important concepts, for students to take a real break (without neither lecturing nor exercises), etc.

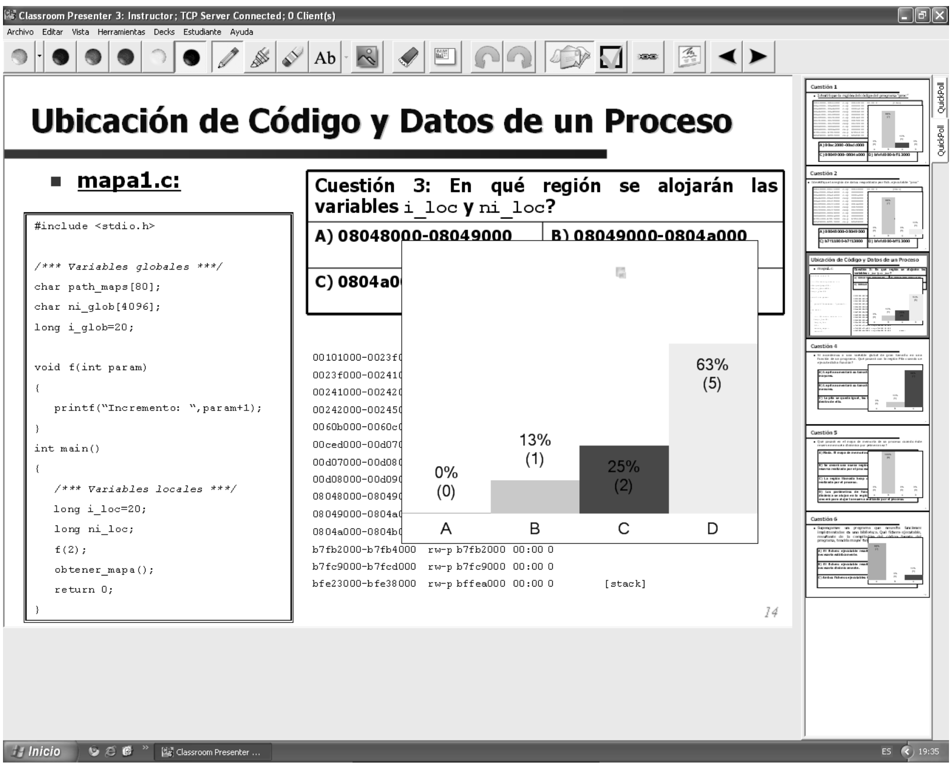

Fig. 4. An example of the results obtained for an objective test.

4. Application to Operating System Lectures

We have applied our proposal to the Operating System lectures at the Technical University of Valencia. Operating Systems is a core module belonging to the second year of several Computing BCs at the Technical University of Valencia. Specifically, we organized and lectured two didactic units using our proposal: Memory Management and File Systems.

As an example, we provide the outline of a lecture organized following our proposal. This lecture is part of the Memory Management didactic unit. This lecture is about how a real OS (Linux) manages memory. This lecture precedes a hands-on session in the laboratories. Moreover, this lecture follows the overall scheme described in the previous section, i.e., the instructor teaches for 15 minutes and the makes a break to obtain feedback from the students. Specifically, the instructor teaches for 15 minutes taking advantage of the digital ink features that CP provides, and then the instructor uses CP to launch electronic polls and gather the results.

For the Computer Science degree at our university, lectures take 120 minutes. We structured these 120 minutes as follows:

- Minute 0: Introduction, outline and relation to other lectures.
- Minute 5: Memory Map in Linux.
- Minute 10: Memory Region Types.
- Minute 15: Code Regions.
- Minute 20: Break 1. Objective test: Students are presented with a Linux memory map. Then, they are asked what region (among 4) is a code region. Then, they discuss in pairs, agree on a common answer, and answer the objective test. After this, the instructor shows the results and she/he starts a short discussion with all of the class.
- Minute 25: Data Regions.
- Minute 40: Break 2. Objective test: Students are presented with a Linux memory map. Then, they are asked what region (among 4) is a data region.

- Minute 45: The Stack region.
- Minute 60: Break 3. Objective test: Students are asked about how the stack region will behave given a specific scenario. One example is the objective test shown previously in Fig. 2.
- Minute 65: The Heap region.
- Minute 80: Break 4. Objective test: Students are asked about the heap region behavior given a specific scenario. For instance, "What will happen to the memory map when allocating dynamic memory for the first time?", giving four options.
- Minute 85: Dynamic and static libraries management.
- Minute 100: Break 5. Objective test: Students are asked about how different Linux treat dynamic and static libraries given a specific scenario. For in-stance, "which binary file is bigger in size, a binary to be linked dynamically, a binary to be linked statically, or both are the same size?".
- Minute 105: Conclusions and Overview of the next lecture.

The 15 minutes missing are for the instructor to use them if required at any feedback process. This is because depending on the results obtained for each break the instructor could decide to explain one concept again. The instructor can also use some of these minutes for a "real" break for the students to rest without objective tests.

5. Evaluation

We carried out an evaluation of our proposal with 45 students following our proposal in 6 lectures during the Operating Systems course and 45 students following the same approach but without the use of electronic polls during the entire Operating Systems course. We evaluated our proposal taking into account four different sources of information: instructor's impressions, participation reports, class surveys and exam grades.

5.1. Instructor's Impressions

Each of the authors of this paper maintained a personal teaching journal over the course of the whole semester, which we usually updated after each class. At the end of the course, we processed the information collected in our teaching journals in order to extract the most important conclusions of each of the teaching journals. After this, we agreed on a set of common impressions about our proposal in this paper. In the following, we detail these impressions.

From the instructor point of view, participation is clearly increased with respect to a traditional lecture. In a traditional lecture, when the instructor launches a question to the students, there are always a big number of students that avoid answering the question. With the anonymous answering process, students have no fear to answer wrongly and their participation increases.

Another crucial advantage for the instructor is that of being aware instantly of what students understand. Thus, with our proposal the instructor has more information (when compared to a lecture without electronic polls) to assess the evolution of students during lectures. Moreover, as the feedback mechanism is instant, it does barely affect the overall time needed for a lecture. Moreover, we were able to teach the same contents regarding the two didactic units (Memory Management and File Systems) as we usually do if we do not use electronic polls when teaching such didactic units.

As in other CRS approaches, our described technique requires some extra efforts from the instructor to prepare classes (when comparing with a traditional approach without feedback) because the instructor needs a previously prepared pool of objective tests to use as electronic polls. Moreover, it requires a fine-grained schedule of the class involving all the expected breaks for obtaining feedback. However, the main barriers that discourage instructors for using CRS (explained in Section 2) systems are avoided by using CP for the realization of the electronic polls. Specifically, the easy loose and breakage of CRS is avoided because it is very difficult to lose a PC and if one of them breaks, IT services usually have a replacement for it. Moreover, IT personal can provide adequate support, they are familiarized with PCs and CP is only one software program more. In addition, none of the instructors encountered any important difficulty in using CP. Finally, instructors do not need to spend time because the PCs do not need being either taken out or put away (as CRS would need so).

5.2. Participation Reports

CP illustrates the number of clients connected. CP also illustrates the number of answers for each one of the options of a quick poll. We calculated the percent of students that participated in each poll as the number of clients connected and the number of student answers per poll. Table 1 shows the results obtained for the class belonging to the memory management didactic unit described in the previous section. As we can see, almost 99% of the student pairs participated in the proposed polls.

Activity	Participation (%)
Question 1	95.55
Question 2	100
Question 3	97.77
Question 4	100
Question 5	100
Average	98.67

Table 1. Participation Report of the Memory Management Class

We also averaged the results for each poll performed during all of the lectures in which we used our proposal and the results are that almost 99% of the student pairs in average participated in all of the proposed polls during the two didactic units (memory management and file systems). Finally we would like to note that we did not reward the students in any means for answering the polls. In other related literature of CRSs, there are many works that reward students for answering [18, 19] (e.g., when the answers contribute to the course grade). This gives even more value to the results obtained.

5.3. Class Surveys

We carried out a class survey among the 45 students following our proposal. The results are summarized in Table 2. The questions made in this survey were selected from a pool of questions proposed by each lecturer. Once we agreed on a set of non-redundant questions, we re-formulated them into simple and short questions. The survey was administered in class at the end of the semester and the responses were completely anonymous.

Question	%		
	Yes	***No***	***DK***
Do you think your interest in attending classes has increased?	82.22	4.44	13.33
Do you think you have worked harder?	82.22	6.67	11.11

Do you think your degree of participation has increased?	86.67	6.67	6.67
Have you lost your concentration because of the software used?	4.44	75.56	20
Do you think you have learned more?	86.67	0	13.33
Would you recommend this experience to a colleague of yours?	82.22	6.67	11.11

Table 2. Class Survey Results

As a key result we have that 86.67% of students think they have participated more than in other classes. This confirms the results obtained for participation reports. Moreover, students think that they have worked harder than in other classes (82.22%), i.e., they have been active in the lecture and not merely passive. Another important result is that 86.67% of students think they have learned more than in other classes. This result confirms that student's attention is increased with this kind of active learning techniques. We were also concerned about whether a new tool could also cause our students to lose their concentration. However, only 4.44% of students (2/45) admit they have lost their concentration in some point of the class due to the software used. Our proposal has also succeeded in increasing the interest of attending classes (82.22%). Moreover, 82.22% of the students would recommend this experience to a col-league of them.

We also performed a free-text opinion survey. We asked the students to provide (if possible) positive and negative comments about the whole experience as well as suggestions to improve the proposal from their point of view. We obtained some positive comments, such as ``More pleasant and increases your attention'' and ``More student-instructor interaction''. We also obtained little negative comments, such as ``Students must advance at the same speed''.

Finally, we also gave the students the chance to rate the whole experience from 0 to 10. The average obtained is greater than 8.

5.4. Exam Grades

We finally sought to evaluate how our approach to teach Operating Systems impacted learning outcomes, i.e. whether the described technique improves the approach in which the instructor asks a question to the students that it is usually (and hopefully) answered by only one student (and often the same student), missing a great opportunity to obtain feedback from the rest of the students. For this reason, we compared the exam grades obtained by 45 students following the technique described in this paper with the ones by 45 students following the approach without electronic polls. All the exams were performed at the same time in January 2010 (first semester exams).

The results obtained show that learning outcomes in the questions of the exam that were directly related to the two didactic units in which we applied our proposal (memory management and file systems) increased in almost 15% when students followed the described technique. In order to assess the significance of the results, we performed a t-test comparing the exam grades obtained by 45 students following our technique to the ones obtained by 45 students following the traditional approach. The result of the t-test was $p=0.039$ ($p < 0.05$). Therefore, we can conclude that learning outcomes obtained following the technique described in this paper significantly improve the learning outcomes obtained when following an approach without electronic polls.

6. Conclusions

Our experiences described in this paper show that an active learning technique based on electronic polls provides many advantages to both students and instructors with respect to an approach without electronic polls. Students following this technique increase their participation, interest in attending classes and learning outcomes. Moreover, this technique is especially suited for classes with large number of students. Indeed, it supports as students as the interaction system (in our case CP) itself can support.

From the point of view of instructors, instant feedback from all the students is a very powerful teaching tool, which allows instructors to assess the evolution of students during the lecture so that misunderstandings can be early detected and corrected. In this sense, instructors do not need to interpret students' facial expressions and non-verbal communication in general that can lead to inaccurate conclusions about the evolution of students during lectures.

The results that we obtained are very similar to the results obtained in the existing literature on CRS, i.e., we increased student participation, interest in attending classes, early misunderstanding detection, and learning outcomes. However, a fundamental advantage of our proposal with respect to CRS is that our proposal avoids the problems that CRS have, which are excessive cost without reusing possibility, and the barriers that discourage instructors from using CRSs.

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Biography

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